A method for the collaborative prioritization of freshwater fish habitat research questions

Cody J. Dey, Adam I. Rego, Michael J. Bradford, Keith D. Clarke, Katherine McKercher, Neil J. Mochnacz, Alex de Paiva, Karin Ponader, Lisa Robichaud, Amanda K. Winegardner, Jonathan D. Midwood, and Marten A. Koops

Fisheries and Oceans Canada
Ontario and Prairie Region
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Road
Burlington, Ontario L7S 1A1

2022

Canadian Technical Report of
Fisheries and Aquatic Sciences 3423

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 3423

2022

A METHOD FOR THE COLLABORATIVE PRIORITIZATION OF FRESHWATER FISH HABITAT RESEARCH QUESTIONS

by

Cody J. Dey, Adam I. Rego, Michael J. Bradford, Keith Clarke, Katherine McKercher, Neil J. Mochnacz, Alex de Paiva, Karin Ponader, Lisa Robichaud, Amanda K. Winegardner, Jonathan D. Midwood, and Marten A. Koops

Fisheries and Oceans Canada
Ontario and Prairie Region
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Road
Burlington, ON
L7S 1A1

Cat. No Fs97-6/3423E-PDF, ISBN 978-0-660-37768-1, ISSN 1488-5379

Correct citation for this publication:

Dey, C.J., Rego, A.I., Bradford, M.J., Clarke, K., McKercher, K. Mochnacz, N.J., de Paiva, A., Ponader, K., Robichaud, L., Winegardner, A.K., Midwood, J.D., and Koops, M.A. 2022. A method for the collaborative prioritization of freshwater fish habitat research questions. Can. Tech. Rep. Fish. Aquat. Sci. 3423: vii + 119 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Dey, C.J., Rego, A.I., Bradford, M.J., Clarke, K., McKercher, K. Mochnacz, N.J., de Paiva, A., Ponader, K., Robichaud, L., Winegardner, A.K., Midwood, J.D., and Koops, M.A. 2022. A method for the collaborative prioritization of freshwater fish habitat research questions. Can. Tech. Rep. Fish. Aquat. Sci. 3423: vii + 119 p.

This document describes the methods used to collaboratively identify research questions that, if answered, would best support the freshwater fish habitat management activities of DFO's *Fish and Fish Habitat Protection Program*. Our methods broadly followed those used in other collaborative research prioritization studies and involved a large group of freshwater fish habitat practitioners (i.e. ecosystem managers and policy experts) as well as a diverse group of researchers (internal and external to DFO). The main steps involved in our methodology included: *i*) the collation of 1903 knowledge gaps identified in previous publications and through an expert survey, *ii*) the refinement and collation of those knowledge gaps to produce a list of 334 candidate research questions, and *iii*) an online Delphi process to identify 93 research questions that were most important to habitat management, as well as identification of the amount of scientific resources (e.g. the costs) of answering each question and the amount of existing scientific knowledge relevant to each question. We discuss the general applicability of our approach to science planning within Fisheries and Oceans Canada, and suggest improvements to increase efficiency and repeatability of the process.

RÉSUMÉ

Dey, C.J., Rego, A.I., Bradford, M.J., Clarke, K., McKercher, K. Mochnacz, N.J., de Paiva, A., Ponader, K., Robichaud, L., Winegardner, A.K., Midwood, J.D., and Koops, M.A. 2022. A method for the collaborative prioritization of freshwater fish habitat research questions. Can. Tech. Rep. Fish. Aquat. Sci. 3423: vii + 119 p.

Le présent document décrit les méthodes utilisées pour déterminer en collaboration les questions de recherche qui, si une réponse leur était apportée, soutiendraient le mieux les activités de gestion de l'habitat du poisson d'eau douce du *Programme de protection du poisson et de son habitat* du MPO. Nos méthodes ont largement suivi celles utilisées dans d'autres études effectuées en collaboration visant à établir la priorité entre les recherches et ont impliqué un grand groupe de praticiens de l'habitat du poisson d'eau douce (p. ex., des gestionnaires d'écosystèmes et des experts en politiques) ainsi qu'un groupe diversifié de chercheurs (internes et externes au MPO). Les principales étapes de notre méthodologie ont été les suivantes : *i*) la compilation de 1903 lacunes dans les connaissances recensées dans les publications précédentes et par une enquête d'experts, *ii*) le raffinement et la compilation de ces lacunes dans les connaissances pour produire une liste de 334 questions de recherche candidates, *iii*) un processus Delphi en ligne pour déterminer 93 questions de recherche les plus importantes pour la gestion des habitats, ainsi que la détermination de la quantité de ressources scientifiques (p. ex., les coûts) nécessaires pour répondre à chaque question et de la quantité de connaissances scientifiques existantes pertinentes pour chaque question. Nous discutons de l'applicabilité générale de notre approche à la planification scientifique au sein de Pêches et Océans Canada, et nous proposons des améliorations pour accroître l'efficacité et la répétabilité du processus.

1.0 INTRODUCTION

Scientific information provides a valuable evidence base for government policy and decision-making. Yet, despite broad awareness of the importance of science, identifying research projects that would best support science users (e.g. policy makers and practitioners) remains a challenge. In part, this issue relates to the challenge of translating the specific needs of science users into testable scientific research questions (O'Connell and White 2017). Additionally, research outputs can fail to meet users' needs if they are not timely, if they are not at a level of analysis relevant to the needs of users, or if they not adequately communicated. While many researchers and science funders consider the utility of proposed research when planning their scientific activities, there is still a gap between the scientific research that is conducted and the needs of science users (Pullin et al. 2009; O'Connell and White 2017). Developing methods to help close this 'science-policy gap' would help to provide a broader base of science that is directly relevant to the needs of government, and would promote a more efficient use of scientific resources.

Fortunately, several global, national, and regional initiatives have been implemented to bring together researchers, science-users and other stakeholders to prioritize scientific research via a formal process that encourages collaboration and discussion (collaborative research prioritization (CRP) approaches: see Dey et al. 2020 for a review). From these exercises, an effective framework for consensus building has emerged that is inclusive and democratic, and serves to identify a set of research questions that best meet specific criteria (Sutherland et al. 2011). These approaches are being increasingly used to identify priority research questions for natural resource management and conservation (e.g. Almeida et al. 2013; Parsons et al. 2014, 2015; Coleman et al. 2019), and could be used to support science planning activities within and across science-based government departments.

In this project, we used CRP methods to identify scientific research questions that, if addressed, would best support freshwater fish habitat management by Fisheries and Oceans Canada's (DFO's) Fish and Fish Habitat Protection Program (FFHPP). FFHPP is responsible for the administration of the Fish and Fish Habitat Protection Provisions in the *Fisheries Act* and relevant habitat provisions of the *Species at Risk Act*. Ensuring these efforts can be directly informed by sound science is essential to successful program delivery. Given the vast quantity and diversity of freshwater fish habitat in Canada, and the importance of the Fish and Fish Habitat Protection Provisions to managing those habitats, effectively linking scientific research with the needs of FFHPP could significantly improve progress towards national and global biodiversity goals.

This document outlines the methods used to develop a list of 93 priority research questions related to freshwater fish habitat management. We describe each step of the project's work plan in detail, and provide suggestions for improvement for future research prioritization methods including a discussion of how research prioritization might fit into a broader scientific life cycle. Finally, we also present the list of 93 priority

research questions, however detailed discussion and interpretation of the priority research questions is found in a separate report (Dey et al., 2021)

2.0 METHODS

Our methods broadly followed those used in previous CRP studies (Sutherland et al. 2009; Fleishman et al. 2011; Rudd et al. 2011), which is an increasingly common framework for groups of experts to identify research questions that meet specific criteria. In their review of 41 previous CRP studies, Dey et al. (2020) identified four steps common to CRP studies, including *i)* assembling a large set of candidate research questions, *ii)* collating and refining the candidate questions to ensure they meet

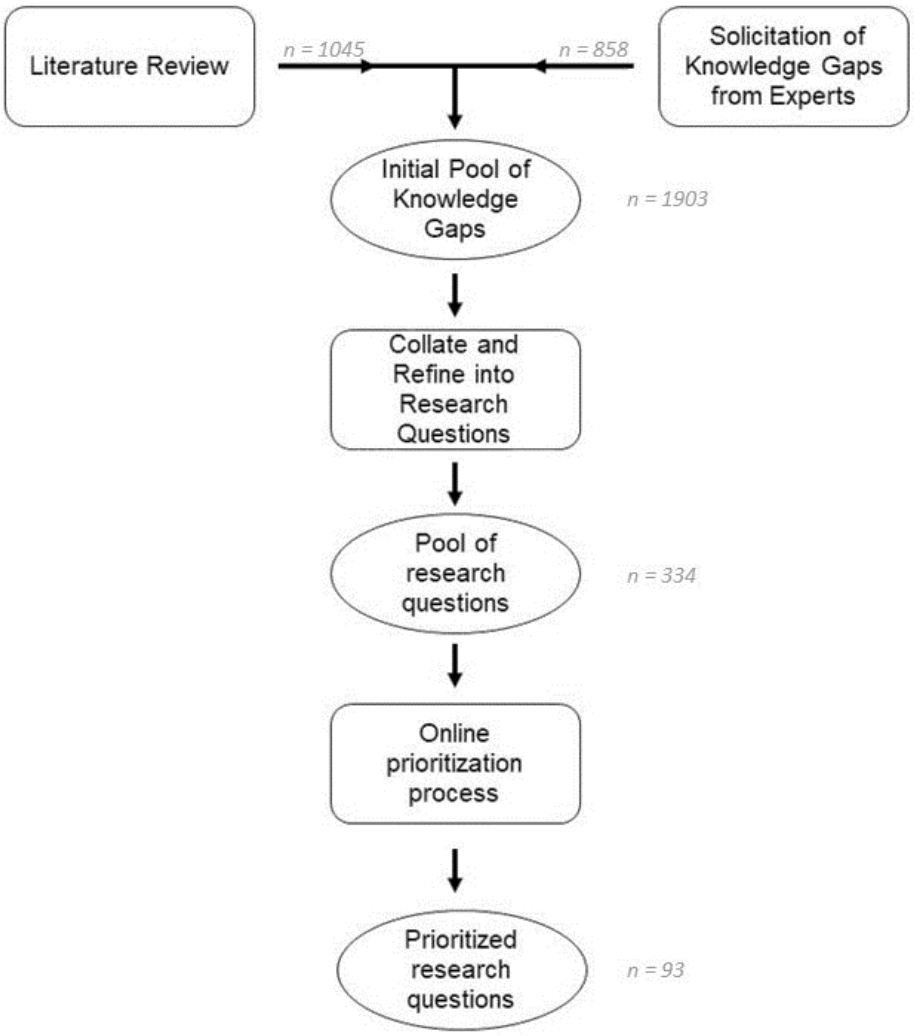


Figure 1. Overview of methods used to identify priority research questions related to freshwater fish habitat management. Values in grey text show the number of knowledge gaps or research questions included at each stage of the process.

inclusion criteria and to remove duplicates, *iii)* democratically ranking or scoring the candidate questions based on predefined criteria, and *iv)* disseminating the identified research priorities in a list. This document outlines our methods for accomplishing these steps (see Figure 1 for an overview).

2.1 PROJECT GOVERNANCE

The authors of this report constitute the project Steering Committee that was formed in April 2019 with representation from DFO - Science and FFHPP. Regional representation by Steering Committee members is held by Ontario and Prairie, Arctic, Pacific, National Capital, Gulf, and Newfoundland and Labrador regions.

The Steering Committee defined the objectives and work plan for this project. In particular, the Steering Committee was crucial in defining the scope of the project and bounded by focusing on identifying freshwater fish habitat research questions that would directly support the activities of FFHPP. While many of these research questions are also relevant to ecosystem management activities performed by other organizations (e.g. Indigenous, provincial or municipal governments), we prioritized engagement with FFHPP as the focal science user for this project. In addition, the project focused on identifying research questions in the natural sciences (rather than policy or social science research questions), while recognizing that there are not hard boundaries between these fields.

2.2 LITERATURE REVIEW

Using the Federal Science Library, and referrals from the project's Steering Committee, we identified documents likely to include scientific knowledge gaps related to Canadian freshwater habitat. In order to meet our inclusion criteria, documents included in our review must have been published between 1986 and 2019, be available online, and be written in French or English. We performed two searches of the Federal Science Library to identify relevant documents. First, we searched all publications produced by the Canadian Science Advisory Secretariat (CSAS) that referenced freshwater or related keywords (see Appendix A). Second, we searched all publications on the Federal Science Library for documents referring to freshwater (or related keywords) and keywords related to scientific gaps and priorities. This second search was meant to identify documents from the primary literature or other grey literature series that specifically identified freshwater research priorities. Given the potential for this second search to match to a large number of documents with low relevance to the current study (i.e. false positives), we used highly restrictive search terms to minimize the number of matches received. The strings used for these searches are shown in Appendix A. Additional documents identified by the Steering Committee were also included in our review. Full text versions of the documents were reviewed by AIR or CJD, and any scientific knowledge gaps identified by the authors were extracted to a database.

We reviewed 401 documents during this process. Each document was subject to an initial review to screen the document against inclusion criteria, including a check of

whether the document was focused on Canadian freshwater fish or fish habitat science. 262 documents met the inclusion criteria and were subjected to a full text review by CJD or AIR. Any scientific knowledge gaps identified in the documents were extracted verbatim into a database, and were also re-stated into a straightforward question describing the knowledge gap. For example, the statement "*In particular data are needed to determine if the life history parameters for the river migrant population are different than the stream residents*" (Caskenette and Koops 2018) was restated as "*How do life history parameters of rainbow trout differ between resident and migrant populations?*". In addition, we collected information on the focal taxa and focal region that were linked to the knowledge gap.

The majority of these documents included in our review were CSAS reports (89%), with additional documents being sourced from the primary literature (5%), other DFO publications (4%), or other external sources (2%). Most documents were written in English, although a small number (n = 7) of French documents were also included. Of these 401 documents, 221 yielded one or more knowledge gaps related to Canadian freshwater fish habitat (mean = 4.7 knowledge gaps per document, range 1 – 110), and we extracted a total of 1045 knowledge gaps across all documents.

2.3 EXPERT SURVEY

We also solicited scientific knowledge gaps from experts in science, policy, and management of Canadian freshwater fish habitat using an online survey that was open from October 11th, 2019 to January 10th, 2020 (13 weeks). Invitations to complete the survey were distributed to DFO employees (primarily within the Ecosystems and Oceans Science Sector and the Aquatic Ecosystems Sector), as well as to external experts (including academics, non-governmental organizations, and external government staff) through email, the GCcollab 'Freshwater Habitat Science Initiative' group, and through a national-level 'In The Loop' article. The survey design (Appendix B) and invitation materials were reviewed and approved by the Lakehead University Research Ethics Board (reference file number 1467329), and was available for respondents to complete in English or French.

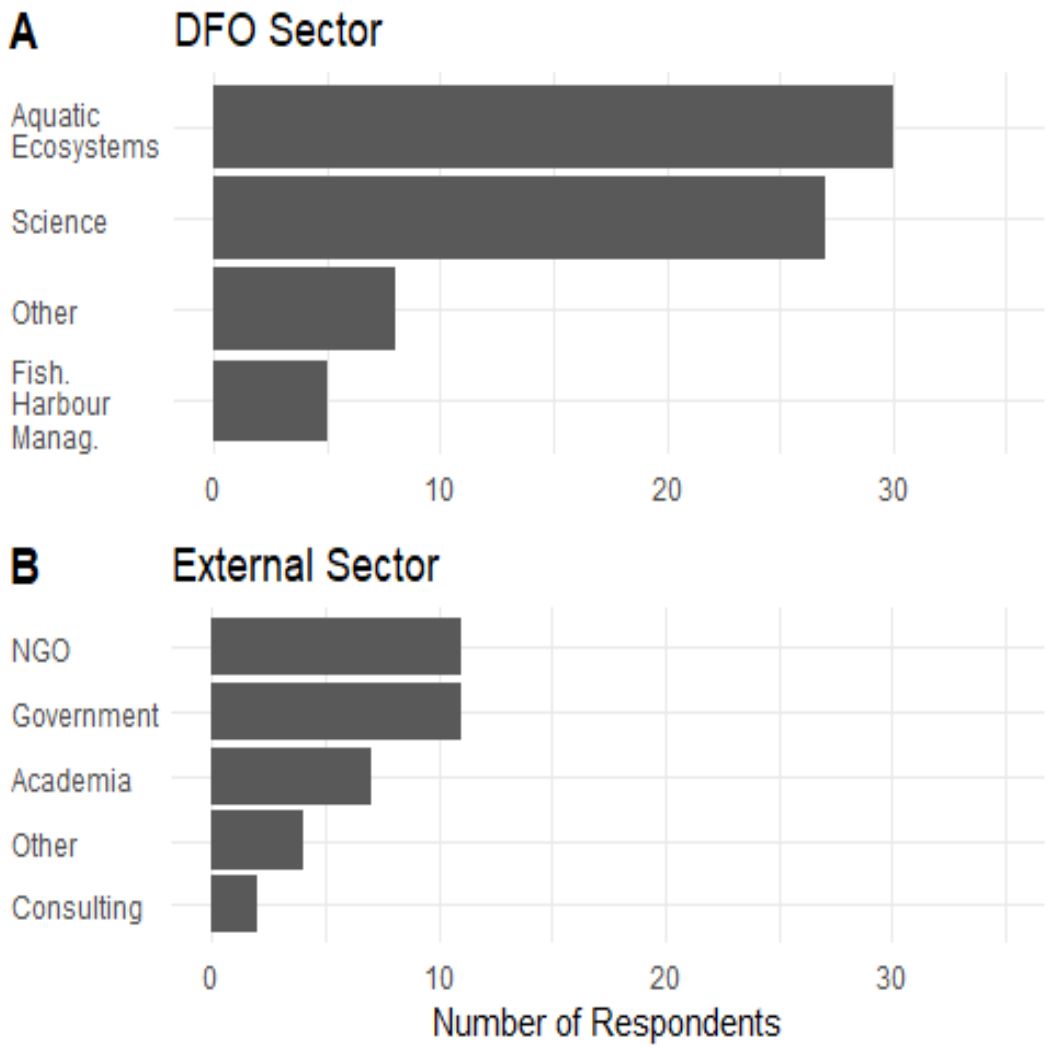


Figure 2. Sectors of current employment for respondents to the expert survey. Note that respondents were not required to provide their sector of employment and therefore the sample size included in this figure does not equal the total sample size for the survey.

We received 112 completed responses to our survey. Due to the diverse methods used to invite participants to participate in this survey, we could not estimate the response rate. Respondents identified being primarily employed as researchers (34%), ecosystem managers (24%), policy experts (12%), science advisors (11%), and in other professions (16%). Figure 2 shows the reported employment sectors for respondents from DFO (Figure 2A) and external respondents (Figure 2B).

Survey respondents reported having a large amount of experience working on freshwater fish habitat issues, with 60% of respondents reporting they had at least 10 years experience, and only 6% of respondents reporting they had less than 1 year experience. In addition, there was strong regional coverage in the survey respondents, with at least 12 respondents reporting expertise in each DFO Region.

On average, respondents submitted 7.7 knowledge gaps (range of 1 – 35), for a total of 858 knowledge gaps across all respondents.

The complete list of 1903 knowledge gaps assembled through the survey and literature review described above is available as Appendix C.

2.4 REFINING AND COLLATING THE POOL OF KNOWLEDGE GAPS

We refined the initial pool of 1903 knowledge gaps by combining conceptually similar knowledge gaps, and rephrasing knowledge gaps into research questions. To conduct this procedure, we used a two-step approach that relied on computer-based text analysis tools and expert judgement from human observers.

During step 1, we used the *R* (R Core Team 2019) package *quanteda* (Benoit et al. 2018) to process each knowledge gap into a standardized format (e.g. acronyms were spelled out, capitalization was standardized, and synonyms were replaced with a common term). Then, we calculated pairwise similarity scores (ranging from 0 to 1) for all pairs of knowledge gaps using cosine text similarity (Gomma and Fahmy 2013). Next, we wrote a custom R script that identified sets of similar knowledge gaps based on walktrap clustering (Pons and Latapy 2006), a method of identifying communities in networks (in this case, a network of similarity scores among knowledge gaps). The set of most similar knowledge gaps was reviewed by an expert observer (CJD) who decided whether those knowledge gaps (or a subset of those knowledge gaps) should be combined (Figure 3). When knowledge gaps were combined, the human observer created new text to represent the combined knowledge gap. Based on the example in Figure 3, these knowledge gaps (and others) were combined into the more general question: “What is the availability, distribution, and quality of habitat for a given species, and how can this habitat be better mapped?” We conducted this process iteratively with new knowledge gaps (resulting from the combination of other knowledge gaps) being fed back into the process. This process continued until there were 1000 knowledge gaps remaining in the pool. The script used to conduct this step can be requested by contacting Cody Dey (cody.dey@dfo-mpo.gc.ca).

```
Evaluate questions to combine?y
[1] "What is the spatial extent and habitat use of the Northern Madtom?"
[2] "What is the current distribution of the Plains Minnow?"
[3] "What is the extent of suitable habitat for the Plains Minnow?"
[4] "What is the current distribution of, and extent of suitable habitat for Silver Shiner
[5] "What is the extent of occurrence and range of Northern Madtom in Canada"
```

Figure 3. Example of a set of similar knowledge gaps from the original pool of 1903 identified using computer-based text similarity approaches.

During step 2, we sorted the 1000 remaining knowledge gaps into groups based on keyword matching, and manually combined similar knowledge gaps within and across keyword groups. This was accomplished by first using R to assign all remaining knowledge gaps to one or more temporary groups based on whether the knowledge

gap contained one of the keywords defining the keyword group (e.g. one keyword group related to area-based conservation was defined by the terms ‘protected area’, ‘protected-area’, ‘significant area’, ‘critical habitat’, and all knowledge gaps containing at least one of those terms were assembled into a keyword group). Similar knowledge gaps were then manually combined into a single knowledge gap, by manually identifying sets of conceptually similar knowledge gaps within and across keyword groups. During this step, knowledge gaps that were unrelated to freshwater fish habitat (e.g. some were specific to marine environments), or deemed too broad (e.g. some survey responses were limited to entire research fields such as ‘invasive species’) were removed from the pool. In addition, retained knowledge gaps were rephrased as research questions, and reworded such that they were not specific to a given species or region. This process resulted in the creation of a pool of 334 research questions that collectively represented the range of knowledge gaps identified from the literature review and expert survey (Appendix D).

2.5 RESEARCH QUESTION PRIORITIZATION

The pool of 334 research questions described above served as a starting point for the creation of a list of priority research questions. Initially, the steering committee had developed methods to host a two day in-person workshop, in which a group of 30-40 researchers and freshwater fish habitat practitioners would identify priority research questions. These methods closely reflected those used in other CRP studies (e.g. Cramer et al. 2016; Antwis et al. 2017; Trnka et al. 2018), and would have relied on a combination of breakout and plenary sessions to refine and select priority research questions.

However, public health restrictions in response to the COVID-19 pandemic required alternative methods to be developed. The steering committee instead opted for an asynchronous, online Delphi approach in lieu of the in-person workshop. Delphi processes are characterized by iterative and anonymous participation by a group of experts that aim to arrive at a consensus (Mukherjee et al. 2015).

Our Delphi process included three steps: (i) An initial scoring phase, in which each participant scored a subset of the initial list of 334 research questions. These scores were used to narrow the scope of the remaining steps of the process by eliminating research questions that were deemed unimportant to fish habitat management in Canada, (ii) A feedback phase, in which participants reviewed the initial scores given to the 93 remaining research questions and provided written comments related to those scores. Participants were invited to comment both on the scores themselves (e.g. if they thought the group had rated a question as more or less important than it ought to be) or on the question text (e.g. if they thought the research question could be improved by small textual changes), (iii) A final scoring phase, in which participants reviewed the comments of their peers and selected their final scores for the remaining research questions. We circulated all materials (and invited responses) in both English and French.

In each step of the prioritization process, participants were asked to score each question based on its importance to freshwater fish habitat management in Canada (six point Likert scale, ranging from Very Unimportant to Very Important), with the highest scores being reserved for questions that, if answered, would have transformative impacts on freshwater fish habitat management in Canada. In addition, participants scored questions based on the amount of scientific resources they thought would be required to answer the question (four point Likert scale, ranging from Very Low to Very High) and the extent of existing scientific knowledge related to the research question (four point Likert scale, ranging from Very Limited to Well Known). These additional metrics were included to help inform researchers, funders and science planners of the likely costs and best approach to addressing each priority research question. See Appendix E for a complete description of the data collection methodology.

In addition to the data described above, we also recorded basic demographic information from each participant. During each step, individuals were asked to report their name and professional affiliation, whether they are primarily engaged in freshwater fish habitat research (researchers) or in freshwater fish habitat policy and management (practitioners), and whether they had more or less than 10 years of professional experience working on freshwater fish habitat issues.

The steps of the prioritization process are outlined below. Appendix E shows the design of the web interface used by participants during the prioritization steps.

Step 1. Initial scoring

The goal of the initial scoring phase was to collect first-pass data on each of the 334 research questions in order to reduce the scope of the exercise by focusing discussion on the most important questions, and provide data to support future discussion (i.e. to inform step 2 and step 3, described below).

In this step, 60 participants each reviewed a subset (n = 48 or n = 49) of the 343 candidate priority research questions. Participants scored each question on its perceived importance to management, scientific resource requirements and extent of existing knowledge, as described above. Participants were not required to provide a score to each question, and could skip a question if they felt they did not have sufficient expertise to respond. Each research question was scored by a minimum of 5 respondents (range 5 – 10), with an effort made to assign an equal number of researchers and practitioners to each question. The initial score data for each of the 343 candidate priority research questions are available in Rego et al. 2021.

Research questions were selected to continue on to step 2 if they met one of the following three criteria:

- All researcher respondents considered it Important or Very Important
- All practitioner respondents considered it Important or Very Important
- More than half of the practitioner respondents considered it Very Important

Step 2. Feedback and question rewording

In step 2, we invited participants to provide comments on each of the outstanding 106 research questions. Participants were prompted with graphical displays that summarized the initial scoring data for each research question (e.g. Figure 4), and asked to contribute comments related to the scores provided (e.g. if they agreed or disagreed with the scores provided by their peers, and the reasons for their agreement or disagreement). To help streamline the process, research questions were sorted into one of ten research theme areas (Table 1), and participants were presented with all of the research questions in a given theme area at a time (e.g. participants would see all of the research questions and initial scoring data for 'habitat management effectiveness' and would be invited to comment on specific questions). In addition to soliciting comments on the initial scores, we invited suggestions for improvements to the wording of each question. Participants were not required to provide comments for each question, and were encouraged to keep their comments concise.

Table 1. The ten research theme areas that individual research questions were assigned to prior to step 2 of the prioritization process

Multiple stressors and cumulative effects
Habitat management effectiveness
Stressors to fish habitat
Habitat, population dynamics and community structure
Habitat monitoring
Flow, fish passage and habitat connectivity
Habitat classification
Climate impacts on habitat
Habitat use
Other habitat issues

Fifty four individuals completed step 2 and provided a total of 766 comments on the scores provided to the research questions. In addition, these participants provided 328 comments on the wording of the questions. For each research question, comments related the scores were manually summarized by combining similar comments, and paraphrasing longer comments. These comments were provided (alongside the graphical described above and shown in Figure 4), for each participant's consideration in step 3.

Comments related to rewording suggestions were collated and circulated among the steering committee members. Through a combination of live and asynchronous discussions, the steering committee used these comments to revise the set of research questions under consideration. As a result of these

discussions, 56 questions were slightly modified, 3 questions were split into a resultant 6 questions, 14 questions were merged into a resultant 7 questions, and 9 questions were removed as not directly applicable to freshwater fish habitat management. This resulted in a revised list of 93 research questions for consideration during step 3.

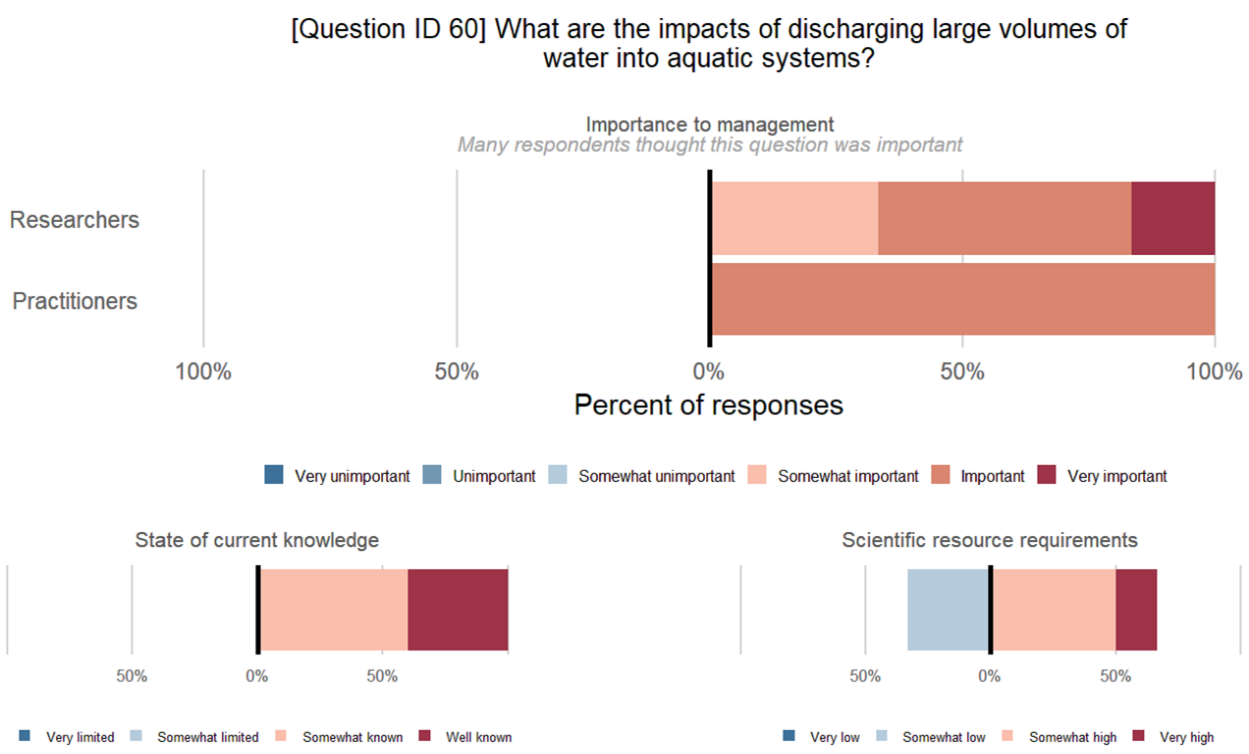


Figure 4. Example of the graphical displays presented to participants during step 2 of the prioritization process. One such display was produced for each of the 106 remaining research questions, with the data coming from participant responses in step 1.

Step 3. Final scoring

In the final scoring phase, participants were presented with graphical displays of the initial scoring data for each research question, as well as the summarized comments related to that question collected during step 2. Participants were then asked to provide a final score for each research question on each of the three metrics under consideration (importance to management, scientific resource requirements, and extent of existing knowledge), after reviewing these materials.

Forty eight participants completed step 3, and the data collected through this step were used to define the final list of priority research questions. First, we converted Likert scales to numeric values and calculated mean importance

scores based on the scores from researchers and practitioners separately. Then, we ranked questions based on equal weighting of the responses from researchers and practitioners, based on practitioner responses alone, and based on researcher responses alone. Importance scores for all 93 priority research questions can be interactively viewed through the affiliated web application created using the *Shiny* package (Chang et al. 2020) and are also available in Rego et al. 2021.

3.0 REFLECTION ON THE METHODS USED AND SUGGESTIONS FOR FUTURE RESEARCH PRIORITIZATION ACTIVITIES

Our project represents a large-scale effort to arrive at research questions that, if answered, would best support the freshwater fish habitat management activities of FFHPP. By involving experts from across Canada who are familiar with the needs of FFHPP, we believe the identified priority research questions will be a useful product for science planners, funders, and individual researchers seeking to advance our understanding of freshwater fish habitat and its management in Canada.

In our study, we used both a literature review and an expert survey to produce an initial pool of knowledge gaps related to freshwater fish habitat science. This contrasts the typical approach from CRP studies, which usually solely rely on soliciting suggestions from experts. Our pool of knowledge gaps contained about equal contributions from each of these sources (knowledge gaps from literature review = 1054, knowledge gaps from expert survey = 858), and knowledge gaps from each source showed similar representation across most topical tags (Figure 5). Relative to the expert survey, knowledge gaps from the literature review included relatively more focus on life history and vital rates, habit impacts on productivity, and the avoidance and mitigation of the harmful alteration, disruption or destruction of habitat (HADD).

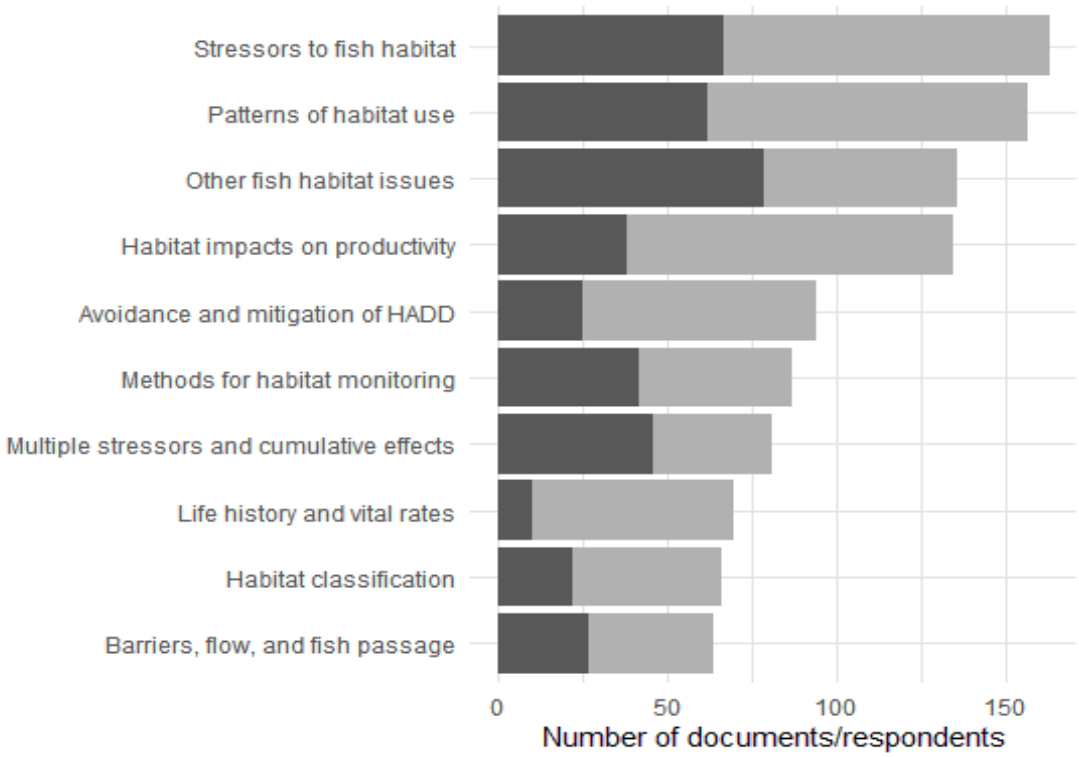


Figure 5. The number of survey respondents (dark grey) and documents (light grey) mentioning scientific knowledge gaps tagged with various topics. The top 10 tags by frequency are shown.

As such, it is challenging to point to a clear benefit of conducting both a literature review and an expert survey to generate this initial pool of knowledge gaps. The literature review included documents published back to 1986, and therefore may have identified some persistent knowledge gaps that were never addressed. However, some knowledge gaps identified in earlier documents may already have been answered or scientific/management solutions may have been developed to avoid the knowledge gap, and therefore the inclusion of knowledge gaps from earlier in our literature review time window may have unnecessarily increased the scope of the project (in terms of increased data processing requirements). Including both the literature review and expert survey makes for a more comprehensive pool of knowledge gaps because some of the identified knowledge gaps were unique to one source. But it is unclear whether the set of candidate priority research questions (n = 334) would have been substantially different if only one of these sources was used. Moreover, most CRP projects allow for new candidate questions to be added during the prioritization phase (e.g. if an important question was missing), and therefore gathering a fully comprehensive pool of knowledge gaps during early project phases may not be necessary as any obvious gaps can be filled by experts during prioritization.

To our knowledge, no CRP study has used an online Delphi process similar to that used in our study. Instead, most previous studies have used in-person workshops for the prioritization phase of the project, involving breakout and plenary discussions, and live

voting. Our approach allowed for participation by a larger group of experts than would have otherwise been feasible during an in-person workshop, while also supporting a more quantitative approach to prioritization (e.g. online data collection and summarization rather than voting in an in-person setting). In addition, the anonymity afforded by Delphi methods should reduce various social pressures (e.g. dominance by senior group members or bias related to halo effects, see Maier 1967; Nisbett and Wilson 1977) that affect many group-based approaches, and may promote more diverse and balanced discussion. The downside of these methods is that they do not allow for the dynamic and in-depth discussion afforded by in-person workshops. Furthermore, online approaches are not as effective at building relationships at the science-policy boundary, which has been identified as an important outcome of previous CRP projects (Rudd 2011).

Delphi approaches depend on the use of multiple rounds of collecting expert opinion, interspersed with rounds of feedback. The assumption is that feedback and discussion will result in greater consensus as relevant information is exchanged among participants. Indeed, Rowe et al. (2005) showed that the proportion of correct responses increased over Delphi rounds when feedback was provided in an experimental setting. As a measure of consensus, we quantified how the correlation between researcher and practitioner responses (related to each question's importance to management) changed between step 1 (initial scoring) and step 3 (final scoring) (Figure 6).

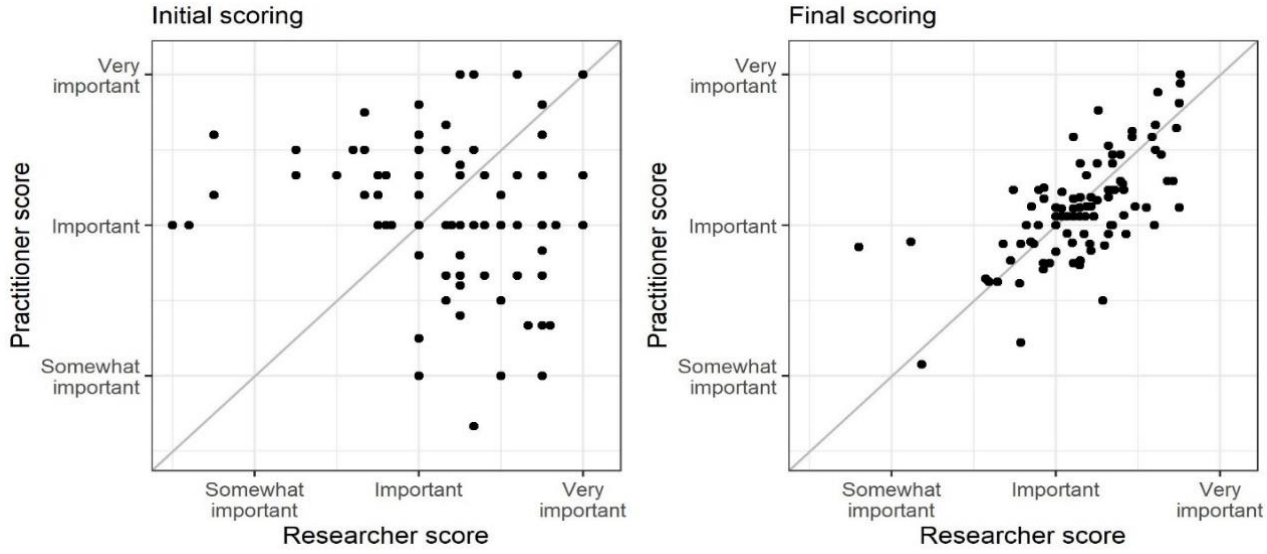


Figure 6. Researcher and practitioner scores for the importance of each research question to freshwater fish habitat management, during the initial scoring step (left panel) and the final scoring step (right panel). Values shown are the mean response for each group of respondents, for each of 93 research questions. The higher correlation during the final scoring step suggests that the prioritization process was successful at building consensus between researchers and practitioners.

We found that researchers and practitioners showed a clear increase in their agreement on each question's importance to management between the initial and final scoring steps (Figure 6), with correlation coefficients (*r*) of -0.10 (95% CI = (-0.30, 0.11)) for the initial scoring step and 0.66 (95% CI = (0.53, 0.76)) for the final scoring step. This difference remained even after using randomization methods to account for differences in the number of respondents contributing to each data point, which controlled for the fact that more individuals scored each question in the final scoring step relative to the initial scoring step. On average, management respondents shifted their score for each question by 0.38 Likert steps between initial and final scoring, while research respondents shifted their scores by an average of 0.25 Likert steps. We suggest therefore, that our online Delphi methods were successful in developing consensus between freshwater fish habitat researchers and practitioners.

One drawback of these methods, however, is that the processing of text comments can be labor intensive. In the current study, our methodology required us to manually combine similar comments, and paraphrase verbose comments, across each of 93 research questions. While respondents were instructed that they did not need to comment on each question and that comments should be concise, we still received up to 609 words of feedback per question, when the comments from all participants were pooled. As such, summarization was necessary so that there was not an overwhelming amount of text for participants to consider during the final scoring activity. For future exercises, the labor intensity of this text summarization could be mitigated by several methods including limiting the number of items under discussion (e.g. having fewer research questions under consideration), imposing word limits on the comments from respondents, or limiting the number of commenters (e.g. only inviting respondents to comment on up to 10 items).

During the prioritization phase of our study, participants scored research questions on three metrics: their importance to management, the amount of scientific resources required to address them (i.e. the costs), and the amount of relevant scientific knowledge that already exists. We suggest that such a multi-dimensional data collection procedure is a major improvement over using a single metric related to the importance or priority of the research question. Many previous CRP studies have scored or ranked questions based solely on their perceived importance. However, such an approach can result in the selection of priority research questions that are broad in scope and that would be very challenging to address over a short or medium time frame. This issue has been cited as a potential hindrance to answering priority research questions identified through CRP methods (Rees et al. 2016; Dey et al. 2020).

Explicit consideration of the costs, and the context (e.g. the amount of research already done on a given topic) can improve research prioritization methods through several mechanisms. The consideration of different aspects of each research question (e.g. importance, cost, existing knowledge) should encourage effective discussion among CRP participants. This is because participants can more accurately identify where their views differ from those of their peers, and focus discussion on those issues (e.g. there may be broad consensus on the amount of existing knowledge, but disagreement on the costs of addressing a

given research question). In addition, a multivariate approach helps to identify the subjective nature of defining a list of priority research questions. While some questions may be of greater importance to management than others, it does not automatically follow that these questions should be priorities for funding and research attention. By providing context and cost data as part of sharing the results of the project, science planners and funders can create lists of priority research questions that meet their own criteria. For example, some funding bodies may wish to prioritize funding research that can deliver results over short time frames, or may be restricted to supporting research that requires lower research requirements due to institutional constraints.

4.0 HOW DOES RESEARCH PRIORITIZATION FIT INTO A SCIENTIFIC LIFE CYCLE?

Collaborative research prioritization projects, such as the current study, are intended to support individual researchers, science planners and funders, and science users. As such, it is worth considering the role that these studies play in the scientific life cycle (Figure 7), and outline how the products of this study could be used.

Ultimately, CRP studies provide a valuation of research questions. In some circumstances, individual researchers may use these valuations to select research questions to investigate. However, a more typical scientific life cycle would see the products of CRP studies used by science planners and funding bodies to support the creation of strategic research plans. In this way, high value research questions can be filtered through the unique goals and constraints of scientific institutions. Viewed as such, the primary clients of CRP studies are science planners and funders, and therefore the involvement of science planners and funders in the CRP process is an important aspect of a successful prioritization project (Dey et al. 2020). In many cases, science users are also a primary funder of research, and therefore the involvement of science users in the research prioritization process may satisfy this objective.

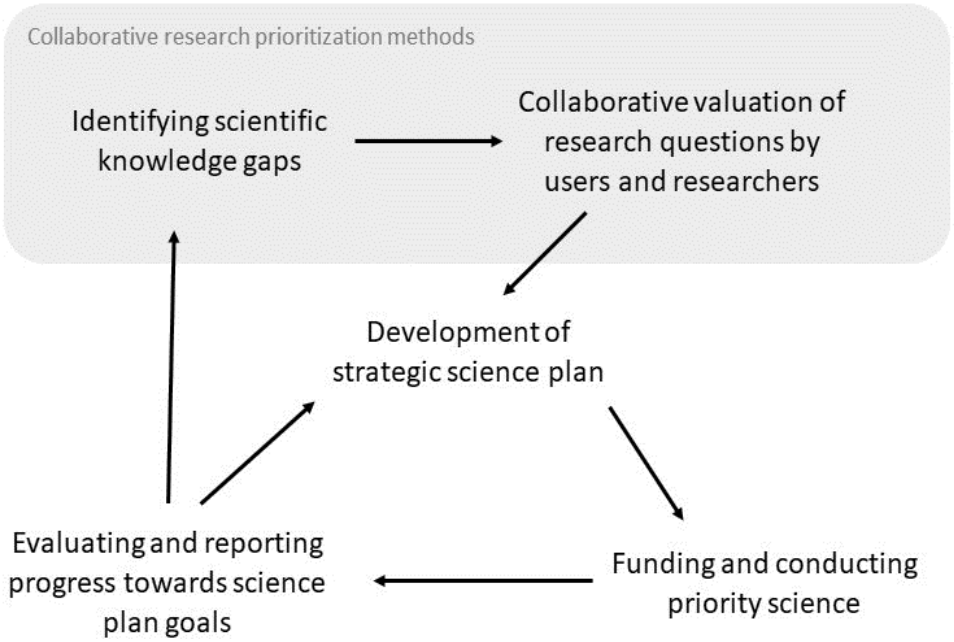


Figure 7. Conceptual outline of a scientific life cycle including the role of collaborative research prioritization methods. Ideally, the identification of scientific knowledge gaps and the collaborative valuation of research questions, would be completed as first steps in initiating this cycle.

The evaluation and reporting of progress towards research goals is a key activity for many science planners and funders. Such activities can take many forms, including stakeholder and researcher surveys, quantification of research products, assessments of research impact or bibliometric analyses. Efficient evaluation and reporting can be supported by identifying key metrics during science plan development, so that the relevant data can be collected while research is conducted rather than as a post-hoc exercise. Cooke et al. (2020) provide a comprehensive overview of the types of metrics that could be used for evaluating progress and success in applied environmental research, including measures of the quality, quantity and relevance of scientific output, measures of the strength of relationships with partners, and measures of the utility of research for solving policy and/or management problems.

In many cases, the outputs created during evaluations of research progress could feed into new research prioritization processes. Evaluating research progress necessarily requires identifying persistent or new knowledge gaps, which could be combined with knowledge gaps identified during previous research prioritization studies to feed into prioritization activities. In this way, CRP processes could be repeated at regular intervals, with a relatively low labor cost (because the time consuming process of creating a pool of knowledge gaps would leverage other products).

In addition, modified CRP methods (including online Delphi methods) could be used in the evaluation of research progress itself. For example, research evaluators could compare scores of ‘the amount of existing knowledge’ for individual research questions from different time points to assess progress on that question. Alternatively, participants could be asked their perceptions on ‘the amount of recent progress in answering this question’ to determine if research funding related to a given topic has resulted in a perceived increase in progress from the perspective of science users. This technique is similar to many stakeholder survey techniques that are already used for research evaluation, but could be conducted as part of a CRP project so long as care was taken to avoid conflating perceived progress with actual progress.

While CRP projects can be relatively resource intensive and time consuming, they provide valuable support for the creation of strategic research plans and the creation of applicable research. In addition, subsequent research prioritization projects can leverage the products produced by earlier projects, and therefore could be conducted with shorter timelines and fewer scientific resources.

ACKNOWLEDGEMENTS

The authors thank the many experts in freshwater fish habitat science, management and policy who participated in different phases of this study. In addition, we thank Ken Minns for suggesting documents for inclusion in our literature review, and James Manicom for helping to connect the project broadly with the Fish and Fish Habitat Protection Program. We also thank the Lakehead University Research Ethics Board for reviewing and commenting on our survey design. Funding for this project was provided by the DFO *Freshwater Habitat Science Initiative*.

REFERENCES

Almeida, R.M., Pinto, V.G., Castro, M.M., Divino, A.C., Alves, A.C.A., Vasconcelos, D., Magalhães Silva, M.R., Mamede, N., Lima, R.N.S., Mello, R.M., Siviero, T.S., Martins, T., Campos, V., Conde, B.E., Brito, P.S., Favoreto, F.C., Vidal, L.O., and Roland, F. 2013. Addressing key ecological questions to support policy-making in Brazil. Brazilian J. Biol. **73**(2): 455–456. doi:10.1590/S1519-69842013000200033.

Antwis, R.E., Griffiths, S.M., Harrison, X.A., Aranega-Bou, P., Arce, A., Bettridge, A.S., Brailsford, F.L., de Menezes, A., Devaynes, A., Forbes, K.M., Fry, E.L., Goodhead, I., Haskell, E., Heys, C., James, C., Johnston, S.R., Lewis, G.R., Lewis, Z., Macey, M.C., McCarthy, A., McDonald, J.E., Mejia-Florez, N.L., O'Brien, D., Orland, C., Pautasso, M., Reid, W.D.K., Robinson, H.A., Wilson, K., and Sutherland, W.J. 2017. Fifty important research questions in microbial ecology. FEMS Microbiol. Ecol. **93**(5): 1–10. doi:10.1093/femsec/fix044.

Benoit, K., Watanabe, K., Wang, H., Nulty, P., Obeng, A., Müller, S., and Matsuo, A. 2018. Quanteda: An R package for the quantitative analysis of textual data. J. Open Source Softw. **3**(30): 774. doi:10.21105/joss.00774.

Caskenette, A.L., and Koops, M.A. 2018. Recovery potential modelling of Rainbow Trout, Oncorhynchus mykiss (Athabasca River Populations). *In* Canadian Science Advisory Secretariat (CSAS) Research Document.

Chang, W., Cheng, J., Allaire, J., Xie, Y., and McPherson, J. 2020. shiny: Web Application Framework for R.

Coleman, J.L., Ascher, J.S., Bickford, D., Buchori, D., Cabanban, A., Chisholm, R.A., Chong, K.Y., Christie, P., Clements, G.R., dela Cruz, T.E.E., Dressler, W., Edwards, D.P., Francis, C.M., Friess, D.A., Giam, X., Gibson, L., Huang, D., Hughes, A.C., Jaafar, Z., Jain, A., Koh, L.P., Kudavidanage, E.P., Lee, B.P.Y.H., Lee, J., Lee, T.M., Leggett, M., Leimona, B., Linkie, M., Luskin, M., Lynam, A., Meijaard, E., Nijman, V., Olsson, A., Page, S., Parolin, P., Peh,

K.S.H., Posa, M.R., Prescott, G.W., Rahman, S.A., Ramchunder, S.J., Rao, M., Reed, J., Richards, D.R., Slade, E.M., Steinmetz, R., Tan, P.Y., Taylor, D., Todd, P.A., Vo, S.T., Webb, E.L., Ziegler, A.D., and Carrasco, L.R. 2019. Top 100 research questions for biodiversity conservation in Southeast Asia. Biol. Conserv. **234**: 211–220. doi:10.1016/j.biocon.2019.03.028.

Cooke, S.J., Rytwinski, T., Taylor, J.J., Nyboer, E.A., Nguyen, V.M., Bennett, J.R., Young, N., Aitken, S., Auld, G., Lane, J.-F., Prior, K.A., Smokorowski, K.E., Smith, P.A., Jacob, A.L., Browne, D., Blais, J., Kerr, J.T., Ormeci, B., Alexander, S.M., Burn, C.R., Buxton, R.T., Orihel, D.M., Vermaire, J.C., Murray, D.L., Simon, P., Edwards, K.A., Clarke, J., Xenopoulos, M.A., Gregory-Eaves, I., Bennett, E.M., and Smol, J.P. 2020. On “success” in applied environmental research – What is it, how can it be achieved, and how does one know when it has been achieved? Environ. Rev. **16**: 1–35. doi:10.1139/er-2020-0045.

Cramer, V.A., Dunlop, J., Davis, R., Ellis, R., Barnett, B., Cook, A., Morris, K., and Van Leeuwen, S. 2016. Research priorities for the northern quoll (Dasyurus hallucatus) in the Pilbara region of Western Australia. Aust. Mammal. **38**(2): 135–148. doi:10.1071/AM15005.

Dey, C., Rego, A., Bradford, M., Clarke, K., McKercher, K., Mochnacz, N., de Paiva, A., Ponader, K., Robichaud, L., Winegardner, A., Berryman, C., Blanchfield, P.J., Boston, C., Braun, D., Brownscombe, J.W., Burbidge, C., Campbell, S., Cassidy, A., Chu, C., Cooke, S., Coombs, D., Cooper, J., Curry, R.A., Cvetkovic, M., Demers, A., Docker, M.F., Doherty, A., Doka, S., Dunmall, K., Edwards, B., Enders, E., Fisher, N., Gauthier-Ouellet, M., Glass, W.R., Harris, L.N., Hasler, C., Hill, J., Hinch, S., Hodgson, E., Hwang, J., Jeffries, K., King, L., Kiriluk, R., Knight, R., Levy, A., MacDonald, J., Mackereth, R., McLaughlin, R., Minns, C.K., Moore, J., Nantel, K., Nessman, C., Normand, C., O’Connor, C.M., Paulic, J., Phalen, L., Post, J., Pratt, T., Reid, S., Rose, A., Rosenfeld, J., Smokorowski, K., Sooley, D., Taylor, M., Treberg, J., Trottier, J., Tunney, T., Veilleux, M.-P., Watkinson, D., Watts, D., Winfield, K., Ziegler, J., Midwood, J., and Koops, M. 2021. Research priorities for the management of freshwater fish habitat in Canada. Can. J. Fish. Aquat. Sci. **0**: 00–00.

Dey, C., Rego, A., Midwood, J.D., and Koops, M.A. 2020. A review and meta-analysis of collaborative research prioritization in ecology, biodiversity conservation, and environmental science. Proc. R. Soc. B Biol. Sci. **287**(1923): 20200012.

Fleishman, E., Blockstein, D.E., Hall, J.A., Mascia, M.B., Rudd, M.A., Scott, J.M., Sutherland, W.J., Bartuska, A.M., Brown, A.G., Christen, C.A., Clement, J.P., DellaSala, D., Duke, C.S., Eaton, M., Fiske, S.J., Gosnell, H., Haney, J.C., Hutchins, M., Klein, M.L., Marqusee, J., Noon, B.R., Nordgren, J.R., Orbuch, P.M., Powell, J., Quarles, S.P., Saterson, K.A., Savitt, C.C., Stein,

B.A., Webster, M.S., and Vedder, A. 2011. Top 40 Priorities for Science to Inform US Conservation and Management Policy. Bioscience **61**(4): 290–300. doi:10.1525/bio.2011.61.4.9.

Gomma, W.H., and Fahmy, A.A. 2013. A Survey of Text Similarity Approaches. Int. J. Comput. Appl. **68**(13): 13–18.

Maier, N.R. 1967. Assets and liabilities in group problem solving: The need for an integrative function. Psychol. Rev. **74**(4): 239–249. doi:10.1037/h0024737.

Mukherjee, N., Hugé, J., Sutherland, W.J., Mcneill, J., Van Opstal, M., Dahdouh-Guebas, F., and Koedam, N. 2015. The Delphi technique in ecology and biological conservation: Applications and guidelines. Methods Ecol. Evol. **6**(9): 1097–1109. doi:10.1111/2041-210X.12387.

Nisbett, R.E., and Wilson, T.D. 1977. The halo effect: Evidence for unconscious alteration of judgments. J. Pers. Soc. Psychol. **35**(4): 250–256. doi:10.1037/0022-3514.35.4.250.

O'Connell, M., and White, R. 2017. Academics can also be culprits of evidence complacency. Nat. Ecol. Evol. **1**(11): 1589. doi:10.1038/s41559-017-0346-9.

Parsons, E.C.M., Baulch, S., Bechshoft, T., Bellazzi, G., Bouchet, P., Cosentino, A.M., Godard-Codding, C.A.J., Gulland, F., Hoffmann-Kuhnt, M., Hoyt, E., Livermore, S., MacLeod, C.D., Matrai, E., Munger, L., Ochiai, M., Peyman, A., Recalde-Salas, A., Regnery, R., Rojas-Bracho, L., Salgado-Kent, C.P., Slooten, E., Wang, J.Y., Wilson, S.C., Wright, A.J., Young, S., Zwamborn, E., and Sutherland, W.J. 2015. Key research questions of global importance for cetacean conservation. Endanger. Species Res. **27**(2): 113–118. doi:10.3354/esr00655.

Parsons, E.C.M., Favaro, B., Aguirre, A.A., Bauer, A.L., Blight, L.K., Cigliano, J.A., Coleman, M.A., Côté, I.M., Draheim, M., Fletcher, S., Foley, M.M., Jefferson, R., Jones, M.C., Kelaher, B.P., Lundquist, C.J., Mccarthy, J.B., Nelson, A., Patterson, K., Walsh, L., Wright, A.J., and Sutherland, W.J. 2014. Seventy-one important questions for the conservation of marine biodiversity. Conserv. Biol. **28**(5): 1206–1214. doi:10.1111/cobi.12303.

Pons, P., and Latapy, M. 2006. Computing communities in large networks using random walks. J. Graph Algorithms Appl. **10**(2): 191–218. doi:10.7155/jgaa.00124.

Pullin, A.S., Knight, T.M., and Watkinson, A.R. 2009. Linking reductionist science and holistic policy using systematic reviews: Unpacking environmental policy questions to construct an evidence-based framework. J. Appl. Ecol. **46**(5): 970–975. doi:10.1111/j.1365-2664.2009.01704.x.

R Core Team. 2019. R: A language and environment for statistical computing. R

Foundation for Statistical Computing, Vienna, Austria.

Rees, A.F., Alfaro-Shigueto, J., Barata, P.C.R., Bjorndal, K.A., Bolten, A.B., Bourjea, J., Broderick, A.C., Campbell, L.M., Cardona, L., Carreras, C., Casale, P., Ceriani, S.A., Dutton, P.H., Eguchi, T., Formia, A., Fuentes, M.M.P.B., Fuller, W.J., Girondot, M., Godfrey, M.H., Hamann, M., Hart, K.M., Hays, G.C., Hochscheid, S., Kaska, Y., Jensen, M.P., Mangel, J.C., Mortimer, J.A., Naro-Maciel, E., Ng, C.K.Y., Nichols, W.J., Phillott, A.D., Reina, R.D., Revuelta, O., Schofield, G., Seminoff, J.A., Shanker, K., Tomás, J., van de Merwe, J.P., Van Houtan, K.S., Vander Zanden, H.B., Wallace, B.P., Wedemeyer-Strombel, K.R., Work, T.M., and Godley, B.J. 2016. Are we working towards global research priorities for management and conservation of sea turtles? Endanger. Species Res. **31**(1): 337–382. doi:10.3354/esr00801.

Rego, A., Dey, C., Bradford, M., Clarke, K., McKercher, K., Mochnacz, N., de Paiva, A., Ponader, K., Robichaud, L., Winegardner, A., Midwood, J., and Koops, M. 2021. Researcher and practitioner ratings of priority research questions in freshwater fish habitat science'. Can. Data Rep. Fish. Aquat. Sci. **Fs97**-**13/13**: ISBN 978-0-660-37769-8.

Rowe, G., Wright, G., and McColl, A. 2005. Judgment change during Delphi-like procedures: The role of majority influence, expertise, and confidence. Technol. Forecast. Soc. Change **72**(4): 377–399. doi:10.1016/j.techfore.2004.03.004.

Rudd, M.A. 2011. How Research-Prioritization Exercises Affect Conservation Policy. Conserv. Biol. **25**(5): 860–866. doi:10.1111/j.1523-1739.2011.01712.x.

Rudd, M.A., Beazley, K.F., Cooke, S.J., Fleishman, E., Lane, D.E., Mascia, M.B., Roth, R., Tabor, G., Bakker, J.A., Bellefontaine, T., Berteaux, D., Cantin, B., Chaulk, K.G., Cunningham, K., Dobell, R., Fast, E., Ferrara, N., Findlay, C.S., Hallstrom, L.K., Hammond, T., Hermanutz, L., Hutchings, J.A., Lindsay, K.E., Marta, T.J., Nguyen, V.M., Northey, G., Prior, K., Ramirez-Sanchez, S., Rice, J., Sleep, D.J.H., Szabo, N.D., Trottier, G., Toussaint, J.P., and Veilleux, J.P. 2011. Generation of Priority Research Questions to Inform Conservation Policy and Management at a National Level. Conserv. Biol. **25**(3): 476–484. doi:10.1111/j.1523-1739.2010.01625.x.

Sutherland, W.J., Adams, W.M., Aronson, R.B., Aveling, R., Blackburn, T.M., Broad, S., Ceballos, G., CÔtÉ, I.M., Cowling, R.M., Da Fonseca, G.A.B., Dinerstein, E., Ferraro, P.J., Fleishman, E., Gascon, C., Hunter, M., Hutton, J., Kareiva, P., Kuria, A., MacDonald, D.W., MacKinnon, K., Madgwick, F.J., Mascia, M.B., McNeely, J., Milner-Gulland, E.J., Moon, S., Morley, C.G., Nelson, S., Osborn, D., Pai, M., Parsons, E.C.M., Peck, L.S., Possingham, H., Prior, S. V., Pullin, A.S., Rands, M.R.W., Ranganathan, J., Redford, K.H.,

Rodriguez, J.P., Seymour, F., Sobel, J., Sodhi, N.S., Stott, A., Vance-Borland, K., and Watkinson, A.R. 2009. One hundred questions of importance to the conservation of global biological diversity. Conserv. Biol. **23**(3): 557–567. doi:10.1111/j.1523-1739.2009.01212.x.

Sutherland, W.J., Fleishman, E., Mascia, M.B., Pretty, J., and Rudd, M.A. 2011. Methods for collaboratively identifying research priorities and emerging issues in science and policy. Methods Ecol. Evol. **2**(3): 238–247. doi:10.1111/j.2041-210X.2010.00083.x.

Trnka, M., Hayes, M., Jurečka, F., Bartošová, L., Anderson, M., Brázdil, R., Brown, J., Camarero, J.J., Cudlín, P., Dobrovolný, P., Eitzinger, J., Feng, S., Finnessey, T., Gregorič, G., Havlik, P., Hain, C., Holman, I., Johnson, D., Kersebaum, K.C., Ljungqvist, F.C., Luterbacher, J., Micale, F., Hartl-Meier, C., Možný, M., Nejedlik, P., Olesen, J.E., Ruiz-Ramos, M., Rötter, R.P., Senay, G., Vicente-Serrano, S.M., Svoboda, M., Susnik, A., Tadesse, T., Vizina, A., Wardlow, B., Žalud, Z., and Büntgen, U. 2018. Priority questions in multidisciplinary drought research. Clim. Res. **75**(3): 241–260. doi:10.3354/cr01509.

APPENDIX A

Documents included in our literature review were identified through a search of the Federal Science Library using two search strings (n = 391), or through direct recommendation by members of the project's steering committee (n = 10). The search strings were as follows:

String 1

(freshwater **OR** river* **OR** lake **OR** pond **OR** stream **OR** lotic **OR** lentic) **AND** (habitat OR product*) **AND** (PublicationSeriesTitle:(Canadian Science Advisory Secretariat))

Date: 1/1/1986 to 12/31/2019

String 2

(TitleCombined:((freshwater **OR** river* **OR** lake **OR** pond **OR** stream **OR** lotic **OR** lentic))) **AND** (TitleCombined:((research **AND** need*) OR (research **AND** prioritiz*) OR (research **AND** gap*) OR (scien* **AND** need*) OR (scien* **AND** prioritiz*) OR (scien* **AND** gap*) OR (important **AND** question*))) **AND** (habitat) **AND** (Canada)

Date: 1/1/1986 to 12/31/2019

APPENDIX B

This appendix shows the outline of the expert survey to solicit knowledge gaps.

Questions 1-4 contain text entry fields, and questions 5-10 contain multiple choice answer options. Sub-questions with text entry fields are denoted by an open-circle bullet point.

QUESTION 1

In your professional experience, what knowledge gaps are currently hindering the development of effective policies and management strategies for freshwater fish habitat in Canada?

Please describe these knowledge gaps. Point form and single sentence answers are welcomed. You may include multiple knowledge gaps.

QUESTION 2

Are you aware of any knowledge gaps related to the following themes that should be priorities for future research to improve policy and management of Canadian freshwater fish habitat?

Please describe any specific knowledge gaps you are aware of under the appropriate theme. Point form and single sentence answers are welcomed. You may include multiple knowledge gaps under a theme.

- Fish distribution and habitat use
- Stressors to freshwater fish habitat
- Impact avoidance, mitigation, offsetting or habitat restoration
- The development and use of decision-making tools
- Habitat classification, measurement and monitoring

QUESTION 3

Are you aware of any knowledge gaps related to the following themes that should be priorities for future research to improve policy and management of Canadian freshwater fish habitat?

Please describe any specific knowledge gaps you are aware of under the appropriate theme. Point form and single sentence answers are welcomed. You may include multiple knowledge gaps under a theme.

- Fish distribution and habitat use
- Stressors to freshwater fish habitat

- Impact avoidance, mitigation, offsetting or habitat restoration
- The development and use of decision-making tools
- Habitat classification, measurement and monitoring

QUESTION 4

Are there any other knowledge gaps that should be priorities for further study to improve policy and management for Canadian freshwater fish habitat?

Please describe any other knowledge gaps that you believe should be priorities for future research. Point form and single sentence answers are welcomed.

QUESTION 5

How would you describe your primary professional activities in relation to freshwater fish habitat?

- I primarily work in a research role
- I primarily work in a policy role
- I primarily work in a management role
- I primarily work in a science advisory role
- I primarily have other responsibilities related to freshwater fish habitat
- Prefer not to answer

QUESTION 6

Do you currently work for Fisheries and Oceans Canada?

- Yes
- No
- Prefer not to answer

QUESTION 7

Which Fisheries and Oceans Canada sector do you work in?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '9 [DFO]' (Do you currently work for Fisheries and Oceans Canada?)

- Ecosystems and Oceans Science
- Aquatic Ecosystems

- Strategic Policy
- Fisheries and Harbour Management
- Other
- Prefer not to answer

QUESTION 8

Which sector do you work in?

- Academia
- Government
- Non-governmental organization
- Industry
- Crown corporation
- Consulting
- Other
- Prefer not to answer

QUESTION 9

How much experience do you have working in the field of freshwater fish habitat science, management or policy?

- less than 1 year
- 1-5 years
- 5-10 years
- 10-20 years
- more than 20 years
- Prefer not to answer

QUESTION 10

Which regions of Canada have been the primary focus of your experience in freshwater fish habitat science, management or policy?

- Pacific
- Central and Arctic
- Quebec
- Newfoundland and Labrador

- Gulf
- Maritimes
- National level
- Prefer not to answer

APPENDIX C

List of scientific knowledge gaps (n = 1903) in freshwater fish habitat science identified through a literature survey and an expert survey. The knowledge gaps included here may contain spelling and grammar mistakes as they are the raw entries from the expert survey and the literature review. The listed ID number refers to the corresponding research question (Appendix E) that the knowledge gap contributed to.

ID	Knowledge Gap	Source
1	What is the impact of habitat alteration on American Eel?	Lit review
1	How does gravel movement impact fish and fish habitat in Pacific streams?	Lit review
1	How does hydrocarbon exploration, extraction and transportation impact freshwater habitat?	Lit review
1	What is the impact of linear corridor development on fish communities?	Lit review
1	What are the longitudinal patterns of water temperature downstream of the EB Campbell dam?	Lit review
1	How does gravel extraction impact species-at-risk such as white sturgeon?	Lit review
1	What is the impact of the development of major transportation routes on Umatilla Dace?	Lit review
1	What is the impact of water extraction and habitat alteration on Atlantic salmon populations in the Southern Upland of Nova Scotia?	Lit review
1	What are the specific shapes and thresholds for the productivity-state relationship based on ecosystem types and classes of activities?	Lit review
1	How can pathways of effects be used to understand changes in productivity?	Lit review
1	What is the amount of Umatilla Dace habitat that is lost due to seasonal drought and water withdrawals?	Lit review
2	What are the interactions between farmed and wild salmon in the Maritime Provinces?	Lit review
2	What are the hazards of chemical inputs from aquaculture to relevant species and sensitive life stages?	Lit review
2	How can more ecosystem friendly diets be incorporated into aquaculture operations?	Lit review
2	Do aquaculture facilities act as a source of disease for Eulachon?	Lit review
2	What are the non-target effects and bath treatments associated with sea lice control chemicals used in aquaculture such as pyrethroids?	Lit review
2	What are the effects of antibiotics used in aquaculture on aquatic organisms and microflora?	Lit review
2	What are the horizontal, vertical, and temporal patterns of total phosphorus distributions around cage aquaculture installations?	Lit review
2	What is the influence of aquaculture chemical exposure type (repeated short-term (or pulsed) exposures, for example) on freshwater fish species?	Lit review
2	What are the long-term effects of escaped farm fish on natural ecosystems, and how can previous escape events help us to better understand and predict these long-term effects?	Lit review
2	What are the relationships between physical structures associated with aquaculture and the surrounding assemblages of organisms?	Lit review
2	What are the dose-dependent relationships associated with physical habitat alterations as a result of aquaculture?	Lit review
2	What are the cumulative effects of chemical inputs from aquaculture on freshwater fish habitat?	Lit review

2	What are the effects of aquaculture, predators, and disease on Atlantic salmon inner Bay of Fundy populations?	Lit review
2	How is freshwater habitat modified by physical structures of aquaculture facilities?	Lit review
2	What is the movement and distribution of escaped farmed Atlantic Salmon in freshwater habitat in Newfoundland and Labrador, and how does this affect native salmonids in terms of transmission of diseases, parasites and genetic implications?	Lit review
2	What is the influence of cage fish farms on oxygen concentrations in the hypolimnia of lakes in the summer, and in the entire water column under winter ice-cover?	Lit review
2	How can aquaculture production be increased while minimizing ecosystem interactions?	Lit review
2	How can laboratory and semi-natural studies be best utilized to predict effects of escaped fish in the natural environment?	Lit review
2	What is the link between the use of antibiotics in aquaculture and the presence of antibiotic-resistant bacteria near aquaculture activities, and what are the resultant spatial and temporal effects?	Lit review
2	What are the ecosystem effects of aquaculture operations?	Lit review
2	Can habitats recover from water quality impairment caused by cage fish aquaculture?	Lit review
3	What are the ecological impacts of parasites to smallmouth bass on other fish species in British Columbia?	Lit review
3	What are the genetic risks of traveller organisms associated with Walleye?	Lit review
3	Would an introduction of Northern pike in British Columbia's larger lakes lead to dramatic alterations to aquatic communities?	Lit review
3	What would the ecological impacts of Grass Carp be on the Great Lakes?	Lit review
3	Would those parasite species that are specific to Northern Pike encounter the secondary hosts required to complete their life cycle in British Columbia?	Lit review
3	What are the parasites of pumpkinseed in British Columbia, and what is the risk that these parasites would be able to encounter susceptible organisms and suitable habitat in British Columbia?	Lit review
3	What is the probability of establishment of parasites of smallmouth bass in areas where smallmouth bass has been introduced, and what level of risk does this impose on native species?	Lit review
3	How do invasive species that affect relevant food abundances influence native fish migration?	Lit review
3	What are the risks associated with parasite introductions from Northern Pike, Pumpkinseed, and Walleye invasion?	Lit review
3	What are the ecological impacts of the parasitic copepod Neoergasilus japonicus on Canadian ecosystems?	Lit review
3	What is the risk associated with the invasion of Grass Carp and Black Carp into the Great Lakes?	Lit review
4	What amount of riparian buffer is required to maintain fish populations?	Lit review
4	How does land use change affect the delivery of accurate cues for migrating fishes?	Lit review
4	How do localized negative impacts to Atlantic salmon populations from land-use practices scale up to effects on the entire river system?	Lit review
4	What is the rate of land use change and its impacts on Lake Superior?	Lit review
4	How does sediment loading impact fish and fish habitat?	Lit review
4	What are the linkages between land use and nutrient loading in the Lake Huron basin?	Lit review

4	What is the degree of disturbance caused by logging surrounding the Sakinaw estuary in the early 20th century, and what are the corresponding implications to Sockeye salmon that utilize this habitat?	Lit review
5	Does lake chemistry influence the feeding, growth and rearing of Little Quarry Lake sticklebacks?	Lit review
5	What is the effect of the low water pH in Bonilla Lake, Curtis Lake, and Devon Lake, B.C. on sockeye salmon stock productivity?	Lit review
5	What is the contribution of illegal fishing to the depressed state of the Atlantic salmon population?	Lit review
5	What is the tolerance threshold of pugnose minnow to turbid environments?	Lit review
5	What is the Plains Minnow's threshold for tolerance to water quality parameters?	Lit review
5	What are the Eastern Sand Darter's threshold levels for water quality parameters?	Lit review
5	How is fish productivity affected by changing water quality and over-fishing?	Lit review
5	Are the levels of pesticides, metals, and other contaminants in inner Bay of Fundy rivers sufficiently high to significantly influence Atlantic salmon smolt survival	Lit review
5	What are the silver lamprey's preferences with respect to water pH, salinity, or hardness?	Lit review
5	How do changes in salinity affect Silver Shiner populations?	Lit review
5	What are the spotted Gar's threshold levels for water quality parameters?	Lit review
5	What are the channel darter's threshold levels for water quality parameters?	Lit review
5	What is the impact water quality on Walleye productivity in Tathlina Lake?	Lit review
5	What are the White Sturgeon's water parameter tolerances, and what water parameters will limit productivity?	Lit review
6	What will be the direct and indirect effects of the Round Goby, as it increases its distribution, on Eastern Sand Darter populations?	Lit review
6	What is the effect of invasive species on pugnose minnow populations?	Lit review
6	What is the impact of invasive fishes on Atlantic whitefish populations?	Lit review
6	What are/would be the impacts of smallmouth bass on Atlantic salmon?	Lit review
6	What are the impacts of invasive species such as the Round Goby and Zebra Mussel on Northern Madtom habitat and populations?	Lit review
6	What is the impact of Brown Trout on Silver Shiner populations?	Lit review
6	What are the direct effects of Round Goby on Channel Darter populations?	Lit review
7	How can spilled diluted bitumen be detected and tracked in freshwater systems?	Lit review
7	How do fish habitat models relate to fish presence and abundance in the oil sands region?	Lit review
7	What specific stressors impact a given system?	Lit review
8	What are the consequences of runoff for the Misty Lake stickleback species pair?	Lit review
8	What are the effects of siltation on Eastern Sand Darter populations and spawning areas?	Lit review
8	What are the point sources of nutrient and sediment inputs in Spotted Gar habitat, and what are their relative effects on Spotted Gar survival?	Lit review
8	What methods could mitigate the impact of sediment starvation as a result of the EB Campbell dam construction?	Lit review
8	What are the direct and indirect effects of siltation on Pugnose Shiner populations?	Lit review
9	How does water quality and bioaccumulation affect white sturgeon populations?	Lit review
9	What are the direct and indirect effects of toxic substances on the Eastern Sand Darter?	Lit review

9	How can we analyze effects at early stages of exposure to contaminants by fish and their habitats in order to prevent catastrophic disruption of ecosystems, including collapse of fish populations and aquatic communities?	Lit review
9	What are the direct and indirect effects of toxic substances on channel darter?	Lit review
9	How do low water quality and endocrine disruptors affect the natural reproduction of copper redhorse?	Lit review
10	Does anthropogenic noise affect the distribution of fish and their ability to navigate?	Lit review
10	How does artificial light at night affect navigation of fishes, especially in coastal areas?	Lit review
10	What is the impact of noise pollution on the spawning success of Eulachon?	Lit review
11	What is the level of risk that microplastics pose to fisheries and aquatic wildlife populations in the Great Lakes?	Lit review
11	What are the impacts of microplastics on Great Lakes water quality and ecosystems?	Lit review
11	What are the sources, methods of transport, and fates of plastic litter and microplastics in Lake Ontario?	Lit review
11	What are the impacts of microplastics on freshwater fauna?	Lit review
11	How can we integrate surveying and sampling methods to better understand the relationship between habitat and productivity?	Lit review
11	What is the role of rivers in the transport of plastic debris?	Lit review
11	What are the effects of microplastics on freshwater systems?	Lit review
12	What are the threats to the Eastern Sand Darter?	Lit review
12	What are the individual and cumulative impacts of threats to the Plains Minnow?	Lit review
12	What is the severity of threats to the channel darter?	Lit review
12	What are the cumulative effects of threats to the American eel such as contaminants and invasive species?	Lit review
12	What is the impact of each threat to Spotted Gar populations?	Lit review
12	What are the threats to the Channel Darter?	Lit review
12	What is the impact of threats to the lake chubsucker on its populations?	Lit review
13	What is the current level of domestic harvest of the Hudson Bay populations of Lake Sturgeon?	Lit review
13	What is the current level of harvest of Lake Sturgeon in DU4?	Lit review
13	What is the current level of domestic harvest of the Nelson River populations of Lake Sturgeon?	Lit review
13	What is the current level of domestic harvest of the Saskatchewan River populations of Lake Sturgeon?	Lit review
13	What is the extent of misreported or unreported fisheries for the American Eel?	Lit review
14	What is the importance of lake margin flooding for salmonids in British Columbia?	Lit review
14	How do juvenile salmonids utilize flooded lands in the interior of B.C.?	Lit review
14	What is the impact of ranching on possible fish habitat in seasonally flooded meadows and wetlands?	Lit review
15	What are the population consequences of fish mortality?	Lit review
15	How can fish mortality be best quantified?	Lit review
15	How can fish mortality best be offset?	Lit review
15	What thresholds of fish mortality constitute serious harm?	Lit review
15	How does fish death impact productivity?	Lit review
16	How can we quantify and assess the impact and risk of hydropower effects on fish habitat?	Lit review

16	What tools can be used to assess HADD and NNL?	Lit review
17	What aspects of the Mountain Sucker's biology affect its response to potential threats, and what are these responses?	Lit review
17	What aspects of Carmine Shiner biology contribute to its potential threats?	Lit review
17	What are the physiological limitations of Bull Trout with regards to environmental regimes such as stream temperature and flow?	Lit review
17	What is the pH range that is tolerated by smallmouth bass, and how does this affect establishment in acid stressed regions?	Lit review
18	How does the differing biology and ecology of the New Zealand mud snail in different Canadian ecosystems influence its potential to survive and reproduce in these systems, and what are the impacts that this gastropod could have should it be introduced or spread from known locations?	Lit review
18	What are the effects of introduced species on the Nooksack dace population?	Lit review
18	Are introduced species a direct or indirect cause of the decline of native species in the areas they establish in, and if so, how do introduced species interact with or affect native species?	Lit review
18	Could introduced walleye populations in British Columbia cause the extirpation of native fish species?	Lit review
19	What are the effects of habitat modification and aquatic vegetation removal on Pugnose Shiner populations and spawning areas?	Lit review
19	What are the effects of mechanical and chemical vegetation control measures on Spotted Gar populations?	Lit review
20	What is the behaviour and life history of escaped wild fish in Canadian waters?	Lit review
20	What is the fate of aquaculture escapees given the biotic and abiotic conditions at the release site?	Lit review
20	What is the relative success of escaped finfish to compete with wild finfish for food, habitat, and mates?	Lit review
20	What are the factors that influence the resilience of natural populations or other ecosystem components to escaped fish?	Lit review
21	How does hardening of land surfaces affect Redside Dace and their habitat?	Lit review
22	What are the links between water quality, site type, and the operational conditions of aquaculture cage farms?	Lit review
22	What is the pattern of water quality degradation in small lakes or hydrological-isolated bays of large lakes as a direct result of aquaculture operations?	Lit review
22	Are there any long-term cumulative impacts of cage fish farms on well mixed sites in the Great Lakes?	Lit review
24	How can science inform our understanding of pathways of effects?	Lit review
24	How can we validate pathways of effects for impacts on habitat?	Lit review
26	What are the mechanisms by which urbanization and agriculture impact Redside Dace habitat and population dynamics?	Lit review
27	What is the linkage between agricultural land use practices and downstream impacts for both nutrients and chemicals used to manage crops and wildlife?	Lit review
28	What is the impact of the proliferation of blue-green algae on lake habitat used by the American Eel?	Lit review
28	What is the extent to which nuisance growth of Cladophora can be managed through increased phosphorus control?	Lit review
29	What are the effects of small and large scale hydroelectric power generation on freshwater habitat?	Lit review
29	What is the potential for hydropower dam reservoirs to act as garbage retainers, and what is the resulting effect on local habitat?	Lit review
29	What is the level of American eel mortality associated with the downstream passage of eels through hydro-electric turbines?	Lit review

30	Does drain maintenance directly decrease survival or reproduction of fishes?	Lit review
30	What is the response of aquatic macrophytes to drain maintenance?	Lit review
31	What is the level of American eel mortality caused by generating stations on the Ottawa River?	Lit review
32	How does boat traffic impact the quality of American eel habitat?	Lit review
32	What are the impacts of shipping traffic on freshwater systems or migratory stocks of fish?	Lit review
33	What is the degree to which the baitfish industry affects Eastern Sand Darter Populations?	Lit review
33	What is the degree to which the baitfish industry affects Channel Darter populations?	Lit review
33	To what degree does incidental harvest through the baitfish industry affect Pugnose Shiner populations?	Lit review
34	How does fishing gear impact aquatic habitat?	Lit review
35	What is the quality of freshwater fish habitat before and after dredging events?	Lit review
37	What are the impacts of the New Zealand mud snail under different population densities?	Lit review
37	What are the densities of Dreissenid mussels across whole ecosystems?	Lit review
40	Which aquatic invasive plant species does Lake Ontario contain suitable habitat for, and what is the extent of these plants within the lake watershed?	Lit review
41	What is the effect of underwater cables on the American eel?	Lit review
42	What would be the effects of Eurasian water milfoil on Coastrange Sculpin (Cultus Population) habitat?	Lit review
42	What is the effect of Didymosphenia geminata on the quality of Atlantic salmon habitat?	Lit review
43	What is the magnitude of habitat degradation in estuarine habitats of Interior Fraser Coho Salmon?	Lit review
44	How do pathogens affect fish migration and are the effects more pronounced under environmental change?	Lit review
44	What is the impact of pathogens on Atlantic salmon health?	Lit review
47	What existing or emerging chemical pollutants have the potential to affect fish migration and how?	Lit review
47	To what degree is the American Eel exposed to toxic chemicals in its habitat and migration routes, and how does this affect populations?	Lit review
48	Which freshwater habitats are at the greatest risk of oil spills, and what is the fate of oil in these systems?	Lit review
48	What physical, chemical and environmental factors influence how diluted bitumen will interact with aquatic habitat?	Lit review
50	What will be the response of the Milipsigate Lake population of Atlantic whitefish to the likely increase in smallmouth bass abundance in the coming years?	Lit review
51	How will diluted bitumen spills influence aquatic habitat in low temperature and ice conditions?	Lit review
52	How prevalent are fish species-at-risk in piscivore diets among habitats at Crown Marsh?	Lit review
53	How many bigheaded carps are released into lakes in Canada each year?	Lit review
54	What is the impact of accumulation of hydrated lime in bottom sediments on benthic communities?	Lit review
55	Is parasitism by lamprey on Sockeye salmon in Sakinaw Lake a significant threat to their survival?	Lit review
56	How do Lake Ontario ecosystems function and remain healthy under conditions of intense human use?	Lit review
57	Which nearshore areas in Lake Superior are most susceptible to eutrophication?	Lit review

63	What is the magnitude of impacts of lampricide on early life stage mortality of Lake Sturgeon?	Lit review
64	What is the role of ultraviolet radiation on juvenile salmonids?	Lit review
65	What are the patterns of total dissolved gas supersaturation related to the EB Campbell dam?	Lit review
66	What are the impacts of invasive aquatic mussels on aquatic food web nutrient cycling in the Great lakes?	Lit review
67	What is the seasonal distribution, feeding behaviour, and abundance of seals in Newfoundland and Labrador nearshore waters, and how does this impact local Atlantic salmon populations?	Lit review
68	How has the introduction of Brown Trout in Silver Shiner habitat affected Silver Shiner populations?	Lit review
69	What is the level of risk to Lake Erie habitats posed by invasive aquatic invertebrates?	Lit review
70	What is is the potential impact of largemouth and smallmouth bass on large water bodies in British Columbia?	Lit review
71	What are the biological and chemical responses to various stressors in freshwater systems, and how can these responses be used to assess the level of stress in a system where macroinvertebrate indicators may not be appropriate?	Lit review
73	What is the distribution of the American Eel in the Canadian maritime provinces?	Lit review
73	How can we measured Canada's freshwater resource inventory across large areas?	Lit review
73	What is the distribution of the Speckled Dace population in the Kettle basin?	Lit review
73	What is the quantity of freshwater habitat available for the American Eel?	Lit review
73	What is the quality of Athabasca Rainbow Trout Habitat?	Lit review
73	What is the quality of Plains Minnow habitat in Canada?	Lit review
73	What is the spatial extent and habitat use of Lake Chubsucker?	Lit review
73	What is the current distribution of the Plains Minnow?	Lit review
73	What is the current distribution of the Eastern Sand Darter?	Lit review
73	What is the spatial extent and habitat use of Pugnose Shiner?	Lit review
73	What is the spawning ground capacity of Fraser River Sockeye salmon?	Lit review
73	What is the distribution of the Umatilla Dace?	Lit review
73	What is the quality of the available habitat for the Pugnose Minnow in Canada?	Lit review
73	What is the sockeye salmon spawning ground capacity of B.C. streams and rivers surrounding nursery lakes?	Lit review
73	Can a database of habitat use by species be developed?	Lit review
73	What is the distribution of Mountain Sucker populations?	Lit review
73	What is the distribution of the Carmine Shiner?	Lit review
73	Does the Lake Chubsucker inhabit any areas that have been identified as suitable habitat, but where presence of this species has not been confirmed?	Lit review
73	What is the amount, location, and condition of freshwater habitat for Atlantic salmon in all inner Bay of Fundy rivers?	Lit review
73	What is the quantity of available habitat for Black Redhorse?	Lit review
73	What is the quality of habitat throughout the range of Black Redhorse?	Lit review
73	What is the distribution of Channel Darter in Canada?	Lit review
73	What is the extent of occurrence and range of Northern Madtom in Canada?	Lit review
73	How can freshwater ecosystem health be effectively measured and documented?	Lit review
73	What is the current distribution and extent of suitable habitat for the channel darter?	Lit review

73	What are the current spatial extents of spawning, rearing, foraging, and overwintering habitats for Bull Trout?	Lit review
73	What are the specific boundaries of the extent of habitat used by white sturgeon?	Lit review
73	What is the current distribution of, and extent of suitable habitat for Silver Shiner?	Lit review
73	What is the total available stream habitat for Atlantic salmon on Prince Edward Island?	Lit review
73	What habitats do fish use and what are the quality of those habitats?	Lit review
73	What is the extent of suitable Bull Trout habitat?	Lit review
73	What is the extent of all invasive species within the Lake Ontario watershed?	Lit review
73	How much freshwater habitat is accessible to coho salmon?	Lit review
73	What is the extent of suitable habitat for the Plains Minnow?	Lit review
73	How has silver lamprey habitat changed over time, especially with respect to habitat in areas that have undergone extensive logging and agriculture?	Lit review
73	What is the current distribution and extent of suitable Pugnose Shiner habitat?	Lit review
73	What is the spatial extent and habitat use of Northern Madtom?	Lit review
73	How much suitable habitat is available for species-at-risk in Little Bear Creek?	Lit review
73	What is the spatial extent and habitat use of Spotted Gar?	Lit review
73	What is the current distribution and extent of suitable Northern Madtom habitat?	Lit review
73	Which salmonid species are present in each Newfoundland and Labrador river?	Lit review
73	What is the quantity and quality of freshwater Atlantic Salmon habitat in the Inner Bay of Fundy region?	Lit review
73	What is the distribution of spawning sockeye salmon in the Fraser River region?	Lit review
73	What is the suitability of habitat in rivers such as the Miramichi River for the accommodation smallmouth bass?	Lit review
73	What is the current distribution and extent of suitable habitat for Silver Chub?	Lit review
73	What is the current distribution and extent of suitable Eastern Sand Darter habitat?	Lit review
73	What is the extent of Nooksack dace habitat loss in Canada?	Lit review
74	What are the habitat requirements of each life stage of channel darter?	Lit review
74	What is the relationship between key life history stages of Lake Sturgeon and habitat in DU1?	Lit review
74	What are the specific habitat requirements of each life stage of the Eastern Sand Darter?	Lit review
74	What are the habitat requirements of young of year Umatilla Dace?	Lit review
74	What are the habitat requirements of Mountain Sucker Populations in DU2?	Lit review
74	What are the habitat preferences of juvenile Lake Sturgeon?	Lit review
74	What are the habitat needs of each life stage of the Pugnose Shiner?	Lit review
74	What are the habitat requirements of fish at different ages and sizes within the Great Lakes?	Lit review
74	What are the habitat requirements of Inconnu?	Lit review
74	What habitat qualities are required for white sturgeon incubation and early life stages?	Lit review
74	What are the habitat requirements of each life stage of Eastern Sand Darter?	Lit review
74	How does the Morrison Creek Lamprey utilize its habitat throughout various life stages?	Lit review
74	What are the essential habitat requirements for aquatic species at risk?	Lit review
74	What are the habitat requirements of Canadian fishes other than salmonids and percids?	Lit review

74	What are the habitat needs of age-0 and juvenile Lake Sturgeon?	Lit review
74	What are the habitat requirements for successful Channel Darter spawning and egg incubation?	Lit review
74	What is the relationship between key life history stages of Lake Sturgeon and habitat in DU5?	Lit review
74	What are the habitat requirements for each life stage of the Silver Shiner?	Lit review
74	What are the spawning habitat requirements of the Carmine Shiner?	Lit review
74	Which habitats are used by White sturgeon for spawning and incubation?	Lit review
74	Is the upstream passage to adults and habitat connectivity suitable for the habitat requirements of the Lake Sturgeon?	Lit review
74	What are the habitat needs for eggs and fry of the Western Silvery Minnow, as well as for later life stages?	Lit review
74	What is the spawning habitat of the Coastrange Sculpin (Cultus Population)?	Lit review
74	What are the habitat requirements of each life stage of Spotted Gar?	Lit review
74	How do different life stages of Umatilla Dace utilize shallow and deep water habitat, and how does the use of these habitats differ over a 24 hour period?	Lit review
74	How does the Coastrange Sculpin (Cultus Population) utilize its habitat throughout its life history?	Lit review
74	What are the habitat preferences of immature Atlantic whitefish?	Lit review
74	What are the habitat requirements for each life stage of the Silver Chub?	Lit review
74	What are the habitat requirements of the pugnose minnow throughout its various life stages?	Lit review
74	What are the habitat requirements of young-of-the-year Northern Madtom?	Lit review
74	What is the relationship between key life history stages and habitat of Lake Sturgeon in DU4?	Lit review
74	What are the habitat preferences of juvenile pugnose minnow?	Lit review
74	What is the relationship between key life history stages and habitat of Nelson River populations of Lake Sturgeon?	Lit review
74	What are the habitat requirements for Northern Madtom throughout all life stages?	Lit review
74	What are the habitat needs of age-0 and juvenile Lake Sturgeon?	Lit review
74	How does the Carmine Shiner utilize its habitat throughout each life stage?	Lit review
74	What are the spawning habitat requirements of Northern Madtom in Canada?	Lit review
74	What is the relationship between key life history stages of Lake Sturgeon and habitat in DU2?	Lit review
74	What are the functional habitat requirements of juvenile Pugnose Shiner?	Lit review
74	What are the habitat requirements of the Channel Darter?	Lit review
74	What is the quality of habitat for Coastrange Sculpin (Cultus Population) in Cultus Lake?	Lit review
74	What are the habitat requirements for juvenile life stages of the Spotted Gar?	Lit review
74	What are the functional habitat requirements of juvenile Lake Chubsucker?	Lit review
74	What are the habitat requirements of juvenile Northern Madtom and related species?	Lit review
74	What are the habitat requirements of juvenile Spotted Gar?	Lit review
74	What are the habitat requirements of different life stages of Redside Dace?	Lit review
74	What are the habitat needs for the Rocky Mountain Sculpin in Alberta throughout all life stages?	Lit review
74	What are the spawning habitat preferences of the pugnose minnow in Canada?	Lit review
74	What are the habitat requirements for each life stage of the Plains Minnow?	Lit review

74	What is the relationship between Lake Sturgeon key life history stages and habitat?	Lit review
75	How do different morphological groups of cisco differ in their habitat use in Great Bear Lake?	Lit review
75	How does the Mountain Sucker utilize its habitat in Saskatchewan?	Lit review
75	How does the Cowichan (Vancouver) Lamprey utilize its habitat spatially and temporally throughout its various life stages?	Lit review
75	Is access to brackish water necessary for the survival of white sturgeon?	Lit review
75	What is the diet and ecology of young of year Black Redhorse, and how do they use their habitat?	Lit review
75	What is the distribution and population density of the silver lamprey?	Lit review
75	Has the range of Umatilla Dace changed since the most recent surveys?	Lit review
75	What habitats do Eulachon use and require in Canada?	Lit review
75	How does habitat use of Speckled Dace differ throughout its range?	Lit review
75	Which interior B.C. ground water sources are utilized by juvenile salmonids?	Lit review
75	How do Dolly Varden utilize their habitat outside of the fall spawning period?	Lit review
75	What is the breeding habitat of the Misty Lake stickleback species pair?	Lit review
75	What habitats do Channel darters select throughout their range, and how should this information affect flow recommendations?	Lit review
75	Where do adult Sockeye salmon reside within Sakinaw Lake?	Lit review
75	Are the walleye that are currently found in the Canadian portions of Columbia basin rivers part of self-sustaining populations, or do they use these habitats on a seasonal basis?	Lit review
75	Where does the Cowichan (Vancouver) Lamprey spawn in Cowichan Lake?	Lit review
75	What are the migration routes for Lake Ontario Atlantic Salmon?	Lit review
75	What are the differences in habitat use of different Dolly Varden stocks in the Rat River and nearby coastal zones?	Lit review
75	Is the presence of Atlantic whitefish in Minamkeek Lake a consequence of their prior existence in the Medway River system or of colonization from the Milipsigate-Hebb lakes?	Lit review
75	How do fish change habitat use over time?	Lit review
76	What are the overwinter habitat requirements for all fish species?	Lit review
76	What is the role of non-natal estuarine drainages as winter habitat for salmonids in British Columbia?	Lit review
76	What is the extent of overwintering and spawning habitat for Dolly Varden in Fish Creek?	Lit review
76	How does the Coastrange Sculpin (Cultus Population) utilize its habitat through the winter months?	Lit review
76	What is the overwintering habitat of young of the year striped bass?	Lit review
76	Why do juvenile Dolly Varden move into overwintering pools later than adults?	Lit review
76	Are constructed ponds in Crown Marsh suitable overwintering habitat for species-at-risk?	Lit review
76	What is the winter life history of Speckled Dace, and what are this species' over-wintering habitats and seasonal movements?	Lit review
76	What are the overwintering habitat requirements of the Rocky Mountain Sculpin?	Lit review
76	What are the overwintering habitat requirements of the Western Silvery Minnow?	Lit review
76	What habitats do Redside Dace use during winter?	Lit review
77	What is the availability and suitability of Black Redhorse habitat?	Lit review
77	What is the availability of suitable Speckled Dace habitat?	Lit review

77	What portion of American Eel habitat in rivers is unavailable as a result of anthropogenic barriers such as dams?	Lit review
77	Why is so little of the available habitat in the Brunette River occupied by the Nooksack dace?	Lit review
77	What is the extent of habitat available for the Atlantic salmon in the Lomond River, Torrent Rivers, and the Western Arm Brook?	Lit review
77	What is the extent to which the Umatilla Dace utilizes the habitat available to it?	Lit review
77	What portion of the available habitat is utilized by Atlantic Salmon on Prince Edward Island?	Lit review
77	What is the extent to which C. artedi utilizes lake habitat?	Lit review
77	What is the amount of juvenile Spotted Gar habitat in Rondeau Bay?	Lit review
77	To what extent is the small estuary at the mouth of Sakinaw Lake Creek utilized by juvenile Sakinaw sockeye salmon?	Lit review
78	Where are the spawning and nursery grounds of the Eastern Sand Darter?	Lit review
78	What are the traits of good and sub-optimal spawning habitats for Chinook salmon?	Lit review
78	What is the exact amount and location of critical spawning habitat for Sakinaw Lake Sockeye salmon?	Lit review
78	Do spawning or nursery grounds for the Plains Minnow exist in Canada?	Lit review
78	What are the nursery and spawning areas of the Pugnose minnow?	Lit review
78	Does slope influence nest building and parental care by Little Quarry Lake sticklebacks	Lit review
78	What is the location of striped bass spawning areas on the Saint John River?	Lit review
78	What are the spawning times and duration, and what are the spawning site characteristics of the Canadian Speckled Dace population?	Lit review
78	What is the location of spawning areas and the impact of certain threats for Atlantic sturgeon, and how can that information help to implement of appropriate mitigation measures?	Lit review
78	What are the spawning and nursery grounds of the Silver Shiner?	Lit review
78	What areas are important spawning grounds for Lake Whitefish in the Lower Athabasca River?	Lit review
78	What are the spawning, rearing, and habitat requirements of Shubenacadie striped bass?	Lit review
78	Where is suitable spawning habitat for Redside Dace?	Lit review
78	What are the spawning and nursery grounds of the Silver Chub?	Lit review
79	What habitat should be designated as critical habitat of the Misty Lake stickleback species pair?	Lit review
81	Which populations of Silver Shiner continue to persist in their historic range?	Lit review
81	What is the distribution of reproducing Pugnose Shiner populations?	Lit review
81	Has the pugnose minnow population in McDougall drain been extirpated?	Lit review
81	What are the white sturgeon's historic spawning sites, and what is the current connectivity to those sites?	Lit review
81	In which historic sites does the Eastern Sand Darter continue to persist?	Lit review
81	Is there still a reproducing population of Spotted Gar at Long Point Bay?	Lit review
81	What is the current distribution of reproducing populations of Spotted Gar, and what are the sizes of these populations?	Lit review
81	Which locations include reproducing populations of lake chubsucker, and what is the size of these populations?	Lit review
81	What is the precise range of the Speckled Dace?	Lit review

82	How could habitat suitability indices be used to classify habitat quality and quantity?	Lit review
83	What is the sensitivity of species and habitats to climate change?	Lit review
83	For Lake Superior, how can we better identify the presence of species of conservation concern, their habitats, habitat range limits, sensitivity to climate change, and other concerns such as habitat connectivity?	Lit review
84	What are the seasonal habitat requirements of all life stages of lake chubsucker?	Lit review
84	What are the seasonal habitat requirements of adult Spotted Gar?	Lit review
84	What are the seasonal movements and habitat requirements of the Rocky Mountain Sculpin?	Lit review
85	Do white sturgeon have residences?	Lit review
85	What is the size of the American Eel's home range?	Lit review
85	What are the residence requirements of the Umatilla Dace?	Lit review
85	What is the home range of white sturgeon?	Lit review
87	What is the minimum area needed for rainbow trout to complete all life stage and migrations?	Lit review
87	What is the area-per-individual requirement for Bull Trout?	Lit review
88	How does the predicted habitat connectivity in the Lower Athabasca River relate to fish movements during biologically significant periods?	Lit review
88	How do the use of Biologically Significant Periods and Habitat Suitability Indices relate to the real habitat requirements of Saskatchewan River fishes?	Lit review
88	How does movement among habitats impact the measurement of habitat - productivity relationships?	Lit review
90	What are the depth preferences of the Eastern Sand Darter?	Lit review
90	What are the depth limits of Grass Carp in lakes?	Lit review
91	How do smallmouth bass utilize riverine habitat?	Lit review
91	What are the life history differences between riverine and lacustrine channel darter populations?	Lit review
92	Would protection against loss of freshwater habitat quality appreciably increase the population viability of Atlantic salmon?	Lit review
92	How does variance in habitat quality impact Atlantic Salmon population viability?	Lit review
93	How do juvenile fish utilize their habitat in areas containing sympatric or parapatric stickleback species pairs?	Lit review
93	What is the relationship between the silver lamprey and northern brook lamprey, and how can this relationship help to explain these species' adaptability and the significance of risks to these species?	Lit review
94	What is the origin and migration tendency of Landlock Salmon in New Brunswick?	Lit review
94	What is the river of origin of Atlantic whitefish samples collected at Weymouth, Yarmouth Harbour, and Hall's Harbour?	Lit review
95	How important is substrate to fishes?	Lit review
95	What is the importance of substrate to flora, fauna, and various wetland functions such as removal of toxics.	Lit review
96	Is the pelagic zone of Sakinaw Lake critical habitat for juvenile Sockeye salmon?	Lit review
96	What are critical habitats for pelagic fish species in the Lower St. Lawrence Estuary?	Lit review
97	What are the best practices for measuring and quantifying habitat?	Lit review
98	Can the area-per-individual for species at risk be estimated from life history and ecological characteristics?	Lit review
99	How can we predict which agricultural drain segments may be occupied by sensitive species?	Lit review

100	Do climatic differences along geographic clines (e.g. latitude) influence migratory phenotypes; if so, is the variation predictable or generalizable among species (e.g. differences in timing or extent of migration)?	Lit review
101	What are the factors responsible for the decline of Atlantic Salmon in Newfoundland and Labrador?	Lit review
101	Is the quantity and quality of spawning habitat, as well as the access to this habitat sufficient for Nelson River Lake Sturgeon?	Lit review
101	Is the access to and from white sturgeon critical habitat sufficient for this species?	Lit review
101	What is the extent of Dolly Varden habitat change in Big Fish River, and how could this limit stock recovery?	Lit review
101	What is the food availability for all life stages of Cowichan (Vancouver) Lamprey?	Lit review
101	Why is there a greater density of Atlantic salmon in the East branch of the St. Mary's River than in the West Branch?	Lit review
101	What are the relationships between area and abundance for Nooksack Dace?	Lit review
101	What are the mechanisms of population decline for the Pugnose Shiner?	Lit review
101	Which habitat factors are limiting recovery of Atlantic Salmon in the Inner Bay of Fundy DU the most, and what mitigation measures would be most effective to improve habitat quantity or quality?	Lit review
101	Is the quantity and quality of spawning habitat for each Lake Sturgeon management unit sufficient?	Lit review
101	What is the threat of sedimentation to the Nooksack dace population in the Brunette River?	Lit review
101	How directly are habitat changes impacting Salish Sucker?	Lit review
101	Is access to habitat limiting productivity of Great Slave Lake Inconnu?	Lit review
101	To what degree do white sturgeon depend on kokanee as prey?	Lit review
101	What is the relationship between river habitat quality and Eulachon population declines?	Lit review
101	What are the threats to Atlantic salmon populations in each river within Nova Scotia and New Brunswick?	Lit review
101	What is the relationship between the Morrison Creek Lamprey's habitat and its abundance?	Lit review
101	Is the quantity and quality of, as well as the access to, spawning habitat for each Lake Sturgeon management unit sufficient?	Lit review
101	Do limitations on the recruitment of sockeye salmon fall fry occur at the spawning stage, egg incubation stage, recruitment to the lake stage, or during lake rearing?	Lit review
101	What is the role of the Stuart River system for the white sturgeon population?	Lit review
101	Is the white sturgeon habitat in the Fraser River estuary sufficient for this population?	Lit review
101	What is the cause for the reduced abundance of Atlantic Salmon on Anticosti Island starting at the end of the 1980s?	Lit review
101	What are the impacts of various threats to the pugnose minnow on its populations?	Lit review
101	What are the reasons for the decline of Atlantic salmon?	Lit review
101	What is the primary prey of the Morrison Creek Lamprey, and how abundant is its prey?	Lit review
101	Is the access to and the quantity and quality of spawning habitat for individual populations of Lake Sturgeon in DU8 sufficient?	Lit review
102	How does reproductive success vary with habitat availability in Little Quarry Lake sticklebacks?	Lit review
102	How can the relationship between habitat state and productivity be described and applied to decision-making?	Lit review
102	What are the effects of ecosystem state change on fisheries and stocks?	Lit review

102	What is the relationship between discharge and speckled dace productivity?	Lit review
102	How does the productivity of a fish population that is part of a commercial, recreational, or Aboriginal fishery vary with changes to the state of the habitat?	Lit review
102	How do stressors impact the relationship between habitat state and productivity	Lit review
102	What is the relationship between the state of ecosystems and the productivity of fisheries?	Lit review
102	What factors control productivity in aquatic systems?	Lit review
103	What is the area-per-individual for the Carmine Shiner, and can this be used to determine the carrying capacity for Carmine Shiner populations?	Lit review
103	What is the relationship between the availability of rearing habitat for coho salmon pre-smolts and stream length?	Lit review
103	Are changes to Atlantic salmon freshwater habitat quality causing changes to carrying capacities?	Lit review
103	What is the freshwater capacity of the Hecate Strait Lowlands in relation to pink salmon productivity?	Lit review
103	What is the limnology of each B.C. sockeye salmon nursery lake?	Lit review
103	What is the relationship between lake limnology and factors affecting sockeye salmon fry survival such as lake temperature and macro zooplankton biomass?	Lit review
103	What is the carrying capacity of the eastern sand darter habitat in Canada?	Lit review
103	What is the carrying capacity of the existing habitat for the Carmine Shiner?	Lit review
103	To what degree are fish species-at-risk populations near the carrying capacity of their habitats?	Lit review
103	What is the limnetic sockeye salmon abundance and growth rate in B.C. nursery lakes?	Lit review
103	How do instream flows relate to channel morphology at given points in the Lower Athabasca River, and how does this relate to fish habitat for the various species found there?	Lit review
103	Why is the carrying capacity of the Stewiacke River population of Atlantic salmon higher than others in the region?	Lit review
104	What are the impacts of altered flow regimes and other environmental factors on egg, larval, and juvenile Lake Sturgeon survival, and what are the corresponding mitigation measures?	Lit review
104	What are the life histories, and morphological and meristic characteristics of ciscoes in Great Bear Lake?	Lit review
104	How does habitat in the upper Qasigiyat Lake contribute to the persistence of Arctic Char in this population?	Lit review
104	What are the impacts of altered flow regimes and other environmental factors on Lake Sturgeon egg, larval, and juvenile survival, and what are the corresponding mitigation measures?	Lit review
104	What are the impacts of altered flow regimes in large rivers on Lake Sturgeon egg, larval, and juvenile survival, and what are the corresponding mitigation measures?	Lit review
104	What is the habitat-dependant survival of Atlantic Salmon for all life history stages?	Lit review
104	What is the relationship between young-of-the-year survival of Plains Minnow and flow rate?	Lit review
104	How would restoring normal flow impact inner Bay of Fundy Atlantic salmon production given other environmental stressors will persist?	Lit review
104	What are the impacts of altered flow regimes and other environmental factors on egg, larval, and juvenile survival of Lake Sturgeon, and what are the corresponding mitigation measures?	Lit review
105	What habitat parameters can be used as surrogates for productivity?	Lit review

105	Is there an association between total sockeye salmon fry biomass and age-0 fall fry weight?	Lit review
105	How can we identify surrogates of productive capacity for major habitat types?	Lit review
105	What is the extent of use and productive capacity of lakes in the Interior Fraser Watershed for Coho salmon?	Lit review
105	Is average coho salmon smolt production an accurate measure of capacity?	Lit review
106	How can models estimate the spawner capacity for Chinook salmon in high gradient or confined-channel systems?	Lit review
106	What is the timing and nature of density dependence in freshwater habitat of Atlantic salmon?	Lit review
106	How many Atlantic salmon redds can be found in Trout River and Dunk River during the spawning season?	Lit review
106	What are the mechanisms underlying density dependence of Atlantic salmon in their freshwater habitat?	Lit review
106	What is the spawner abundance of pink salmon in the Hecate Strait Lowlands CU?	Lit review
106	What is the intensity, precise form, and point at which density dependence begins to operate on Atlantic salmon in freshwater habitats?	Lit review
106	Are Arctic Char run sizes temporally stable?	Lit review
106	Do white sturgeon experience density dependence mediated through food supplies at any life stage?	Lit review
106	How can Sakinaw Lake Sockeye salmon egg-to-fry survival be described as a function of spawner density, habitat quality, and location?	Lit review
107	What factors are constraining Sockeye salmon production in the Skeena river?	Lit review
107	What are the factors limiting Pacific lamprey populations and how can they be mitigated?	Lit review
107	What are the factors limiting sockeye salmon production in Kitwanga Lake, B.C.?	Lit review
107	Is Atlantic Salmon productivity in the Miramichi River consistent with productivity of other Atlantic Salmon populations in Maritime Province rivers?	Lit review
107	Is freshwater production of Atlantic Salmon in the Tobique River low, and if so, why?	Lit review
108	How does habitat relate to fish productivity?	Lit review
108	How can we incorporate habitat into models of productivity?	Lit review
108	How does fish habitat relate to productivity?	Lit review
108	What is the composition of fish assemblages within navigation channels in Crown Marsh and Long Point Bay?	Lit review
109	What options are available to increase Skeena River Sockeye salmon fry recruitment from nursery lakes?	Lit review
109	What is the escapement of sockeye salmon in each B.C. Nursery Lake?	Lit review
109	What should the biological escapement goal be for sockeye salmon stocks?	Lit review
110	How can the ability of fish to adapt to changes in habitat availability be considered in project review?	Lit review
110	What is the capability of Speckled Dace to adapt to changes in water flow?	Lit review
111	What are the temperature tolerances of the various life stages of the lake chubsucker?	Lit review
111	At what temperature does the development of large populations of quagga mussel reduce significantly?	Lit review
111	Are changes in environmental conditions (e.g. temperature, oxygen) and migratory obstacles (e.g. dams, currents) disproportionately affecting fish with specific swimming modes, physical characteristics, or life histories?	Lit review
112	Do larval white sturgeon occur in the Kootenay system in Canada?	Lit review

112	What is the role of larval drift in the life history of white sturgeon, and do white sturgeon larvae occur in Canada?	Lit review
114	For different egg deposition rates, what is the population productivity and smolt yield of Lake Ontario Atlantic Salmon?	Lit review
114	Do the Atlantic salmon egg deposition targets from Eastern Canada apply to Lake Ontario tributaries?	Lit review
115	What are the consequences of implementing buffer zones around wetlands during development?	Lit review
116	How do physical processes, multiple interacting forms of human-induced rapid environmental change, and life history variation within and among species influence recruitment to the Great Lakes fishery and fishery dynamics?	Lit review
116	What drives fish recruitment patterns in complex systems as large as Lake Erie?	Lit review
117	To what extent are artificial habitats, such as reservoirs, mortality sinks for migrating fishes and how can such mortality be minimized?	Lit review
118	How does nearshore coastal habitat contribute to the function of Lake Ontario?	Lit review
120	What are the correlations between demographic rates of black redhorse?	Lit review
120	What is the rate of immigration of Atlantic Sturgeon into their Saint John river habitat?	Lit review
120	What is the population size, growth rate, and harvest rate in each management unit for Lake Sturgeon?	Lit review
120	At what age do Lake Chubsucker mature?	Lit review
120	What is the population size and growth rate of each Nelson River Lake Sturgeon management unit?	Lit review
120	What are the population dynamics of Pacific lamprey populations in Canada?	Lit review
120	What is the population growth rate and abundance of Carmine Shiner populations?	Lit review
120	What is the present size and growth rate of each Channel Darter population in Canada?	Lit review
120	What are the demographic parameters of the Eastern Sand Darter in areas where it is abundant?	Lit review
120	What is the fecundity, population growth rate, and survival of young of the year for Plains Minnow?	Lit review
120	What is the population size and growth rate of the Pugnose Shiner in Canada?	Lit review
120	What are the egg-to-smolt survival rates of each Atlantic salmon population?	Lit review
120	What is the population abundance of the Channel Darter?	Lit review
120	What are the young of the year and juvenile survival and population growth rates of the Rocky Mountain Sculpin?	Lit review
120	What is the size of the Dolly Varden population in North Slope?	Lit review
120	What is the size of the Firth River Dolly Varden stock?	Lit review
120	What are the maximum age-specific and stage-specific survival rates for Atlantic salmon populations?	Lit review
120	What is the population growth rate, fecundity, and survival of young of the year of the Silver Shiner?	Lit review
120	What is the population size and population dynamics for Atlantic Salmon on Anticosti Island?	Lit review
120	What is the growth rate, fecundity, mortality, and longevity of Bull Trout in Designatable Unit 4?	Lit review
120	What is the fecundity and maturity rate of Arctic Char in Cambridge Bay, Nunavut?	Lit review
120	What are the vital rates of all stickleback species pairs?	Lit review
120	What is the annual mortality for all age classes of Bull Trout?	Lit review

120	What is the population size, growth rate, and harvest rate of Lake Sturgeon in each management unit?	Lit review
120	What is the size of the Pugnose shiner population in Canada?	Lit review
120	What is the size of the Redside Dace population in Canada?	Lit review
120	What is the age and size at maturity adult Lake Ontario Atlantic Salmon?	Lit review
120	What is the size of the silver lamprey population in Lake St. Clair?	Lit review
120	What is the abundance of the Western Silvery Minnow in the Milk River?	Lit review
120	What are the recruitment and mortality rates of the Pugnose Shiner?	Lit review
120	What is the population size, growth rate, and harvest rate in each management unit for Lake Sturgeon?	Lit review
120	What is the annual mortality for all age classes of Silver Chub?	Lit review
120	What is the abundance of each sympatric and parapatric stickleback species pair?	Lit review
120	What is the abundance and growth rate of juvenile Sockeye salmon in the Skeena river?	Lit review
120	At what size and age do Dolly Varden undergo smoltification in the Rat River?	Lit review
121	What is the early life history of Saint John River striped bass?	Lit review
121	What is the life history of Rainbow Trout across its range?	Lit review
121	What is the life history of the Redside Dace?	Lit review
121	What is the life history of the Speckled Dace?	Lit review
121	What is the life history of the Black Redhorse?	Lit review
121	What is the life history of Eulachon in Canada?	Lit review
121	What is the life history of the Pugnose Minnow in Canada?	Lit review
121	How do life history parameters of rainbow trout differ between resident and migrant populations?	Lit review
121	What is the life history of the Channel Darter?	Lit review
121	What are the life history characteristics of Channel Darter in Canada?	Lit review
121	What are the life history characteristics of the Pugnose Shiner in Canada?	Lit review
121	What is the life history of the Redside Dace?	Lit review
121	How do the habitat requirements and physiological tolerances of Ontario Redside Dace differ from populations in the USA?	Lit review
121	What is the life history of Mountain Sucker populations in DU2?	Lit review
122	What are the reasons for the differences in survival of different ages of Atlantic salmon in rivers of SFA 4?	Lit review
122	What determines recruitment variability for Arctic Char in Nunavut?	Lit review
122	How do environmental variables influence inter-annual variability in sockeye salmon recruitment in the Fraser River?	Lit review
122	Does variation in life history traits, and stochastic variation in vital rates, lead to significant changes in the amount of required habitat for fish species at risk?	Lit review
122	What is the reason for the wide variation in freshwater survival of Atlantic salmon in the Conne River?	Lit review
122	How do environmental factors affect Fraser River Sockeye and Pink Salmon survival?	Lit review
122	What are the environmental variables that could explain inter-annual variability in Fraser River Sockeye salmon recruitment?	Lit review
122	Could liming efforts mitigate the effects of acidification on Atlantic salmon reproduction?	Lit review
122	Do environmental conditions influence recruitment of Walleye in Tathlina Lake?	Lit review

122	What is the response of the Mountain Sucker to potentially limiting environmental factors such as temperature extremes, turbidity, and flow?	Lit review
122	Which environmental variables could be used to explain the inter-annual variability in Fraser River Sockeye salmon recruitment?	Lit review
122	What factors, other than anthropogenic factors, affect population dynamics of the black redhorse and other species at risk?	Lit review
122	How are acidification and hypoxia influencing aquatic ecosystems in the Lower St. Lawrence Estuary?	Lit review
122	What is the maximum age, size, and growth rate of black redhorse among different populations?	Lit review
122	What is the response of the Rocky Mountain Sculpin to temperature extremes, turbidity, and flow?	Lit review
123	What are the sex-ratios of pugnose minnow populations?	Lit review
123	What are the details of the habitat ecology of white sturgeon living in the tidal estuary of the Fraser River?	Lit review
123	What are the details of the life history of the Plains Minnow?	Lit review
123	What is the average clutch size and fecundity of channel darter?	Lit review
123	What is the life history of the Rocky Mountain Sculpin, and how should that influence decisions regarding critical habitat identification?	Lit review
123	What are the current fecundities, sex-ratios, size distributions, and run timings of Atlantic Salmon populations on Prince Edward Island?	Lit review
123	What are the details of the pugnose minnow's life history, including age of maturity, growth, and longevity.	Lit review
123	What is the growth rate, age at maturity, and longevity of the Plains Minnow?	Lit review
123	What are the life history traits of Eastern Sand Darter populations in Canada, including first year survival and reproduction?	Lit review
123	What is the life history of the Silver Shiner, including growth rate, age at maturity, and longevity?	Lit review
124	What is the Speckled Dace's survival rate at each life stage?	Lit review
124	What is the survival of Umatilla Dace at each life stage?	Lit review
124	What are the survival rates of various life stages of the Carmine Shiner?	Lit review
124	What are the early life survival rates of the Rocky Mountain Sculpin?	Lit review
124	What are the survival rates during early life of the Western Silvery Minnow?	Lit review
124	What are the survival rates during early life of the Lake Chubsucker in Canada?	Lit review
124	Can early life survival for species at risk be estimated from life history and ecological characteristics?	Lit review
124	What are the early life survival rates of the Mountain Sucker?	Lit review
125	What is the spawning periodicity of Black Redhorse?	Lit review
125	How does flow impact survival and spawning behaviour in Plains Minnow?	Lit review
125	What are the reproductive strategies of the Western Silvery Minnow?	Lit review
125	How do Atlantic salmon precocious post smolts (PPS) contribute to egg deposition?	Lit review
125	What is the reproductive strategy of the Rocky Mountain Sculpin?	Lit review
125	Does the Carmine Shiner exhibit repetitive spawning?	Lit review
126	What is the abundance and survival of larval and juvenile copper redhorse?	Lit review
126	What is the survival of juvenile Chinook salmon in the Cowichan river?	Lit review
126	What is the survival of juvenile sockeye salmon in the Fraser River?	Lit review
126	What is the abundance and life history of juvenile Copper Redhorse?	Lit review
126	What is the abundance of larval and juvenile fishes at Crown Marsh?	Lit review

127	Where is the spawning and feeding habitat of Nelson River Lake Sturgeon?	Lit review
127	Do the silver lamprey and northern brook lamprey exhibit plasticity in feeding morphology and behaviour?	Lit review
127	What are the essential feeding areas and habitat selection of copper redhorse?	Lit review
127	What is the feeding behaviour and diet of the Coastrange Sculpin (Cultus Population), and how do these elements affect this species' habitat use?	Lit review
127	What is the feeding and spawning habitat of Lake Sturgeon in DU5?	Lit review
127	Where do spawning and feeding habitat for Lake Sturgeon occur?	Lit review
128	What is the relationship between fecundity and body size of Lake Chubsucker?	Lit review
128	What is the fecundity of adult Lake Ontario Atlantic salmon?	Lit review
128	What is the fecundity of Canadian populations of Plains Minnow?	Lit review
129	What is the total and natural mortality of the American Eel in Ontario?	Lit review
129	What is the natural mortality associated with threats to Eulachon populations?	Lit review
129	What is the fishing mortality and level of recruitment of pink salmon in the Hecate Strait Lowlands CU?	Lit review
130	What is the reproductive capacity of hybrids between the northern brook lamprey and silver lamprey?	Lit review
130	What is the reproductive success of stocked American Eels?	Lit review
131	To what extent do changes to habitat quality override spawning site fidelity, informing fish to abandon their destination habitat for more suitable habitat?	Lit review
132	What is the run-timing and former abundance of Atlantic whitefish in the Petite RiviÃ¨re?	Lit review
133	Why are live Eulachon eggs often found to be mobile in river systems, and does this mobile incubation confer a selective advantage?	Lit review
134	What factors affect upstream and downstream fish passage for multiple species and life stages	Lit review
134	How can fish passage be improved?	Lit review
134	How do the hydraulic conditions presented by fishways challenge the physiology of the affected fish species?	Lit review
134	How do hydraulic conditions impact fish passage?	Lit review
134	Can Atlantic whitefish migrate upstream through the breached Conquerall Mills dam?	Lit review
134	What are the constraints to passage and requirements for passage for all fish species?	Lit review
134	How can nutrition or available energy limit migration ability, either directly or indirectly?	Lit review
135	What are the impacts of physical habitat changes to Northern Madtom?	Lit review
135	What are the physiological parameter limits of the Silver Shiner with respect to temperature, pH, dissolved oxygen, and pollution?	Lit review
135	How does temperature limit the distribution of the Salish Sucker?	Lit review
135	What is the relationship between environmental factors such as sediment load and turbidity and the abundance of the Western Silvery Minnow?	Lit review
135	What are the physiological parameter limits of the Silver Chub with respect to temperature, pH, dissolved oxygen, and pollution?	Lit review
135	What waterflow, substrate, and temperature parameters limit the distribution of Umatilla Dace?	Lit review
135	What is the nutrient load in Lake Huron?	Lit review
135	How do changes in physical conditions in river habitat impact Western Silvery Minnow populations?	Lit review
136	How does flow rate affect Redside Dace movement?	Lit review

136	What are the impacts of flow regime change on fisheries production?	Lit review
136	What is the relationship between flow, habitat and population dynamics?	Lit review
136	How will changes to river flows affect the migratory performance of species with different locomotor performance and larval recruitment dynamics?	Lit review
137	What are the movement patterns of individuals between different habitats in Crown Marsh and Long Point Bay?	Lit review
137	How can we develop effective risk-based tools related to science advice?	Lit review
137	What are the movement patterns of the Mountain Sucker?	Lit review
137	What are the patterns of movement of different fish species between the Great Lakes?	Lit review
137	How do Redside Dace move among areas of suitable habitat?	Lit review
138	What are the connections between ground and surface water in the areas surrounding the Kettle River?	Lit review
138	What is the origin of ground water at the Sockeye salmon spawning beaches in Sakinaw Lake?	Lit review
138	What is the connection between surface and groundwater in the Nooksack River basin?	Lit review
139	How do variations in hydrodynamic variables influence fish passage efficiency, swimming ability, and behaviour in fishways?	Lit review
139	What are the passage and attraction efficiencies of fishways?	Lit review
139	How do hydrodynamic conditions (e.g. turbulence, flow rate, currents) influence migratory fish navigation?	Lit review
140	How do barrier removals impact fish and fish habitat?	Lit review
140	What are the likely effects of barrage and barrier removal on the recovery of Atlantic Salmon?	Lit review
140	How does the removal of anthropogenic barriers and their associated headpools affect the productivity of the American Eel?	Lit review
141	How does river flow management impact habitat and productivity?	Lit review
141	What is the extent of hydrological connectivity in the Morrison Creek Lamprey's habitat?	Lit review
141	How do hydrologic conditions relate to fish movement?	Lit review
142	Under what conditions is it necessary to aid fish passage through anthropogenic barriers such as dams?	Lit review
142	What is the effect of high density resulting from migration barriers on cannibalism, predation, competition, disease, and growth for American Eel?	Lit review
142	How successful are Grass Carp at moving across barriers such as locks or falls in the Great Lakes?	Lit review
142	What is the relative impact of different types of aquatic barriers and infrastructure on fish migration patterns and survival?	Lit review
143	What impacts does the creation of reservoirs have on fish populations and communities?	Lit review
143	How do reservoir drawdowns and erosion impact fish habitat?	Lit review
143	How can habitat impacts from reservoir creation be mitigated?	Lit review
143	How does the creation of reservoirs alter aquatic habitat?	Lit review
144	How biologically effective are all fishways designs, including nature-like and pool and weir?	Lit review
144	What biological criteria should be set to determine the success of fishways?	Lit review
144	Are the impediments to fishway passage behavioural, or are they related to physiological capacities?	Lit review
144	What are the post-passage effects of fishways on fish survival and reproduction?	Lit review

145	What components of natural flow are required to maintain the ecology of river environments?	Lit review
145	What is the natural range of lake levels for those lakes inhabited by sympatric stickleback species pairs and the Misty Lake stickleback species pair?	Lit review
146	What are the physical and biological processes that move nutrients and energy from the nearshore to offshore?	Lit review
146	How do nutrient levels in aquatic habitat compare before and after development?	Lit review
147	How does flow influence the presence and abundance of the Silver Shiner?	Lit review
147	What are the effects of minimum flow on fish community structure downstream of the EB Campbell Hydroelectric station?	Lit review
147	Can the Plains Minnow recruit in years and areas of poor flow?	Lit review
148	What is the restoration potential of each method for barrier removal or fish passage improvement in inner Bay of Fundy Atlantic salmon habitat, and which method is the most effective?	Lit review
148	What are the consequences of entrainment from passage through various turbine technologies?	Lit review
149	What is known about the movement of Atlantic salmon individuals among populations?	Lit review
150	How should habitat connectivity be considered in offsetting?	Lit review
151	Will human-induced changes to fish life history (e.g. changes in size-at-age of maturity due to size selective fishing) affect the locomotor performance of migratory species?	Lit review
151	To what extent are external drivers conflicting with rapidly changing environmental conditions that influence migration success?	Lit review
151	What environmental thresholds exist that initiate partial and facultative migration, and how do these influence the likelihood of migration?	Lit review
152	How does the distribution of wetlands impact water quality and hydrology?	Lit review
152	How do wetlands impact hydrological and nutrient pulses in different size watersheds?	Lit review
152	How much benefit is achieved from a 100-foot or 300-foot strip along the edge of a wetland receiving the discharge from a highly developed watershed?	Lit review
153	What is the availability of fluvial habitat for Atlantic salmon spawning in Gulf region rivers?	Lit review
153	How applicable are fluvial area models from the Bay of Fundy Rivers to Lake Ontario tributaries in regards to Atlantic salmon conservation?	Lit review
156	How do stocked fishes disperse from their original stocking locations within the Great Lakes?	Lit review
156	Do stocked American eel in Lake Ontario mature and migrate normally, relative to wild eels?	Lit review
157	How can the movement of larval and juvenile Pacific lamprey be tracked more effectively?	Lit review
157	What is the dispersal behaviour of Atlantic salmon smolts in estuaries?	Lit review
158	How can flow management be designed with whole ecosystems in mind?	Lit review
159	Can new technologies be used to evaluate physical conditions experienced during passage through turbines?	Lit review
160	How can fish body shape be used to predict entrainment and impingement risk?	Lit review
161	Are Lake Ontario water levels expected to increase or decrease over time?	Lit review
162	Will Westslope Cutthroat Trout be able to adapt to isolating mechanisms that would reduce or prevent hybridization and/or increase competitiveness with invasive non-indigenous salmonids	Lit review
162	What is the effect of poor habitat connectivity on white sturgeon population recruitment?	Lit review

162	What are the impacts of climate change on freshwater ecosystems?	Lit review
162	What is the degree of Bull Trout habitat fragmentation?	Lit review
162	How will climate change impact Redside Dace habitat and population dynamics?	Lit review
162	What is the extent of habitat fragmentation for the American eel in Lake Ontario and the Ottawa River?	Lit review
163	What is the impact of climate change on the ability of freshwater habitat to support Atlantic salmon?	Lit review
163	Are hypoxia, hyperthermia, or other climate-associated stressors affecting the distribution (e.g. prey availability), quality (e.g. energetic content), and access to critical resources needed by migratory fishes?	Lit review
163	What will be the impact of climate change on Northern Madtom populations?	Lit review
163	How will climate change impact ecosystem composition, structure and function?	Lit review
163	What will be the effect of warmer water caused by global warming on the pre-maturation growth rate of walleye?	Lit review
164	How will climatic forces and their consequences cumulatively interact with other stressors that aquatic ecosystems are already subjected to?	Lit review
164	How can climate change be incorporated in cumulative effects?	Lit review
165	Which aquatic habitats are the most vulnerable to climate change, and what is the nature of these vulnerabilities?	Lit review
165	How will the nearshore habitat in Lake Ontario respond to future conditions?	Lit review
165	How do different regions in Lake Ontario differ in productivity, thermal conditions, and expected future change?	Lit review
165	What is the vulnerability of each cold-water tributary to Lake Superior to various stressors such as climate change?	Lit review
168	How, if at all, is climate change mediated floodplain inundation affecting the recruitment of different migratory fishes?	Lit review
168	When should the effects of climate change on thermal thresholds, water availability and flow regimes be incorporated into project reviews?	Lit review
170	How should climate change be considered in offsetting?	Lit review
170	When should the effects of climate change on distributional shifts of fishes be incorporated into project reviews?	Lit review
171	How much can/will fishes behaviorally adapt (e.g. alter the timing or nature of their migration) to cope with environmental changes?	Lit review
171	How are changes in water temperature, acidity, and flow, as mediated by global climate change, affecting fish sensory systems and the role they play in different fish species abilities to navigate?	Lit review
172	How can we downscale climate models to understand the impacts of climate change on freshwater habitat?	Lit review
173	How can we operationalize the concept of regime shifts?	Lit review
177	How can management incorporate cumulative effects into decisions about fish and fish habitat?	Lit review
177	How can we integrate management of multiple impacts to freshwater habitat?	Lit review
177	What methods can be used to best assess cumulative effects?	Lit review
177	What is the level of Atlantic salmon mortality from contaminant input, habitat loss, or river usage in the Saint John River basin?	Lit review
177	What frameworks are best for incorporating cumulative effects?	Lit review
177	What is the best approach to landscape-level cumulative effects and reporting?	Lit review
177	How sensitive is Lake Ontario nearshore habitat to cumulative impacts from multiple stressors?	Lit review
177	What is the degree of harm imposed by each threat to the silver lamprey?	Lit review
177	How can the impact of multiple stressors on productivity be considered?	Lit review

178	What are the impacts of pollutants and nutrient loading on Northern Madtom?	Lit review
178	What are the effects of contaiminants on fish and aquatic ecosystems in the Arctic, and how can these effects be mitigated?	Lit review
178	How do mixtures of urban use pesticides impact fish reproduction, growth and survival?	Lit review
178	What is the significance of contaminated groundwater discharges on the Great Lakes Basin?	Lit review
179	Do multiple stressors have additive or synergistic effects on migratory behaviour?	Lit review
180	What are the the interactions between pollutants and other environmental stressors on the Salish Sucker?	Lit review
180	What are the individual and cumulative effects of anthropogenic stressors (e.g. water quantity/quality, sedimentation, anthropogenic sound and light) on physiology and ecology of migratory species and how can we mitigate these threats?	Lit review
181	How can landscape-scale data inform cumulative effects assessments?	Lit review
181	How can fish population models be incorporated into assessments of the impact of cumulative effects?	Lit review
182	What are the cumulative effects of anthropogenic barriers on Lake Sturgeon populations?	Lit review
182	What are the cumulative effects of anthropogenic barriers on Lake Sturgeon populations?	Lit review
182	What are the effects of barriers on fish movement in the Great Lakes?	Lit review
182	What are the additive or cumulative effects of multiple barriers on Lake Sturgeon populations?	Lit review
183	How does the inner Bay of Fundy Atlantic salmon population respond to the cumulative effects of small habitat losses?	Lit review
184	Can a new framework for cumulative effect review be created or adapted for FFHPP?	Lit review
184	Is the pressure-state-response framework useful to define fish and fish habitat indicators?	Lit review
186	How effective is habitat restoration and what factors determine effectiveness?	Lit review
186	How can entire management programs be evaluated?	Lit review
186	How effective can mitigation or compensation of habitat destruction be?	Lit review
186	How do the management strategies of: maximizing adult returns, maximizing juvenile out-migration, and preserving spawning habitat compare in their performance as management objectives with regards to desirable population outcomes?	Lit review
186	How effective are fish habitat compensation projects?	Lit review
186	How effective are offsetting and restoration activities?	Lit review
186	How can projects be monitored to assess if development led to net benefits or costs to fish and fish habitat?	Lit review
186	How can we effectively mitigate adverse impacts on fish habitat?	Lit review
186	How can impacts and offsets be quantified on a common scale?	Lit review
188	How can data science and data mining improve assessments of management?	Lit review
189	How can we better leverage existing data to inform management and policy decisions?	Lit review
190	What is the relationship between probability of recovery and extent of decline?	Lit review
190	What is the possibility of a natural or man-made rescue effect among the four isolated Nooksack dace populations in Canada?	Lit review
190	What is the recovery potential of at-risk populations of the silver lamprey?	Lit review
192	What are the science gaps for fisheries management objectives?	Lit review

194	Should Larkin benchmarks be considered in assessment of status for Pacific salmon?	Lit review
195	What should the target population abundance be for a reintroduction of Lake Ontario Atlantic salmon?	Lit review
196	What parameters are useful for modelling the response of walleye to harvest in Tathlina Lake?	Lit review
197	How effective is each management option for addressing white sturgeon habitat connectivity deficiencies?	Lit review
198	How can we evaluate different ecosystem indicators?	Lit review
199	What scientific information is needed to design codes of practice for proponent decision-making?	Lit review
202	How can equivalency standards be set for offsetting?	Lit review
202	What tools and approaches are most effective for effectiveness monitoring?	Lit review
202	What is the effectiveness of habitat offsets and when do they fail?	Lit review
202	What tools and approaches are most effective for compliance monitoring?	Lit review
202	What tools are most effective for population, community and ecosystem monitoring?	Lit review
202	What tools and approaches are most effective for functional monitoring?	Lit review
202	How can monitoring programs best track the state of habitat and the effectiveness of management?	Lit review
202	How effective is habitat restoration, including dam removal and fishway installation, and how can we accurately evaluate the costs and benefits to make better decisions?	Lit review
203	How can monitoring be best conducted to parameterize habitat suitability models?	Lit review
204	Can new sampling methods be developed to improve monitoring?	Lit review
204	What existing sampling methods can be used for monitoring?	Lit review
204	How can new technology improve monitoring?	Lit review
206	How can effective monitoring be conducted in the face of limited resources?	Lit review
210	How can large scale projects be best monitored?	Lit review
211	What is the effort required to detect whole fish assemblages in agricultural drain habitat for each type of sampling gear?	Lit review
211	What is the effort required to detect either a specific or any sensitive species in agricultural drain habitat for each type of sampling gear?	Lit review
212	When should each of the various methods be used in an assessment of productivity?	Lit review
212	What is the role and extent of the riparian habitat for Cowichan (Vancouver) Lamprey?	Lit review
212	How can habitat and fish productivity be effectively linked in decision-making tools?	Lit review
212	How can science improve the production of rules based management systems?	Lit review
212	What methods can be used to identify and measure habitat impacts?	Lit review
212	How can science be integrated into everyday operations and decision-making in FFHPP?	Lit review
212	What is the typical pattern of change in habitat on the axis perpendicular to a river?	Lit review
212	What is the structure and function of riparian habitat for fish?	Lit review
212	How can we develop standardized methods to link productivity and habitat?	Lit review
212	What are the relative benefits of protecting riparian zones or aquatic habitats?	Lit review
212	How can we develop indices, models, and tools to support decision-making related to habitat impacts?	Lit review

212	What tools can improve flow management?	Lit review
212	What tools can be used to support thresholds and other decision-making?	Lit review
212	How can tools be developed to support offsetting decisions?	Lit review
213	What is the frequency of low adult survival years for the Rocky Mountain Sculpin?	Lit review
217	What is the structure of the food web in Great Bear Lake, and how can molecular approaches be used to track stable isotopes and fatty acids of prey species as well as track allochthonous input from local terrestrial sources?	Lit review
217	How can we better understand lower food web productivity in Lake Huron, and what are the spatial differences of food webs within the lake?	Lit review
217	What are the linkages between lower and upper food webs in Lake Huron?	Lit review
217	To what degree do shifts in trophic dynamics affect Pugnose Shiner populations?	Lit review
217	What are the major drivers of primary production in Lake Ontario?	Lit review
217	How do climate and changes in lake trophic state influence fish population dynamics and fishery production potential in the Great Lakes, and how can an increased knowledge of fish recruitment mechanisms help us to understand these influences?	Lit review
217	What is the importance of lower trophic level species to the Bay of Quinte ecosystem?	Lit review
218	What is the relationship between coho salmon and cutthroat trout within coastal seasonal wetlands of British Columbia, and how should the development and maintenance of habitat take place accordingly?	Lit review
218	How can we quantify community composition and health in low diversity systems?	Lit review
218	What is the relationship between community composition and productivity?	Lit review
218	How are population and community productivity related to habitat characteristics?	Lit review
218	How is productivity of Fraser River sockeye salmon impacted by juvenile survival and growth in both marine and freshwater	Lit review
218	How do fish communities impact productivity?	Lit review
219	How do capture fisheries (recreational, subsistence, and commercial) that may remove migratory fishes and/or their prey affect the distribution and abundance of migrating fishes (both immediately and in terms of artificial selection on population traits)?	Lit review
219	How can improved models of ecosystem form and function be used to understand how introduced species change food webs (energy flow through the system) and how this impacts contaminants and sustainable harvest levels of target species?	Lit review
219	How can improved models of ecosystem form and function be used to predict the impacts of various aquatic community shifts due to fish harvesting, introduced species and productivity changes?	Lit review
220	How have fish communities changed in river habitat of Nova Scotia?	Lit review
220	How does freshwater fish habitat change over time?	Lit review
221	How does the Carmine Shiner interact with other species?	Lit review
221	What are the ecological interactions between Speckled Dace and other fish species that occupy the same habitat?	Lit review
221	Are Atlantic salmon eggs depredated by fish and birds eggs that would likely have hatched or those that are outside of the redd and have little chance of hatching?	Lit review
221	What are the ecological interactions of Umatilla Dace with other species that share its habitat?	Lit review
222	What is the extent of competition between smallmouth bass and Atlantic salmon in eastern rivers?	Lit review
222	What is the degree of competition between Common carp and Umatilla Dace?	Lit review
222	What is the degree of competition between potential competitors such as stickleback or mysids and juvenile sockeye salmon in Lakelse Lake, B.C.?	Lit review

223	What are the predator-prey interactions between pikeminnow and all juvenile sockeye salmon?	Lit review
223	How will changing inshore pelagic fish distribution and variable ice conditions impact seal predation of salmonids in various river systems?	Lit review
223	What proportion of Eulachon eggs die or are consumed by predators prior to hatching in river habitats?	Lit review
224	What is the survival rate of sockeye salmon hatchery fry in Cultus Lake?	Lit review
224	What are the competitive interactions between wild Cultus Lake sockeye salmon and hatchery fish?	Lit review
225	What is the historic, current, and anticipated ice chronology of key salmonid rivers and estuaries in Newfoundland and Labrador, and how does this impact seal predation pressure?	Lit review
225	How do man-made structures impact ice chronology and affect seal predation on salmonids?	Lit review
227	What is the relationship between trophic richness and nutrient trapping and release by reservoirs?	Lit review
228	What is the impact of Northern Pikeminnow on migrating salmon smolts throughout the year?	Lit review
229	What is the relationship between juvenile salmon habitat in the Fraser estuary and white sturgeon habitat?	Lit review
230	What are the linkages between biodiversity change, fisheries productivity, and human activities?	Lit review
231	Are changes in the overall fish community indicative of changes in habitat quality for Atlantic salmon?	Lit review
233	What is the current distribution, abundance, and population trajectory of channel darter?	Lit review
233	What is the status of Sockeye salmon stocks in Skeena lakes?	Lit review
233	What is the population size and trajectory of Silver Shiner, and what are its trends over time?	Lit review
233	What is the population abundance and density of Mountain Sucker, and what is its trajectory?	Lit review
233	What are the population sizes and trends of Bull Trout?	Lit review
233	What is the current abundance of Nooksack dace?	Lit review
233	What is the status of Atlantic salmon habitat in Nova Scotia and New Brunswick?	Lit review
233	What are the range-wide trends in population status of the Pacific lamprey in Canada?	Lit review
233	What is the abundance and trajectory of the Speckled Dace population in Canada?	Lit review
233	What is the trajectory of Atlantic salmon populations in the eastern Cape Breton region?	Lit review
233	What is the population size and trajectory of Silver Chub, and what are its trends over time?	Lit review
233	What is the status of Atlantic salmon populations in non-index rivers?	Lit review
233	What is the current population size of Black Redhorse?	Lit review
233	What is the number of Atlantic salmon smolts in each river in Labrador each year?	Lit review
233	What is the population status and life history of Mountain Sucker in DU2?	Lit review
233	What is the size and trend of each Black Redhorse population in Canada?	Lit review
233	What is the life history and what are the habitat requirements of the Carmine Shiner?	Lit review
233	What is the population trajectory of lake chubsucker in L Lake, Ontario?	Lit review
233	What is the abundance of Umatilla Dace within Canada?	Lit review

233	What are the trajectories of Pugnose Shiner populations?	Lit review
233	What is the population abundance and trajectory of Pugnose Minnow in Canada?	Lit review
233	What is the population trajectory of Plains Minnow in Canada?	Lit review
233	What is the status of the Silver Chub population in Lake St. Clair?	Lit review
233	Have Atlantic Salmon abundances on Anticosti Island stayed lower than the observed levels in the 1980s?	Lit review
233	What is the status of the channel darter population in the Detroit river?	Lit review
233	What is the population size and trajectory of the Plains Minnow in Canada?	Lit review
233	What is the population abundance and trend of the Misty Lake stickleback species pair?	Lit review
233	What is the status of the Atlantic salmon population in the Nepisiguit River?	Lit review
233	What is the size and trajectory of the pugnose minnow population, and what are its trends over time?	Lit review
233	What is the number of mature Pugnose Shiner individuals in Canada?	Lit review
233	What is the size of the Plains Minnow population, and what are its trends and trajectories?	Lit review
233	What is the population size, trajectory, and trend of Eastern Sand Darter?	Lit review
233	What is the status of Atlantic salmon habitat in Canada?	Lit review
233	What is the relative abundance of the pugnose minnow?	Lit review
233	What is the status of River Darter populations in their northernmost habitat?	Lit review
233	What is the status of Atlantic salmon populations in SFA 19 with respect to extinction risk?	Lit review
234	Why are there low numbers of juvenile of striped bass caught in the Saint John River?	Lit review
234	What are the recent demographic changes that have taken place in Rocky Mountain Sculpin populations?	Lit review
234	What are the sex ratios of adult Lake Ontario Atlantic salmon?	Lit review
235	What is the accuracy of adult survival estimates for Mountain Sucker?	Lit review
235	What environmental variables could help to decrease the uncertainty associated with estimating Fraser River Sockeye Salmon run sizes?	Lit review
237	What factors are driving the increase in alewife body condition in Lake Ontario?	Lit review
238	Are there thresholds, related to pulse flow duration or frequency, beyond which cumulative effects (adverse or beneficial) on fish and fish communities would be expected.	Lit review
238	How much additional human-induced harm could be sustained by Atlantic whitefish?	Lit review
238	How do species differ in their threshold for harm, harassment and destruction of critical habitat?	Lit review
238	How can thresholds be developed and implemented for different ecosystem properties?	Lit review
238	What are thresholds for development that cause fundamental ecosystem change?	Lit review
238	What are appropriate thresholds for flow change including minimum levels and ramping rate thresholds?	Lit review
238	What are the flow requirements for all fish species?	Lit review
239	Can benchmarks be established for a variety of metrics across different habitat types?	Lit review
239	How is local and regional variation within waterbodies partitioned across the landscape, what are the underlying mechanisms that explain the observed spatial patterns, and how can this information be used to assign accurate reference conditions?	Lit review

239	How can baselines for wetland restoration be determined from unimpacted wetlands?	Lit review
239	What values should be used as baselines to evaluate the level of wetland habitat degradation?	Lit review
239	How can habitat based conservation targets contribute to fisheries management objectives?	Lit review
239	How does productivity vary among systems and how can those data inform policy and management?	Lit review
240	How should we deal with uncertainty in setting standards and thresholds?	Lit review
240	What is the optimal complexity of habitat models?	Lit review
240	How can ecological complexity be accommodated when defining thresholds in policy and management?	Lit review
241	What are the lake chubsucker's thresholds for water quality parameters such as nutrient load and dissolved oxygen?	Lit review
241	What is the Silver Shiner's tolerance to changes in water quality parameters such as changes in nutrients, dissolved oxygen, and salinity?	Lit review
241	What is the Silver Chub's tolerance to changes in water quality parameters such as changes in nutrients, dissolved oxygen, and salinity?	Lit review
243	How much genetic diversity is there in fish populations in Canada and is it important to protect?	Lit review
243	What is the variation of the locus MHC II ÃŸI for Atlantic salmon in Newfoundland?	Lit review
243	What is the level of genetic distinctiveness between Salish Sucker populations?	Lit review
243	What is the population structure of Rocky Mountain Sculpin in the Milk River System, Lee creek and Aetna creek?	Lit review
243	What is the level of genetic variation across Pugnose Shiner populations in Canada?	Lit review
243	What is the genetic variation of Atlantic salmon populations in the rivers of Cape Breton, Newfoundland, Labrador, Ontario and Quebec?	Lit review
243	What is the level of genetic diversity between Spotted Gar populations, and what is the population structure and connectivity of these populations?	Lit review
243	What is the genetic structure of Silver Chub populations in Lake Erie and Lake St. Clair?	Lit review
243	What is the level of genetic variation across all channel darter populations in Canada?	Lit review
243	What is the importance of straying and mixing among populations for maintaining Atlantic Whitefish populations?	Lit review
243	What is the genetic structure of the Atlantic salmon population from the Gulf New Brunswick?	Lit review
243	What is the genetic structure of the Nooksack dace population in Canada?	Lit review
243	What is the importance of genetics in the viability of inner Bay of Fundy Atlantic salmon populations?	Lit review
243	How genetically distinct are Mountain Sucker populations across various habitats, and could these populations constitute distinct species?	Lit review
243	What is the level of genetic variation across all Eastern Sand Darter populations in Canada?	Lit review
243	What is the genetic structure of Eulachon in Canada?	Lit review
243	What is the abundance and population structure of Atlantic whitefish?	Lit review
243	What is the level of genetic divergence among Atlantic salmon populations in rivers of eastern Canada?	Lit review
243	What is the degree of relatedness of lower Fraser chinook salmon and those outside the drainage?	Lit review
243	What is the level of genetic variation among Silver Shiner populations?	Lit review

243	What is the number of genetically distinct populations of Umatilla Dace in Canada?	Lit review
243	What is the size and structure of the Eulachon population in Canada?	Lit review
243	What is the level of genetic variation in Northern Madtom populations, and what is the genetic relationship between populations in both Canada and the United States?	Lit review
243	What is the abundance and population structure of Northern Madtom in Canada?	Lit review
244	What are the adaptive characteristics of putative separate populations of Umatilla Dace?	Lit review
244	Are phenotypic variations observed among Atlantic salmon populations in Canada heritable, and are these differences adaptive?	Lit review
244	How many independent demographic units of Redside Dace are needed to secure high probabilities of species persistence in the future?	Lit review
244	Is cisco variation in Great Bear Lake functionally similar to cisco variation in the Laurentian Great Lakes?	Lit review
244	Are the genetic differences between American Eel populations significant enough to necessitate the creation of separate designatable units?	Lit review
244	How should different populations of Pacific lamprey be delineated?	Lit review
244	Is the lower Fraser summer group of Chinook salmon a valid Evolutionarily Significant Unit?	Lit review
244	What is the ecological variation among rivers and what are the phenotypic differences among Atlantic salmon populations?	Lit review
245	How will genetic adaptation to local habitat influence stocking of Inconnu in the Yellowknife River?	Lit review
245	When does stocking work as an effective offset?	Lit review
245	Do the Annapolis River or Saint John River populations of striped bass exhibit adaptations to local conditions?	Lit review
246	What is the present contribution of the Babbage River stock of Dolly Varden to any mixed stock fishery?	Lit review
246	What is the population structure of Arctic Char in Nunavut, and what is the contribution of putative populations to the mixed-stock fishery?	Lit review
246	What is the present contribution of the Big Fish River stock of Dolly Varden to the mixed stock fishery at Shingle Point?	Lit review
247	What is the minimum viable population of Lake Sturgeon?	Lit review
247	What is the minimum viable population size of Atlantic salmon in the Southern Upland region, and how do genetic effects influence this value?	Lit review
248	What is the degree of introgression of pure native Westslope Cutthroat Trout, and at what threshold is a fish or population considered to be pure?	Lit review
248	What is the level of threat to recovery from introgression on inner Bay of Fundy Atlantic Salmon?	Lit review
249	What is the taxonomic relationship between the Umatilla dace and Speckled dace?	Lit review
250	What is the stock structure of Rat River Dolly Varden in regards to the proportion of the population that is anadromous?	Lit review
252	What is the frequency and impact of toxic spill events on pugnose minnow?	Lit review
252	What is the frequency and extent of catastrophic events in Mountain Sucker populations?	Lit review
252	What is the frequency and extent of winterkill events for Lake Chubsucker in Ontario?	Lit review
252	What is the frequency and magnitude of catastrophic events in Rocky Mountain Sculpin populations?	Lit review
252	What is the frequency and magnitude of catastrophic events affecting habitat occupied by Eastern Sand Darter?	Lit review

252	What is the probability of catastrophic events among Carmine Shiner populations?	Lit review
252	What is the frequency and extent of catastrophic events for the Rocky Mountain Sculpin?	Lit review
252	What is the frequency of catastrophic decline in black redhorse populations?	Lit review
252	What is the frequency and magnitude of catastrophic events in Western Silvery Minnow populations?	Lit review
252	What is the frequency and extent of catastrophic events for the Western Silvery Minnow?	Lit review
252	What is the frequency of catastrophic decline in Plains Minnow populations?	Lit review
252	What is the frequency of catastrophic events in Athabasca Rainbow Trout habitat?	Lit review
252	What is the frequency and extent of catastrophic events for Pugnose Minnow populations?	Lit review
254	How can improved models of ecosystem form and function be used to assist in determination of minimum volume, flow and quality standards for sustaining aquatic resources?	Lit review
254	How can improved models of ecosystem form and function be used to assist in the ecologically sound allocation of water resources?	Lit review
255	How can mixed models be used to investigate the relationship between fish density and body size from electrofishing data?	Lit review
255	How can models used to estimate Atlantic salmon abundance for Middle and Baddeck rivers be improved using a mixed effects structure?	Lit review
256	How do pooled life history models of escapement perform for stocks with mixed life-histories?	Lit review
256	How do habitat-based models perform in predicting Chinook salmon escapement when multiple stocks spawn within a watershed?	Lit review
257	Is the pugnose minnow able to hybridize with any other closely related species?	Lit review
257	How could habitat changes trigger hybridization in the Misty Lake stickleback species pair?	Lit review
259	How can angling statistics be utilized to refine abundance estimates of Atlantic Salmon?	Lit review
260	How can proponent predictions be validated?	Lit review
260	How can proponent tools be best evaluated?	Lit review
262	How can we develop mechanistic models relating fish habitat to fish populations and communities?	Lit review
263	How can spatial and individual-based models that functionally link habitat to fish populations be used to increase our knowledge of area-dependant survival?	Lit review
265	What is the extent of macrophyte coverage in lakes containing a stickleback species pair?	Lit review
266	How can habitat modelling be standardized for consistent impact assessments?	Lit review
266	How can geospatial analysis be used to support habitat management?	Lit review
266	How can GIS be used to help classify habitat and assess habitat connectivity?	Lit review
267	How can critical habitat and habitat thresholds be determined?	Lit review
267	To what extent does the geospatial area proposed as critical habitat for the speckled dace actually contain suitable habitat for this species?	Lit review
267	What is the cause of recruitment failure for White Sturgeon, and how can this information be used to make critical habitat more functional?	Lit review
267	What is the current and future distribution of fishes?	Lit review
267	What is the suitability of the proposed critical habitat for the Speckled Dace?	Lit review
267	Should the fish ladder be considered essential habitat for copper redhorse?	Lit review

267	What is the abundance of speckled dace within the area proposed as critical habitat?	Lit review
267	Where are the areas of critical habitat for Redside Dace?	Lit review
267	What is the extent of critical habitat required for all life stages of the White Sturgeon?	Lit review
267	Do Atlantic whitefish annually reproduce in Minamkeak Lake?	Lit review
268	How can important habitats be identified and classified?	Lit review
268	How can habitat be classified?	Lit review
268	How can habitats best be categorized and delineated to best reflect fish abundance?	Lit review
269	What are the factors that facilitate the introduction and establishment of non-native fishes, and what are their impacts on native communities?	Lit review
269	How do invasive species spread throughout the great lakes, and how can their movements be predicted?	Lit review
269	What is the extent of the New Zealand Mud snail's distribution and spread, and what are its most relevant dispersal vectors?	Lit review
269	What is the likelihood of bigheaded carps arriving and establishing in Lake Huron?	Lit review
269	What is the likelihood of establishment for diploid Grass Carp in Lakes Superior, Ontario and Huron?	Lit review
269	What is the likelihood of spread of Grass Carp among Great Lakes?	Lit review
270	Is habitat protection more effective for certain communities?	Lit review
270	How effective are mitigation measures designed to protect fish and fish habitat?	Lit review
270	How effective are routine mitigation measures?	Lit review
270	How can we assess the effectiveness of mitigation measures?	Lit review
271	To what degree do pulsed flows affect water quality factors, such as water temperature or dissolved oxygen, in ways that influence behaviors such as predation and migration?	Lit review
271	Does increased habitat complexity, such as presence of boulders, crevices in bedrock, or large wood, influence downstream displacement for different species and age classes, and over over what magnitudes of pulse flows could this complexity reduce displacement?	Lit review
271	What are the effects of different magnitudes, ramping rates, and timing (season and photophase) of pulsed flows on the abundance and longitudinal displacement of stream fishes at different life stages?	Lit review
271	Could negative effects of pulsed flows be minimized through increase of habitat complexity (to provide shelter to small fish during pulses) and increased food availability or quality (to compensate for shorter feeding times)?	Lit review
271	Can relatively small, but repeated pulsed flows alter instream habitat and have indirect effects on fishes?	Lit review
272	How can avoidance and mitigation standards be applied and monitored?	Lit review
272	How can thresholds be established for avoidance and mitigation?	Lit review
275	How does salvage logging affect flow in Umatilla Dace habitat?	Lit review
276	What are the best practices for fish-outs?	Lit review
277	Which locations in Arctic Canda pose minimal environmental risk if used for ballast water exchange?	Lit review
280	How can the impact of large scale projects be quantified and offset?	Lit review
281	How can offsetting and habitat banking credits be calculated?	Lit review
283	What tools can help prioritize species actions versus restoration actions?	Lit review

283	Are the abundances of Atlantic Salmon populations in Nova Scotia and New Brunswick sufficient that a response to recovery actions is possible?	Lit review
283	Are populations of Atlantic Salmon in the Inner Bay of Fundy region large and diverse enough to respond to conservation action?	Lit review
286	What habitat types should be restored in each ecoregion?	Lit review
286	How should new habitat be designed to best achieve the goals of offsetting?	Lit review
286	How should habitat offsetting be conducted in pristine conditions?	Lit review
287	How effective are habitat banks and in which situations should they be used?	Lit review
288	What is the relevant service area for offsetting decisions?	Lit review
289	How does food web structure impact the effectiveness of offsetting?	Lit review
291	How should climate change be involved in the classification of ecologically significant areas?	Lit review
291	How can ecologically and biologically significant species and areas be used in reporting on inland habitat status and trends?	Lit review
291	How can ecological criteria developed for identifying Ecologically and Biologically Significant Areas (EBSA) in marine ecosystems be applied to all habitat types and regions within Lake Ontario to identify the appropriate spatial scale of ecologically significant areas?	Lit review
291	How can thresholds of habitat alteration be applied to ecologically significant areas?	Lit review
291	How can knowledge and criteria of significant areas from various conservation programs be integrated into EBSA criteria to better suit them to freshwater systems?	Lit review
291	What frameworks are best for identifying ecologically significant areas?	Lit review
291	Can Ecologically and Biologically Significant Areas (EBSA) criteria from marine ecosystems be effectively used in watersheds, Canada's northern regions and data-deficient areas?	Lit review
292	What is the degree of protection afforded to the Misty Lake stickleback species pair by the ecological reserve, which prohibits fishing?	Lit review
292	How quickly do population or community effects of aquatic protected areas emerge, and is there a â€œsuccessionâ€• pattern of effects?	Lit review
292	Do aquatic protected areas result in increased community stability and communities that are more resistant to invasion, and if so, does this effect differ with invader taxa?	Lit review
292	Do no-take zones have cascading effects throughout the aquatic food web?	Lit review
292	How do aquatic communities change after the establishment of new aquatic protected areas?	Lit review
292	How effective are existing aquatic protected areas?	Lit review
293	What are the best methods for habitat valuation?	Lit review
293	What tools can improve habitat valuation?	Lit review
295	Where should "aquatic protected areas" be located to maximize their effectiveness?	Lit review
295	Do some species require aquatic protected area networks? Which species? Are there any patterns such as trophic level or body size?	Lit review
297	What are the current distributions of species, habitat, and threats as they relate to aquatic protected areas?	Lit review
298	How can local knowledge be incorporated into Arctic Char population assessments in the Northwest Territories?	Lit review
298	How can Indigenous knowledge be included in research projects?	Lit review

298	How should Inuit knowledge be used to supplement environmental impact assessments relating to fish and fish habitat around the Lower Churchill Hydroelectric Generation Project?	Lit review
298	How can Indigenous knowledge be integrated in science advice?	Lit review
298	What traditional knowledge is available on Tathlina Lake and the importance of the walleye fishery?	Lit review
298	How can the Traditional Knowledge of experienced fishers and elders surrounding Qasigiyat Lake be used to inform fishery and science sampling plans?	Lit review
298	How can non-indigenous local knowledge be integrated in science advice?	Lit review
298	What Aboriginal Traditional Knowledge is available for Pacific salmon throughout their freshwater range, and how can it be incorporated into conservation efforts?	Lit review
298	What traditional knowledge is available on Walleye ecology in Tathlina Lake?	Lit review
300	How can a range of stakeholders effectively collaborate on fish and fish habitat issues?	Lit review
304	How can we restore degraded aquatic habitat and develop new habitat?	Lit review
304	How can regional impacts and restoration efforts be accounted for in project reviews?	Lit review
305	How does the quality of created or restored wetland habitat compare to that of natural wetlands?	Lit review
305	How does the stability and persistence of restored or created wetlands compare to natural systems?	Lit review
306	Is it possible to rehabilitate degraded habitat for Redside Dace and reintroduce this species?	Lit review
308	How can we best conduct integrated assessments of aquatic ecosystems?	Lit review
309	How do we include the social and economic sciences in risk assessment?	Lit review
309	How can we evaluate the economic and social benefits of fish habitat?	Lit review
310	How can multiple management objectives be considered during hydropower developments?	Lit review
310	How can multiple management objectives be simultaneously addressed?	Lit review
310	How can multiple objectives be incorporated in risk assessment?	Lit review
311	How can monitoring and reporting be effectively distributed in space?	Lit review
312	How can monitoring protocols be optimized and standardized?	Lit review
312	How can we develop standardized data collection, archival and analysis protocols that could be used by proponents and others to collect sound monitoring information?	Lit review
312	What is the level of risk associated with anthropogenic activities such as forest harvesting and development on spawning tributaries used by Lake Utopia Rainbow Smelt?	Lit review
312	What are the environmental impacts of increased boating and associated infrastructure?	Lit review
312	Do stamp sands (legacy mining waste piles) surrounding Lake Superior pose a great enough threat to water quality, habitat, and species to be a management concern?	Lit review
312	How can we ensure that the objectives of monitoring programs are sufficiently clear that the programs produce valid information?	Lit review
312	How can external protocols be adapted for use in monitoring programs?	Lit review
312	How can data and information best be shared to best understand the impacts of human activities on fish habitat?	Lit review
312	What are the impacts of human-driven stressors on fish populations?	Lit review
312	How can fish and fish habitat reporting be improved to better reflect outcomes?	Lit review

312	What is the impact of past and present mining activity conducted in the Lake Superior watershed on nearshore environments?	Lit review
312	How do human activities influence fish and fish habitat?	Lit review
312	How can we measure and compare natural and human-induced changes to habitat?	Lit review
314	Can science advice on fish and fish habitat be transferred across systems?	Lit review
315	How can risk assessment tools be improved for fish habitat?	Lit review
316	How can improved models of ecosystem form and function be used to assess the impacts of cumulative development (municipal, industrial, cottage, recreational, water power, resource extraction) on a water body and a watershed scale, and how to mitigate their effects?	Lit review
316	What emerging technologies can help the mitigation of climate change impacts?	Lit review
316	How can technologies help mitigate and recover from habitat impacts?	Lit review
319	Is there a relationship between historical year class strength of walleye in Tathlina Lake and weather data?	Lit review
319	What is the catch efficiency of gill nets in rivers and lakes used to estimate reservoir and river productivity?	Lit review
320	How applicable are fish age validation methods for species with large geographic ranges?	Lit review
320	Does the ability to successfully validate ageing structures depend on differing life history strategies and fish biology?	Lit review
320	How valid are ageing structures of endangered and at risk freshwater fish species?	Lit review
322	How can fish population science be better integrated into assessments of management?	Lit review
324	What are the ecosystem services provided by riverine ecosystems?	Lit review
324	What are the interactions between ecosystem services provided by riverine ecosystems in Canada?	Lit review
327	How can fishing efforts be managed to maintain sustainable wild fish stocks?	Lit review
329	How can large scale experiments be leveraged to improve management and policy?	Lit review
330	How does the Earth's rapidly shifting magnetic field and increasing anthropogenic electromagnetic fields affect fish migration?	Lit review
1	how the effects of disturbance (pipeline, culverts, roads) impact fish populations.	Survey
1	an understanding of temporary impacts to fish and fish habitat and how detrimental these may be to all fish (i.e., gravel removal and dredging - very big items)	Survey
1	How anthropogenic water extraction from water tables and rivers is impacting the different life stages of salmon in freshwater. In particular, the magnitude of impacts to migration (timing, behaviour, and survival), redd site selection, egg and alvein survival, access to juvenile rearing habitat and juvenile survival, and general impacts to hydrology.	Survey
1	Traditional stormwater management vs. low impact development.	Survey
1	Increase knowledge of impacts that anthropogenic development has on fish and fish habitat to public and proponents, and discourage closed-bottom culverts to prevent fish passage barriers.	Survey
1	Groundwater use impacts to Pacific Salmon. The first step would be monitoring and managing water extraction, followed by monitoring the changes to hydrology of connected river systems.	Survey
1	Reduced flow effects, and influence of drought and groundwater extraction on flows seems at forefront of climate change effects, but how much influence do they have on fish populations.	Survey

1	Water withdrawal impacts on groundwater flows into streams (coastal and interior British Columbia)	Survey
1	linkages from habitat classifications to species vital rates to population productivity	Survey
1	Water temperature studies and analysis of before-after of impacts on water temperature should translate into policy	Survey
1	Effects of mining effluent discharges on aquatic environments in northern Canada (modification or regulation of flow, change in water temperature, change in nutrient concentration, etc.).	Survey
1	Very few effective measures of population-level changes with respect to habitat change that are brought to a practical level of usability.	Survey
1	Long-term effects (more than 40 years) of effluent discharges on downstream fish habitats	Survey
1	Water use, extraction, impoundment, human fish and wildlife conflict	Survey
1	stormwater management impacts (thermal increases, hydrology impacts, erosion, etc.)	Survey
1	understanding how (both positive and negative) habitat Changes (in quantity or quality) affect fish behaviour and vital rates.	Survey
1	The use of clay berms during construction of major bridges should be further studied to determine why they consistently fail and result in project delays. Why are they continually allowed if they do not work well?	Survey
1	Changes in populations and productivity.	Survey
1	long term impacts of gravel removals in anadromous salmonid streams	Survey
1	Effects of effluent discharges (municipal, industrial, mining) in a watercourse. Synergy of pollutants from various sources.	Survey
1	What impact would national defence, in the arctic in particular, have on fish and fish habitat	Survey
2	impacts to ecosystems, freshwater and marine, from harvesting plankton, forage fish, lesser fish to make fish meal for aquaculture industry, which is then applied at an unsustainable local site rate to cause ecosystem harm to both the receiving and producing environments	Survey
2	impacts of aquaculture on the long-term sustainability of wild Atlantic salmon populations - specifically causes of declines of wild salmon in rivers close to aquaculture sites	Survey
2	How do Recirculating Aquaculture Systems (RAS) affect freshwater fish habitat?	Survey
3	Freshwater invertebrate invasive/non-indigenous risk assessment	Survey
3	The ecological effects of many Aquatic Invasive Species are poorly understood. Particularly, non-predator-prey interactions.	Survey
3	no standard reporting of threat from invasive species	Survey
3	The pathways of effect for non-indigenous (invasive) species on habitats and ecosystems.	Survey
3	impacts of invasive species to targeted offsetting	Survey
3	Impact of key invasive species (e.g. Asian Carps) on future habitat	Survey
3	Aquatic invasive species indirect impacts to fish and fish habitat is not well known and not usually taken into account	Survey
3	effects of invasive species on native species	Survey
4	Clear summaries of the effects of terrestrial land use and land cover, at the scale of both watersheds and riparian zones, on fish habitat and fish-habitat formation processes.	Survey
4	broad understanding of land cover and land use change is needed e.g., the effects of urbanization versus forestry both mechanistically (changes in water	Survey

	quality and physical habitat) and ecologically (changes in fish habitat use as a consequence of these changes)	
4	develop benchmarks for the amount of land use that will maintain watershed and ecosystem processes.	Survey
4	the Fisheries Act focuses on fish habitat but many of the impacts to fish habitat originate outside of the stream (e.g. changes in impervious cover, removal of wetlands and woodlots, water extraction, etc.). How can the link to activities on the land be strengthened to improve protection of fish and fish habitat?	Survey
4	Benchmarks for land use activities that allow us to make decisions about land use planning. For example, I don't think we know the percentage of a watershed that can be logged while maintaining key watershed processes.	Survey
4	What are the groundwater-surface water interactions, and how do nitrates and road de-icing materials impact groundwater and subsequently freshwater habitats?	Survey
4	How do we assess the indirect effects of human activities on watercourses, particularly small permanent or intermittent streams.	Survey
4	How to mitigate landscape level development and land based development on fish habitat.	Survey
4	De-icers and road salt impacts to receiving environment and to fish (salmonids in particular)	Survey
4	How can the direct and indirect effects of land-based activities be assessed through a conservation approach?	Survey
6	Aquatic Invasive Species information in general.	Survey
6	Aquatic invasive species	Survey
6	Aquatic and terrestrial invasive species impacts, how to prevent and eliminate once present	Survey
6	aquatic invasive species	Survey
6	Aquatic and terrestrial invasive species impacts, how to prevent and eliminate once present	Survey
7	The Pacific Salmon Foundation's Pacific Salmon Explorer is a great example of an easy to use decision-making tool. More like it, (maybe ones supported by the Federal Government), would be good for decision makers.	Survey
7	Any given number of map products could be created and maintained to show the parameters and stressors upon any given freshwater habitat	Survey
7	Mapping related to point source and non-point source pollution is lacking	Survey
7	How can water treatment practices be improved to reduce the quantity of pollutants entering freshwater systems (including road runoff)?	Survey
7	Impervious cover mapping is lacking	Survey
7	Non point source impacts	Survey
7	How to mitigate non-point source pollution.	Survey
8	how do geomorphology processes affect fish habitat?	Survey
8	Is limited or controlled sediment release a bad thing in all situations?	Survey
8	Limited, controlled, planned releases of sediment during some dam decommissioning projects	Survey
8	Effects of open-water dredged sediment disposal in dispersive sites in fresh water ?	Survey
8	Land clearing and subdivision development results in a lot of sediment run-off. Is there a better way to approach land clearing and sediment management?	Survey
9	toxicity data of new herbicides and aquatic pesticides	Survey
9	There is a limited amount of information on population-specific physiological tolerances to environmental stressors.	Survey

9	Impacts of endocrine disruption from pesticides on ability of smoltification for juvenile salmonids	Survey
9	impacts of sublethal incidental or chronic exposure to pesticides (insecticide, herbicide, algaecide, fungicide) coupled with reduced food because the pesticides are killing off fish (salmonids in particular food supply).	Survey
9	Human waste water treatment plants regulations releasing pesticides, organochlorines, heavy metals, pharmaceuticals and nanoparticles into freshwater the environment impacts on fish and salmonids in particular	Survey
10	underwater noise impacts, are in-water piers (for bridges) negatively impacting fish behavior (i.e. avoidance, change in habitat use, etc.)	Survey
10	In projects where there is a potential presence of species at risk, what restrictions to noise levels noise in the aquatic environment (geophysical surveys in lakes or rivers, for example) should be set to to ensure that no fish are harmed or killed?	Survey
10	There are loads of gaps here related to temperature, hypoxia, noise and light pollution. For most species and stressors we have very few high quality empirical data on the effects of stressors (or their interactions) on behaviour, physiology, fitness, and population demographics.	Survey
10	Underwater sound.	Survey
10	Improving bioacoustics through research and monitoring	Survey
13	inadequate knowledge about recreational and indigenous fishing for remote locations	Survey
13	Legal and illegal harvesting levels not well estimated for multiple species	Survey
14	River dredging and bedload sediment management for flood mitigation	Survey
14	how to reduce harm to the environment and fish (salmonids in particular) habitat forming and self sustaining processes from flood prevention- damming, diking, pump stations, flood boxes, pirated water courses	Survey
14	What are the productivity benefits of flooding and access to floodplain habitat for fisheries? How can floodplains and flooding be better protected under the Fisheries Act?	Survey
14	how to reduce risk to built and natural environment from flood and flooding events, research on how to motivate and move human development off the floodplain	Survey
15	fish mortality - the tools are outdated	Survey
16	Establish habitat monitoring programs for important commercial and recreational species; and for habitats affected by landscape-related stressors	Survey
16	better understanding of the impacts of habitat pressures on habitat state and condition and the biological consequences at the salmon population (CU) level	Survey
16	Consistent and long term monitoring of habitat pressure and state indicators (i.e. water temperature, quality, flow, sedimentation, dissolved oxygen levels etc.) at the watershed or CU level to allow for the evaluation of habitat condition trends	Survey
16	Local gaps in information about environmental stressors	Survey
17	identify stressors for each species and for a given community of species (e.g., guilds)	Survey
17	The physical niche for each species and its capacity to shift with acclimation or adaptation (e.g., niche for temperature, oxygen, light levels, nutrients, etc.)	Survey
18	Impacts of aquatic invasive species (AIS) on Canadian freshwater fish habitats are ill-known and documented.	Survey
19	effects of aquatic pesticides for the use of aquatic vegetation removal on fish and fish habitat	Survey
19	how do riparian vegetation processes affect fish habitat?	Survey
19	can we develop threshold for aquatic vegetation removal like we have for eel grass? how much removal is too much and how much vegetation is too dense?	Survey
20	Impacts to genetics and wild fish health from aquaculture	Survey

21	effect of shoreline hardening (e.g. armourstone revetments)	Survey
21	What are the effects of impervious surfaces and the subsequent increase in runoff on stream flows and the freshwater fish habitat therein, specifically in British Columbia?	Survey
21	Is there a quantifiable effect of large armourstone revetment infills on fish behaviour/populations?	Survey
21	large scale study of the impacts of bank hardening	Survey
22	impacts to the receiving environment from fish processing and other food animal processing, surface and ground water quality impacts from intensive feed animal lots and from the abattoirs	Survey
22	more research on temporary stressors, both in noise, sediment, water quality, in-water works, etc. and more research to support general best management practices to strengthen regulations, policies and enforcement	Survey
23	How do chlorides and emerging pharmaceuticals affect freshwater habitat?	Survey
23	Impacts of chemicals (prescription drugs, hormones) in freshwater systems near or downstream of Canadian urban centers	Survey
23	Impacts of chemicals on fish including hormones etc.	Survey
23	Contaminants of emerging concerns, endocrine disrupters, etc.	Survey
24	revisit or validation of Pathways of Effects since these are a current and effective tool to understand stressor-habitat linkages.	Survey
24	An updated suite of Pathways of effect that are more systematic in how they describe the effect pathways, are aligned with a standardized list of pressures, and are based on a consistent set of works, undertakings and activities.	Survey
25	the development of watershed and CU specific habitat vulnerability indicators	Survey
25	How can easy to use metrics of fish habitat health be developed?	Survey
25	What criteria should be used to assess the vulnerability of a habitat or species (dilution effect, swimming capacity, population status, etc.)?	Survey
25	better understanding of how to "roll up" the cumulative impacts of multiple habitat pressure and vulnerability indicators to determine overall watershed CU specific habitat status	Survey
26	It is sometimes a challenge to establish cause-and-effect relationship of fish habitat stressors, which means managers will have a hard time developing effective policies in response to the observed effects.	Survey
26	for many species we do not know their responses to stressors or human landscape alterations	Survey
26	Some stressors have been fairly well studied (for example Pacific salmon responses to flow and temperature), however we lack this basic information for many species and we lack knowledge of how stressors interact or how species respond to multiple stressors.	Survey
27	What are the effects of agricultural modifications (ditching and especially tile drainage) to downstream fish habitat, including sedimentation, nutrient transport, and flow regime modification?	Survey
27	What is the effect of large scale farming on prairie watersheds with respect to a lack of buffer zones, loss of ephemeral habitat due to ploughing, sediment, pesticides, and fertilizers?	Survey
27	Impacts of agricultural practices in channelized streams to salmonid habitat and health.	Survey
28	impacts from aquatic invasive species and harmful algal blooms	Survey
28	Freshwater systems facing increasing threats from Aquatic Invasive Species and Harmful Algal Blooms but these don't seem to factor heavily in current management or policy	Survey
29	impacts on freshwater fish of alternative and renewable energy	Survey

30	What is the effect of tile drainage to freshwater systems with regard to erosion, bank failure, landslides, sediment loading, nutrient loading, low oxygen, fish kills, and eutrophication?	Survey
30	effect of agricultural drain enclosures on an ecosystem and fish movement	Survey
31	What is death of fish? How many deaths are acceptable? What percentage of fish deaths are acceptable during a fish rescue? At what point should death of fish be authorized and at what point would it be considered an occurrence?	Survey
31	more research into death of fish for in-water works, both the likelihood during specific types of works (i.e., dredging, works without isolation, etc.) and how to account for death of fish both in measurement of death and how to offset for death of fish.	Survey
32	how does boat traffic (e.g. type/size of engine, frequency of traffic) affect fish behaviour in freshwater habitats?	Survey
34	Right now, net fisheries on the Fraser River, and other river systems is having a large effect on survival of salmon and steelhead DUs, and likely on white sturgeon as well. I would strongly advocate science effort to experiment with fish traps as an alternative to net fisheries. Resurrect the traditional First Nation traps. Try applying new technologies to old ways... check the success of this in Oregon / Columbia river pilot studies.	Survey
34	impacts to genetics from fishing practices: net size, bait, habitat destruction from authorized fishing activity	Survey
35	how does dredging spread non-native species such as Starry Stonewort and Eurasian Milfoil?	Survey
35	effects of dredging (what happens to large spots that have been dredged - do fish avoid?	Survey
36	Aquatic invasive species impacts on fish habitat (i.e. European green crab on eel grass). Effective eradication.	Survey
36	little is known about how to manage for aquatic invasive species. life cycles of pickerel smallmouth bass in Maritimes region. Can they be controlled or eradicated?	Survey
36	new technologies and techniques for eradication and or control of aquatic invasive species	Survey
38	The lack of data on fish species assemblages in each watershed. That is, what freshwater fish species are present where, even just presence or absence.	Survey
38	Presence/absence of non-native species in freshwater systems and how these species impact native fishes.	Survey
39	fragmentation, but also invasive species, multiple factors related to changing climate (temperatures, flow levels, timing of life history events, resilience of communities to more variable abiotic conditions).	Survey
39	How can we ensure that Canadian freshwater ecosystems have a natural resilience towards invasive species?	Survey
40	knowledge gaps on freshwater plants: Aquatic Invasive Plants although can cause harm to fish and fish habitat, it can also be considered a fish habitat it self up until the point that it becomes noxious; the knowledge gaps exist with threshold/conditions when an aquatic Invasive plant species is considered to be harmful towards fish and fish habitat; when an aquatic invasive/non-indigenous plant species is competing with native plant species; whether landscape level thresholds/tipping points exist in which aquatic invasive plants can be seen to cause harm to fish and fish habitat.	Survey
41	do underwater cables impact fish behavior?	Survey
43	The extent of habitat loss and degradation in fresh water systems is not fully known in agricultural areas, especially where intensive farming is expanding.	Survey
45	Phragmites removal - would this be an effective offsetting measure?	Survey

45	At what point does the harm caused by an aquatic invasive species justify its removal as a habitat restoration measure (e.g., what density of Eurasian water-milfoil can be considered harmful to native fish populations)?	Survey
46	Lack of understanding of geochemical controls on not only fish, but fish food (i.e. invertebrates).	Survey
46	Lack of focus on stressors on the fish's food source leads to a lack of understanding of how fish will respond to stress.	Survey
49	both direct harm, and indirect / delayed harm (e.g. egg resorption, spawning delays, stress-related immune suppression, etc.) caused by recreational catch-release fisheries (especially on white sturgeon in Fraser River).	Survey
49	lack of knowledge about impacts of ice fishing on vulnerable species (e.g. lake trout)	Survey
58	There's also the issue of streams being ditched, re-located and buried underground, without permits or environmental reviews. The full extent of this activity is unknown.	Survey
59	it's common practice to lower water levels in the fall. How does this activity impact aquatic species such as turtles, American Eels, frogs and other burrowing aquatic organisms that hibernate?	Survey
60	Water pumping for development operations can discharge huge volumes of water into small lakes, such as in the arctic from mining operations. While the discharge values may be in line with the law. What happens when the entire volume of a lake is replaced with discharge water?	Survey
61	How can early detection of invasive species be improved such that management strategies can be implemented in time to reduce invasion?	Survey
62	tool for small HADDs that are not authorized	Survey
72	impact of use of biological control in an aquatic environment	Survey
73	Classification of water bodies according to the level of risk of invasion by non-indigenous species.	Survey
73	Historical versus current distribution of common and widespread species?	Survey
73	Therefore, fish distribution and habitat use information will not be collected, nor will it be updated as land use evolves/intensifies.	Survey
73	Get the youth involved with mapping and fishing to describe distribution and habitat use.	Survey
73	Distribution, should also be a concern for low sampled regions.	Survey
73	A lack of detailed fish distribution and habitat data.	Survey
73	Lack of knowledge about current fish habitat amount, condition, value and types.	Survey
73	Where fish species may be present needs updating with DFO	Survey
73	Current distributions and abundances of many species (particularly species at risk)	Survey
73	The actual availability and how much habitat has been lost or altered needs to be quantified.	Survey
73	A MAJOR knowledge gap is the extent of available and used spawning habitat and habitat descriptions for different populations of salmon e.g. even within Chinook, there are multiple life-history strategies that return at different sizes and exhibit different behaviours. An up-to-date and easily accessible database with river maps and habitat quality layers is what is a crucial aspect for effective management.	Survey
73	By updating the fish distribution maps, species ID features and educating the public, freshwater fisheries conservation will improve.	Survey
73	Species distribution maps are often times out of data, especially within a changing climate, and rarely include indigenous or traditional knowledge.	Survey
73	lack of a national inventory	Survey

73	No updating species distribution maps and new species	Survey
73	Understanding of how much habitat we have (effectively mapping our habitat resources)	Survey
73	Detailed juvenile chinook habitat use and distribution in the Fraser.	Survey
73	Fish distribution and habitat use either don't exist or not detailed enough to make proper management decisions	Survey
73	knowledge of the presence of Aquatic Invasive Species prior to conducting habitat restoration (no point in attempting to re-establish a species at risk, in a water body that is still invaded by an aquatic invasive species)	Survey
73	national base habitat layer maps	Survey
73	Online mapping for fishes and mollusks is lacking.	Survey
73	How can fish habitat information be updated effectively?	Survey
73	Current distribution for many species (particularly species at risk)	Survey
73	Maintain up to date records of species distributions through regular inventory and monitoring	Survey
73	incomplete (but improving) inventory of habitats (past focus has been on spawning / nursery habitat and therefore nearshore but complete life history habitat inventory is needed	Survey
73	Accessible and complete habitat mapping with supporting data in an easily accessible data repository will help inform decision making, but must be kept current	Survey
74	Too little is known about the habitat requirements (qualities and quantities) of individual fish species by life stage.	Survey
74	comprehensive knowledge of complete habitat requirements for most fish species (from spawning through juvenile to adult hood). Limited knowledge for species without direct economic value but still playing key ecological roles (e.g. prey fish, competitors, important conduits of energy in food webs, etc.)	Survey
74	How fish use different habitat patches at different life stages and seasons.	Survey
74	Habitat use at different life stages	Survey
74	Limited information for most Canadian species on distributions (spatial ecology) and habitat use at all life stages	Survey
74	focus on salmonids but not much information on warm water system fish habitat requirements	Survey
74	Core ecology of fish - fish-habitat associations at all life stages for all species.	Survey
74	Habitat use is always useful info. Habitat use of some species and life history stages may be lacking	Survey
74	habitat needs of most non-fishery species	Survey
75	Microhabitat use studies are often outdated or limited in geographic scope; revisit habitat-use relationships with newer study methods and over greater range of regions	Survey
75	Northern Fraser River juvenile Coho and Chinook salmon habitat use is limited to a handful of specific studies.	Survey
75	Nearly all Fraser River Coho and Chinook have incomplete spawning and rearing distribution maps, particularly in the watersheds upstream from the Bridge River confluence.	Survey
75	fish distribution and habitat use information is generally lacking outside of major watercourses. Governments rely on proponents or consultants to complete surveys but this information is not always shared to benefit others.	Survey
75	Lack of baseline or monitoring impacts North of 60	Survey
75	habitat use in northern systems	Survey

75	Too little is known about the ecological factors determining the distribution and abundance of Canada's freshwater fish fauna.	Survey
75	monitoring to better understanding distribution and use in multiple seasons	Survey
75	In the area where I work - Central Coast of British Columbia - we lack baseline data on habitat use and distribution for many locations, species and seasons.	Survey
76	What do fish do in winter (e.g. how far do fish move to find overwintering habitat, do they congregate in a few select pools or are they spread out, what do fish do during a melt, how do they react to high chloride levels associated with melt events)?	Survey
76	winter habitat use??? can proponents design winter habitat effectively and if so how beneficial or limiting is winter habitat in riverine system...	Survey
76	Overwinter habitat use and fish distribution - particularly in large lakes	Survey
76	The big knowledge gap is WINTER especially in streams, and especially in streams that go anoxic in the winter	Survey
76	Understanding of winter habitat use of multiple species	Survey
76	Seasonal habitat use - particularly in winter	Survey
77	Habitat use by migratory species	Survey
77	The precise locations of fish species in the freshwater environment and the location of their ecological functions.	Survey
77	Habitat availability for many species	Survey
77	Habitat use by various fish species. We have a great lack of knowledge on how species and populations of various fish species use different habitats and what life processes they entail.	Survey
79	Identification of critical habitat for species at risk, population distribution and recovery goals for species at risk.	Survey
79	often habitat classification not at high enough resolution	Survey
79	Mapping is not precise enough, especially with species at risk	Survey
79	High resolution and broad coverage data on the distribution of habitats, as well as native and non-indigenous species.	Survey
79	methods to identify critical habitat and bottleneck habitat for different species	Survey
79	improve understanding of distribution for species at risk, cryptic species	Survey
79	Maps and geographic data of both aquatic invasive species and at risk species (listed under the Species at Risk Act) in watersheds	Survey
79	Habitat mapping, distribution of species and identification of SAR habitat needs to be more precise.	Survey
79	Fish presence in fresh water habitat is only associated with 1:20000 scale mapping in BC but finer scale fish presence and flows information is needed to adequately fresh water fish populations.	Survey
79	The natal, first order streams of major river systems like the Lower Fraser are not mapped or poorly mapped because detailed water course mapping is extremely inadequate. First order watercourse inventory needs to be fully supported throughout the settlement areas of BC.	Survey
79	Updating Fishes of Alberta, Scott and Crossman to have accurate updated information. This should be considered for all provinces in Canada as right now, is there an understanding of fish distribution beside the SARA listed species?	Survey
80	More information is required on habitat requirements of northern anadromous species (e.g. arctic Char) and on the impact of changing thermal regimes.	Survey
80	While there is a need for additional research, so much less is know about northern fishes that Canada's north should be a priority.	Survey
80	Fish distribution and habitat use is limited in the Maritimes Region.	Survey
80	distribution and habitat maps for certain parts of Canada are not available, especially North of 60	Survey

80	fish-habitat associations in northern systems	Survey
80	With the exception of generic information available in reference documents (e.g., lake trout spawn on a particular substrate type in the fall), relatively little is known about northern species and their habitats.	Survey
80	Blatant lack of data on less well known (e.g., Far North) and potentially more fragile environments.	Survey
80	For many species fish distribution and habitat use is not known, again, in particular the Arctic	Survey
80	Fish distribution and habitat use is generally only known for well studied watersheds. Many watersheds are data deficient	Survey
80	There is a great need for information for northern regions	Survey
80	The north and other remote parts of Canada still has rudimentary understandings of habitat associations.	Survey
82	More specific information on habitat suitability as opposed to habitat use is needed. Many species have behavioral mechanisms that lead to subordinate individuals being in higher density in less suitable habitat.	Survey
82	More research on what fish prefer vs tolerate in terms of habitat	Survey
82	Information about species dependence on specific habitat and habitat suitability (not just presence) would be helpful.	Survey
82	Proportionality of habitat use with estimated areas of use, to guide development of offset projects with the correct ratio of habitat spaces for fish to use.	Survey
82	Habitat Suitability Index / modelling would be a helpful tool	Survey
83	many water courses in central region have never have a thorough assessment with provincial agencies which DFO relies on data.	Survey
83	Specific to NWT and Nunavut, we are lacking from access to baseline information on fish and fish habitat.	Survey
83	baseline information on habitat availability, dependence and sensitivity are needed.	Survey
84	Lots of data about fish distribution but not necessarily current. Most data is from the summer with little to no idea of habitat use during the other 3 seasons.	Survey
86	How can sufficient data to support best management practices concerning freshwater fish species at risk be collected from rare or elusive species?	Survey
86	Small-bodied, non-commercial/recreational species are seldom studied, but still important to understand their distribution and habitat needs.	Survey
86	small-bodied species distributions and fish communities in remote habitats are still unknown.	Survey
86	There is a deficit of data concerning the distributions and habitat use of freshwater fish species at risk. How can we improve our knowledge of habitat use by freshwater fish species at risk in a manner that is resource efficient enough that management bodies will not be greatly restricted in their efforts?	Survey
87	revisit how much habitat is enough	Survey
87	Update and expand upon previous Area-per-individual research (see previous Minns and Randall papers). Increase the breadth of species (niche, body size) and regions studied.	Survey
89	We need to continue to do a better job (with electronic tagging) of understanding dynamic aspects of habitat use.	Survey
89	Can we account for the range of habitat that is used under different conditions?	Survey
89	How does habitat generate the variability that is required for organisms to respond to changes in environmental conditions.	Survey
97	quantifying watershed anthropogenic stressors and pressures that inform fish habitat status	Survey

101	Magnitude of effect for many of the current stressors including fishing (recreational and illegal) and habitat destruction affecting habitat availability and quality	Survey
101	Identification of limiting factors (e.g. overwintering habitat in some systems) would be useful.	Survey
101	Currently available habitat and identification of limiting habitat	Survey
101	Currently available habitat and identification of limiting habitat	Survey
101	identifying limiting factors in a lake or river reach - is building a spawning shoal next to a bridge really a good use of resources?	Survey
101	Questions about the relationship between habitat quality and availability and fish productivity is a gap.	Survey
102	Investigate how primary and secondary productivity affects the amount of habitat required by individuals (can also reframe in terms of habitat quality or availability of preferred habitats)	Survey
102	Improved understanding of the link between area of habitat occupied and abundance, status and productivity of populations (can also frame this research gap in terms of availability of suitable habitat)	Survey
102	further development of productivity-state response curves, with thresholds where they may exist.	Survey
102	direct quantitative linkages between changes in habitat and fish production (or surrogates thereof)	Survey
102	A clear, species (or even taxa)-specific understanding on quantitative links between habitat availability and fish production	Survey
102	improved technologies for habitat classification, and how different habitat categories or suitabilities interact to affect fish populations and productivity	Survey
102	Data on the link between freshwater fish habitat and fish productivity are the basis of the Fisheries Act, yet these data are challenging to obtain and inherently lacking for many freshwater fish species in lotic and lentic systems, especially in northern ecosystems.	Survey
102	The link between habitat and population or community production.	Survey
102	Better relationships between habitat changes and productivity of fish communities (beyond general rules of thumb on home range size, habitat suitability indices)	Survey
103	Quantitative associations with physical habitat characteristics (HSI curves) and biological characteristics (predator, prey, competitor interactions)	Survey
104	re-assessment of current regulations for minimum flow requirements for salmon in spring and summer; have these changed as a result of climate change?	Survey
104	Effects of the disappearance of headwater lakes or small streams at the head of a basin on downstream aquatic ecosystems.	Survey
105	Need to consider fish condition and other indicators when evaluating habitat value.	Survey
105	Where population information is not available, what are the minimum indicators that would allow us to determine the status of fish populations and their habitat (especially for non-commercial species or species of interest to recreational fishing)? What parameters should be collected in order to make observations?	Survey
105	Effective and validated indices of fish productivity, which is the unit of measurement for assessing impact and compensation under the fisheries act	Survey
105	What indicators are useful in capturing structural or functional change.	Survey
105	In addition, there are no standardized indicators or report production methods.	Survey
107	The importance of large river habitats for fish productivity. Due to the difficulty in assessing habitat and fish populations in larger rivers, most of our understanding, especially in the Pacific Region is about small stream ecosystems.	Survey
107	The lack of productivity data for the vast majority of ecosystems and on how they have varied over time and will vary in the future is a major impediment.	Survey

108	Clear and quantifiable metrics of habitat classification that relate directly to the presence/productivity of species of interest	Survey
108	Need to have a better understanding of Regional productivity ties to specific species to be able to account accurately for habitat losses authorized under s 35(2) (b) of the Act and the associated gains in created, restored or enhanced habitat	Survey
110	how urban development is impacting fish and fish habitat and how they have adapted	Survey
113	There is also a huge knowledge gap in the cumulative effects of catchment modifications to hydrology and salmon behaviour and survival at multiple life stages.	Survey
113	methods and tools to address effects of land (and groundwater) management on habitat.	Survey
115	What area that would need to be protected around a watercourse or waterbody to ensure the conservation of an aquatic ecosystem of significant ecological value for one or more target species?	Survey
117	The Class Authorization system for classifying fish habitat in municipal drains barely takes into account the health of the habitat. So we are data deficient on the health of these systems where they lie within agricultural blocks,	Survey
119	realistic averages or total pool estimates of limiting nutrients	Survey
120	Not enough parameters are collected with fish sampling programs, to look for correlations	Survey
120	Recent and region (i.e., lake) specific life history vital rates	Survey
120	Species and region specific vital rates	Survey
120	We have little idea of the size of many species breeding populations or the survival rate of young.	Survey
121	understanding geographic variation across Canada and how This affects both fish productivity and fish responses to anthropogenic perturbations.	Survey
121	quantification of habitat use is often site specific and non-transferable which leads to questionable modelling results for impact assessments.	Survey
121	Species habitat requirements often vary among ecosystem types (e.g. rivers, lakes, wetlands) within areas and across the range of their distribution (boreal, taiga, arctic, etc.) and yet most of the extant knowledge tends to come from particular eco types at the centre of their distribution.	Survey
121	information on how habitat use varies across the species distribution and why	Survey
122	Impacts and possible mitigation options in Southeastern Canada to address acidity issues from acid precipitation on Atlantic Salmon habitat	Survey
122	acidification remediation	Survey
123	Some species have huge data gaps surrounding the fundamental ecology. And some species fundamental ecology hasn't been updated in 100 years.	Survey
123	specific details of life cycles	Survey
123	For many species we do not know basic information, such as habitat preferences and life history characteristics, making managing to protect species incredibly challenging	Survey
125	Climate change impacts on spawning windows and ecology of species.	Survey
126	Knowledge gaps in early life history of many fish and invertebrate species	Survey
134	Scientific requirements for fish passage through culverts is a massive science gap.	Survey
134	The passability and state of most watercourse structures is lacking, as is the state of the riparian zones.	Survey
134	improved understanding of barrier passage (staging, upstream and downstream passage)	Survey

134	Fish passage	Survey
134	Habitat accessibility with fish passage in general and seasonally	Survey
134	Locations of dams and reservoirs, and related attribute data, is not readily available to consultants.	Survey
134	There is no cohesive database that identifies where there are issues to fish passage or degraded habitat.	Survey
134	impacts to migration (both upstream and downstream) to stocks due to dams	Survey
134	Habitat accessibility with fish passage in general and seasonally	Survey
134	knowledge of the presence of barriers is weak in most areas.	Survey
134	A national inventory of all dams, dykes, bridges, stream crossings and piers would be useful for determining cumulative impacts.	Survey
135	Fish distribution, habitat use, and physical parameters of rivers and watersheds	Survey
135	The effects of major habitat 'forces' (e.g. temperature, flow, nutrients etc.) are still an important area for research as it is often easier to manage these attributes than habitat per se.	Survey
136	flow management and fish passage on impacted rivers	Survey
136	site-specific information on movement and flow impacts on managed rivers (i.e. rivers impacted by hydroelectricity)	Survey
136	How can other elements of fish habitat such as thermal regimes, flow regimes, and spatiotemporal connectivity (both physical barriers and timely access to different habitat patches) be better addressed?	Survey
136	How much water does a freshwater fish or stream need?	Survey
137	More financial resources for tagging studies around Newfoundland and Labrador (acoustic, radio and satellite tagging), to improve our understanding of the migration, behaviour and survival of Atlantic salmon offshore and in the Labrador Sea.	Survey
137	Clear understanding of fish movement and migration patterns in large lakes	Survey
137	Connectivity and movement of fish between different fish habitats	Survey
138	Some research has been done, but a clear protective distance from a surface body (thermal), aggregate extraction etc. features that have potential and possible impacts to surface water from groundwater are not developed.	Survey
138	How do anthropogenic landscape changes impact the thermal profile of shallow aquifers?	Survey
138	Changes in water quality, quality, regime- surface, subsurface, groundwater and non replenishing aquifers	Survey
138	In southern Ontario, cold water fisheries are normally in areas with abundant sand and gravel and groundwater resources. There are few tools in planning and policy to protect fish species from a groundwater perspective.	Survey
139	Knowledge is lacking on how to apply fish swimming curves against culvert velocities, and what is considered passable for fish.	Survey
139	Need improvement to fish passage (better infrastructure maintenance and assessment)	Survey
139	Swim Performance Online Tools (SPOT) is great, but more decision-making guidance is required to be able to better apply this is required.	Survey
140	Evidence based-policies surrounding decisions that place native species/habitat improvements (e.g. barrier removal) and invasive species containment in direct conflict	Survey
140	Should barrier removal be considered where there is aquatic invasive species below the barrier? Where the barrier also inhibits movements of indigenous/native species.	Survey
140	Should we be removing barriers to fish passage to improve habitat for native species despite increasing the spread of Aquatic Invasive Species?	Survey

141	how do hydrology processes affect fish habitat?	Survey
141	Gaps include information on how to determine environmental flows in rivers and how these flows impact coastal areas.	Survey
141	how do connectivity processes affect fish habitat?	Survey
142	How to determine adequate fish passage through proposed culverts. We need a consistent approach across Canada.	Survey
145	Water Quantity and Flow Regimes	Survey
145	How do we measure and validate the success of a project in relation to the natural variability of a watercourse?	Survey
146	lack of understanding of terrestrial and aquatic fluxes that can impact fish habitat	Survey
146	understanding the fluxes and subsidies of nutrients, run-off etc. between terrestrial and aquatic ecosystems	Survey
148	Waterpower and lack for upstream /downstream support (example American eel, lake sturgeon)	Survey
149	understanding connectivity among habitats and fish use of those corridors (habitat use and meta-population structure)	Survey
149	lack of understanding of connectivity among habitats	Survey
150	How can habitat connectivity and whole ecosystems be of greater consideration when managing isolated habitat segments?	Survey
150	longitudinal connectivity as well as lateral connectivity, while understood in concept, is not really utilized in habitat management, primarily a result of lack of site specific information related to same.	Survey
154	drought planning for the future, where will fish passage become more difficult from drought or flow restriction- too much water at the wrong time of year	Survey
154	where will fish passage become more difficult from drought or flow restriction- too much water at the wrong time of year	Survey
155	Developing guidelines for removal of natural barriers (landslides) to fish passage	Survey
155	Big Bar landslide in the Fraser River	Survey
162	Importance of maintaining connectivity in the face of lowering water levels in glacial streams from long term climate change	Survey
162	effects of land use, fragmentation etc. through most parts of the country.	Survey
162	impacts of climate change	Survey
162	Climate Change Impacts.	Survey
162	Climate change impacts to fish (salmonids in particular)	Survey
162	Climate change and habitat fragmentation	Survey
162	ecosystem processes. in the area of aquatic connectivity for example, we still don't know very well how fragmentation impedes many life history processes for well studied fish, much less prey species. Even the basic GIS information is lacking to determine how much fragmentation there is in most systems.	Survey
162	the effects of reduced freshwater functional connectivity on local, regional and landscape levels, how we measure this consistently and how to incorporate this into mitigation and restoration plans	Survey
162	Effects of fragmentation and habitat loss	Survey
162	climate change	Survey
162	Climate change impacts on fish habitat	Survey
162	Effects of fragmentation on fish habitat - given numerous small projects may be allowed to occur which impact fish habitat - yet what does it do on the whole	Survey
162	projected habitat changes associated with climate change	Survey
163	There are large knowledge gaps for fish distributions and habitat use in the Pacific region (within DFO) and likely in the Yukon and Arctic. How distributions are going	Survey

	to change with climate is a major knowledge gap, especially for highly migrator species that may hit bottlenecks in their migration.	
163	How can we expect freshwater fish species distributions to change as a result of climate change?	Survey
163	How will fish community compositions change as a result of range shifts due to climate change?	Survey
163	Effects of climate change on fish physiology and environmental stressors	Survey
163	Climate change on the physiology, distribution, growth and survival of juvenile salmon in freshwater.	Survey
163	Understanding sub-lethal impacts (changes in growth rate, immune response, fecundity, movement, metabolism) on salmonids of increasing water temperatures during summer months on coldwater streams	Survey
163	Some models in development (e.g. HEAT) that remain ambiguous in terms of their utility. Models incorporating thermal tolerance of species (and food web requirements, to recognize impacts of sensitive prey fish species) are critical for evaluating climate change impacts.	Survey
163	Related to climate change - how an increase in freshwater temperature in Newfoundland and Labrador rivers will impact Atlantic salmon juveniles growth and survival until their first migration to sea as smolts, as well as how it will impact adult Atlantic salmon that return to spawn.	Survey
163	Understanding climate change impacts on lake fishes via complex habitat interactions between deepwater oxygen and thermocline depth/ season length (some good work on this focused on e.g. cisco in Minnesota lakes)	Survey
164	guidance on how to address climate change as a threat to assessed species at risk	Survey
164	how to address and mitigate climate change and threats exacerbated by climate change	Survey
164	climate change impacts, especially in context of multiple stressors	Survey
164	Climate change is very seldom factored in when making present decisions on the future of fish and fish habitat	Survey
164	Cumulative effects of impact of climate change in addition to habitat losses need to be evaluated, and offsetting ratios need to consider all of this.	Survey
164	I'm assuming we haven't got a good handle on climate change impacts to freshwater fish habitat. Not just primary effects (water temperature), but also things like sedimentation (think BC wildfires and investation)	Survey
164	Climate Change as a long term stressors.	Survey
164	Cumulative effects including climate change considerations such as predicted temperature changes in streams (note: this consideration will not be taken into account with the current policy for project decisions in FFHPP so it may not be useful to study further unless the policy is updated).	Survey
164	impacts of invasive species, climate change and other stressors	Survey
165	perhaps some thought regarding climate change scenarios - are there some habitats that are particularly vulnerable?	Survey
165	Climate change: potential exacerbation of spread of aquatic invasive species, from anthropogenic activity/pathways, vs natural habitat range expiation through climate change.	Survey
165	changes in local, regional and landscape hydrography (via climate change or infrastructure) on native and invasive species assemblages, but also on habitat stability and availability.	Survey
166	water futures, where will high quality cold freshwater be available to freshwater fish, salmonids in particular, in 25-50 years, given sea level rise and salt water inundation coupled with glacier disappearance and changing precipitation patterns with longer droughts	Survey
166	More info on climate change impacts (i.e., warmer streams, lower DO)	Survey

166	Climate Change impacts to marine and freshwater fishes of Canada (water supply, air/water temp, ocean currents, predation, ecosystem changes).	Survey
166	climate change: when do habitats no longer warrant protection because of changing temperature and flow regimes	Survey
166	air and stream temperature	Survey
166	Changes is dissolved oxygen and dissolved gas levels to changes in thermal changes	Survey
167	Changes in Thermal regimes not mapped	Survey
167	aquatic thermal properties were researched in some areas but the extent of these have not been mapped.	Survey
167	Thermal classifications of watercourses in the Grand River watershed - approximately half of all watercourse remain unclassified.	Survey
167	Gaps on thermal regimes of rivers	Survey
167	Protection of thermal refugia	Survey
167	thermal (habitat) regime protection (climate change lens)	Survey
168	How can we expect temperature changes (if they do occur as a consequence of climate change) to impact the productivity of habitats.	Survey
168	Temperature effects and climate change impacts on available and future habitat	Survey
169	Generational Habitat loss - each generation see their habitats as real.	Survey
169	Decent baseline understanding of populations distribution, abundance, and trends over time. Taking into account ideas of historical abundance and avoiding shifting baseline.	Survey
169	The effect a changing climate may have on habitat associations and the changing baseline.	Survey
169	This is one area [fish distribution] where the changing baseline (climate driven) can be an issue.	Survey
170	Are current measures provide desirable outcomes across different ecosystem contexts, due practices include considerations for changes in the future due to climate change or other drivers?	Survey
170	Effects of freshwater distribution due to water warming	Survey
172	Climate change is an obvious issue that will greatly alter aquatic ecosystems, but there's inherent uncertainty in predicting these changes. We need to diversify adaptation strategies for various climate change scenarios to ensure freshwater fish habitat in Canada is resilient.	Survey
173	changing climates are changing species colonization. Invasive species are becoming the norm moving out native species at what point do we accept and manage for invasive species	Survey
174	inland estuary planning to accommodate fish (salmonids in particular) in the future with sea level rise and coastal squeeze	Survey
175	Mitigating climate change and water level impacts have be come a focus of offsetting ideas in the far north. Better understanding of how this impacts may effect far north waterbodies would be important. Seasonal flow is very important to reproduction strategies.	Survey
176	What impact will a thawing arctic have on fish and fish habitat, as more fish are migrating up the Mackenzie river, populating lakes and stream previously frozen, more fisheries being declared on anadromous fishes	Survey
177	oversight regarding cumulative effects, particularly in large, contiguous bodies of water (Great Lakes, for example)	Survey
177	ability to quantify cumulative effects that would support zero further change policies in nearshore fish habitats	Survey
177	Cumulative impacts and how to deal with them remains and area for further work.	Survey

177	How can a federal fish habitat strategy be implemented that considers cumulative effects, listing of sensitive areas or habitat types, guidance to FFHPP on what core habitat areas or offsets would benefit regionally.	Survey
177	what cumulative impacts might mean to individual fish populations, what does considering cumulative effects mean?	Survey
177	cumulative impacts	Survey
177	ability to quantify the current state of fish habitat on a national scale (would facilitate the cumulative effects assessments)	Survey
177	frameworks that consider cumulative effects or multiple stressors limited	Survey
177	how to assess and manage cumulative effects in freshwater systems when a Department only has legislative or regulatory tools for some components (e.g. current Fisheries Act).	Survey
177	effect of cumulative impacts from multiple stressors	Survey
177	watershed level cumulative effects of land-based development	Survey
177	Extent of cumulative effects	Survey
177	How to assess cumulative effects.	Survey
177	How do we consider the cumulative effects of the different stressors on fish populations and their habitats in regulatory reviews? What temporal and spatial scale should be considered?	Survey
177	capacity to map stressors at different spatial and temporal scales	Survey
177	The cumulative impacts of multiple habitat changes.	Survey
177	Freshwater systems under multiple threats but for most Canadian ecosystems information and data on specifics is lacking, especially in context of cumulative effects which is needed for effective management and policy	Survey
177	We need to consider how our policies direct the restoration of fish habitat and species - our policies can contribute to cumulative effects	Survey
177	the cumulative effect of multiple stressors, and the overall impact on the fish	Survey
177	Impacts from cumulative effects	Survey
177	methods for assessing the cumulative effects of human activities in freshwater.	Survey
177	No consideration or understanding of cumulative effects on freshwater water fish habitats.	Survey
177	lack of knowledge on cumulative effects of stressors on fish habitat	Survey
177	the effects of multiple stressors are unknown	Survey
177	Another huge gap is understanding cumulative impacts.	Survey
177	Broadly, we are still extremely limited in our understanding of cumulative impacts from multiple stressors and how to manage for them.	Survey
177	Cumulative effects	Survey
177	Cumulative effects (both temporal and spatial) and how do we manage multiple impacts?	Survey
177	How do we account for changes in multiple stressors and build resilience for those that can not be anticipated?	Survey
177	Cumulative effects	Survey
177	How should cumulative effects be measured, and how can the additive effects be quantified?	Survey
177	how does offsetting address cumulative impacts	Survey
177	cumulative effects assessment	Survey
177	Cumulative and historic impacts need to be better considered and addressed.	Survey
178	The integration of Multiple Contaminants and fish habitats need more work.	Survey
178	Lack of ability to assess cumulative impacts of physical and chemical stressors.	Survey

178	Aggregate effects of pollution on fish and fish habitat	Survey
178	Methods to relate contaminants, pesticides and other chemicals into fish responses (individuals and populations) are needed)	Survey
179	Consideration of multiple stressors in ecosystem ecology. We need to refocus research from single stressors to how multiple stressors interact to produce synergistic, antagonistic or additive effects.	Survey
179	How can we determine the point of no return and whether or not there are synergistic effects?	Survey
179	We need more information on how fish habitat changes are interacting with other biotic and abiotic stressors (temperature changes, hypoxia and contaminants).	Survey
179	The vetting of a mathematical model for use in determining the magnitude of interaction between pressures and ecological components in cumulative effects assessment is also needed.	Survey
179	Methods to combine the effects of stressors are needed	Survey
179	determine the synergistic or cumulative effects of stressors on fish species and their habitats	Survey
179	The effects of multiple stressors are generally not well understood yet these studies will need to be conducted to understand the complexity of responses in the wild.	Survey
180	Changing climate is a pervasive threat and a stressor to all Canadian aquatic ecosystems. How climate alone, and in conjunction with other stressors, may alter fish productivity across all fish guilds is a knowledge gap that should be a priority.	Survey
180	interactions between multiple stressors at both habitat and landscape scale	Survey
180	How anthropogenic stressors will interact with climate change.	Survey
180	How different stressors interact (cumulative effects) in freshwater habitats.	Survey
180	Methodological and empirical approaches to understanding stressors, their interactions, and their impacts in Canada's freshwater ecosystems will improve decision-support tools.	Survey
181	Science to measure and predict cumulative impacts, and shared information base at all levels of scale	Survey
181	Cumulative impacts and a large scale data base that ties together all impacts to fish	Survey
181	What are the cumulative and relative effects of all stressors in the landscape (terrestrial and aquatic) on fish habitat, and what gaps exist in their protection and remediation?	Survey
181	Ecosystem-based assessment criteria to support decision-making in the context of the broader environment including the assessment of cumulative effects.	Survey
183	Cumulative impacts of small- and large-scale habitat alterations and projects	Survey
183	Lack of knowledge of impacts of small and medium scale development, industrial, commercial or residential on freshwater fish habitat	Survey
183	What are the cumulative effects of incremental habitat loss from small projects? How can these be placed in an ecosystem context when individually and superficially, they may appear not to cause harm?	Survey
184	lack of understanding of effects of multiple stressors or frameworks to map effects on fish communities and species	Survey
185	cumulative effects - understanding the increased value of impacted habitats. Industry tends to say that habitat is already impacted therefore not high value. There may need to be a shift in what is considered high value habitat in high density areas especially on heavily impacted systems (i.e. Fraser River).	Survey
186	incomplete understanding of effectiveness of avoidance, mitigation, offsetting, or habitat restoration activities	Survey
186	monitoring of active construction projects to help develop effective mitigation measures	Survey

186	As for habitat offsetting and restoration, it is difficult to expect to receive a lot of baseline information before project acceptance and the results are sometimes (or often) mixed.	Survey
186	effectiveness of avoidance, mitigation, Offsetting and habitat restoration activities	Survey
186	determine the best avoidance and mitigation measures for each type of human activity that causes stress to fish and fish habitat	Survey
186	Additional guidance on offsetting requirements.	Survey
186	The monitoring of any mitigation/offsetting/restoration measures done for replacing juvenile salmon rearing habitat that was destroyed from anthropogenic development is a large gap in knowledge. The effectiveness of habitat offsetting in most scenarios has not been assessed or monitored.	Survey
186	How effective are management actions that are commonly used for fish habitat?	Survey
186	How can we ensure that offsetting projects really offset the residual effects of a project and do so in a sustainable manner?	Survey
186	What is the effectiveness of efforts for avoidance, mitigation, offsetting, and restoration?	Survey
186	Lack of understanding of how effective individual offsetting/compensation projects have been at addressing impacts to freshwater fish habitats.	Survey
186	We have implemented a number of measures for mitigation, conservation for protection of fish habitat, but these measures are often not evaluated post application to identify whether or not they achieved the desired results.	Survey
186	Avoidance and mitigation. There seems to be very little peer reviewed information on the efficacy of many avoidance and mitigation measures used during project construction.	Survey
186	Mitigation and restoration of habitats impacted by agriculture	Survey
186	In the case of offsetting projects, how can we ensure that the proposed project targets the enhancement of a habitat that is limiting to the population of the target species?	Survey
186	With respect to restoration projects, gaps remain in terms of what provides the greatest benefit: projects aimed at restoring fishery productivity or enhancements/developments aimed at restoring ecological processes (which will eventually result in the restoration of fish habitat).	Survey
186	There is a need to develop best practices for measuring habitats and assessing the effectiveness of mitigation and compensation efforts; best management practices and standardized procedures for proponents to help reduce losses in habitat productivity.	Survey
186	Effectiveness of fish habitat mitigation and compensation measures, particularly in northern environments	Survey
186	effectiveness of commonly prescribed management and restoration measures	Survey
186	important to monitor the effectiveness of mitigation and offsetting. The proponent gets credit for doing it, but are they doing it well, or are we all just going through the motions?	Survey
186	understanding the effectiveness of mitigation strategies in reducing or eliminating residual impacts.	Survey
186	Development of effective policies are also hindered by how to adequately and consistently offset habitat losses that occur from development.	Survey
186	Comparison of different offsetting techniques to determine which is most effective	Survey
186	More guidance on offsetting requirements. What are the basic ratio requirements?	Survey
186	effectiveness of habitat restoration and offsetting	Survey
186	effective monitoring conditions and methodologies to ensure offsetting are actually functioning and appropriate lengths of time to follow offsetting to ensure effectiveness	Survey

186	I don't think we know whether most of the mitigation and offsetting work has the intended effect and I tend to be very skeptical of many of these efforts.	Survey
186	Whether offsets and habitat restoration is actually functional post-construction	Survey
186	How effective are our avoidance, mitigation, offsetting and habitat restoration at achieving our desired or intended outcomes?	Survey
186	the effects of our routinely applied management measures in achieving their desired outcome	Survey
186	Updated mitigation techniques to the latest new discovers by following the research closely,	Survey
186	What strategies work the best for compensation (e.g., habitat banking)?	Survey
187	adequate quantification of effectiveness of offsetting measures and capture of data to facilitate meta analyses.	Survey
187	How can the "Bowtie analysis of avoidance and mitigation measures within the legislative and policy context of the Fisheries Protection Program" be better implemented into effects management?	Survey
187	Effective monitoring of compensation projects to evaluate if compensation measures are indeed achieved	Survey
187	habitat compensation projects should follow standard guidance on methods and study design for evaluating effectiveness of compensation projects	Survey
187	Proper and standardized methods to evaluate fish habitat compensation projects for effectiveness monitoring.	Survey
187	We need to work on our five stressors and performance indicators that will show that the Fish and Fish Habitat Protection Program preserves fish and habitat For example, habitat alteration, by addressing cumulative effects - standards (speed limits) in our management measures, shows that stressors are being taken into consideration. By restoring habitat, we can demonstrate success. The best construction tools, bridge instead of culvert, floating docks instead of infilling	Survey
188	better data sharing and data management platforms are needed	Survey
188	How can the outcomes of offsetting and habitat restoration efforts be made more readily available to help researchers determine what does and doesn't work, and to share lessons learned from each project?	Survey
189	APPLICATION of EXISTING Scientific information to inform decision makers/policy	Survey
189	how best to leverage freshwater data from various sources and jurisdictions	Survey
191	quantification of ecosystem health will facilitate offsetting.	Survey
191	prioritization schemes could be used more to determine the best gains for restoration. that will require quantification of ecosystem health however.	Survey
192	How can management objectives continue to be effective under environmental change?	Survey
193	Decision making tools should be developed and updated until they have a real-world result in how DFO achieves sustainable management of freshwater habitat. This requires follow through with policy development and ensuring that capacity exists within the department to constantly update and truly understand the final real-world outcome of the decision making tool.	Survey
193	Pacific's Habitat Monitoring Unit also has a report prepared but not published that concerns effect of habitat management efforts to slow net loss of habitat. A follow-up should be on the Harper government approach to habitat management, and another on the new approach back to HADD. How else do we learn lessons how to improve management than to look and compare results?	Survey
200	A general lack of systematic awareness to consider aquatic invasive species (AIS) and their introduction via construction equipment that has been in or near water	Survey
201	How do we develop management plans that best allow us to learn.	Survey

202	A lot of restoration efforts in the past do not have post monitoring to assess their effectiveness	Survey
202	For many systems, we might have broad categorization of habitats, but detailed knowledge of the state of the system is not known.	Survey
202	determine and monitor the effectiveness of mitigation and offsetting measures for the effects of human activities on fish and fish habitat (what data to collect and how to include consistent and realistic monitoring protocols for industry).	Survey
202	A study evaluating the effectiveness of Fisheries Act authorizations and LOAs, to ensure that DFO polices are meeting objectives to protect habitat	Survey
202	effectiveness conditions for riparian offsets in particular	Survey
202	follow up studies on how effective mitigation, offsetting and restoration has been, i.e. have the measures we have implemented done what we wanted them to do.	Survey
202	How can we improve monitoring efforts of habitat compensation or restoration efforts based on the No Net Loss policy to improve effectiveness?	Survey
202	The effectiveness of offsets continues to be poorly studied, and high uncertainty leads to chronic underperforming of offsets relative to the harm that they are meant to address.	Survey
202	How can habitat monitoring efforts be made more consistent nationally?	Survey
202	Methodologies to monitor and measure reliability and effectiveness of measures.	Survey
202	scientifically defensible monitoring is critical (proper design including control/comparator and adequate temporal scale).	Survey
202	Standard protocols for post effectiveness monitoring	Survey
202	More monitoring of mitigation efforts	Survey
202	The gap is in evaluating the effectiveness of those policies and management strategies.	Survey
202	authorization conditions and time lines for offset effectiveness monitoring	Survey
203	Lack of long-term monitoring	Survey
203	Are there any monitoring measures that could be put in place and compiled under the FFHPP that would allow us to document changes in the habitat and populations?	Survey
203	Lack of long-term Habitat restoration studies	Survey
203	We need more long term data to assess how habitat usage has changed over time.	Survey
203	Long-term monitoring of fisheries offsets is lacking.	Survey
203	landscape based broad scale monitoring tools such as those still being developed in Ontario	Survey
203	Habitat monitoring is a key gap at present. We should follow up with regular surveys started by Quigley and Harper back a couple decades ago concerning net loss. monitoring provides a good back-end stick for proponents to do better than they may otherwise try.	Survey
203	We lack long term monitoring in many areas across Canada, in particular in Arctic ecosystems.	Survey
203	Limited fish community health monitoring spatially in Ontario and over time. No idea about trends in populations or densities, what constitutes a healthy population.	Survey
203	There needs to be a dedicated division that surveys river features (e.g. cobble size, water temperature, flow, velocity at narrow points, density of small and large woody debris, habitat complexity, etc.) on a 4-5 year cycle	Survey
204	new technologies and techniques for early monitoring	Survey
204	continue to compare different monitoring techniques to improve our understanding of the strengths and weaknesses of each (e.g., eDNA, hydroacoustics, telemetry vs. traditional sampling; sidescan sonar vs. substrate sampling)	Survey

204	The program lacks significant scientific knowledge on human activities that take place in estuaries and marine areas. Fish stock sampling protocols are not adapted to meet the needs of the Fish and Fish Habitat Protection Program.	Survey
204	How can existing habitat monitoring methods and tools be made more efficient to facilitate monitoring of greater areas and more habitat?	Survey
204	The Canadian Biomonitoring Network (CABIN) is underused. Great stores of data, current and historical, already exist and could be better utilized if everyone got on board and set up their monitoring programs in such a way that data could be entered into the national database.	Survey
204	What new technologies can be implemented to improve our knowledge of the state of fish habitat?	Survey
205	multi-year time series of depth segregated water temperatures (required for cumulative degree day calculations)	Survey
205	Real-time data on water quality is non-existent in Ontario.	Survey
205	Limited monitoring of Flow and temperature, and only near urban areas (limited travel budgets)	Survey
205	Increased integration of water quality into habitat studies.	Survey
205	How can we increase our knowledge of stream flows and water quality?	Survey
205	More temperature and hydrology monitoring would be helpful.	Survey
205	residence time or daily flow volumes of water	Survey
206	Limited monitoring of change at the scale of Canadian Freshwater ecosystems making it hard to detect change or recovery that could inform management and policy	Survey
206	Given that watercourses are complex dynamic systems, which parameters should be systematically evaluated before beginning development work and which ones should be monitored afterwards?	Survey
206	habitat monitoring and change over time is not being conducted	Survey
206	cost-effective monitoring programs.	Survey
206	what are cost-effective ways to monitor the impacts of freshwater fish habitat stressors.	Survey
207	Far North species composition and productivity research and monitoring. Lots of potential for eDNA to help inform us of species distribution.	Survey
207	How can eDNA be utilized to protect fish and fish habitat?	Survey
207	There's a knowledge gap for remote areas that have never been monitored or assessed or that lack adequate attention. These areas should be strategically prioritized and studied to facilitate a more robust understanding of these habitats and their conservation.	Survey
208	There is little information on the best practices that should be used to collect reliable data without causing fish mortality.	Survey
208	How can we characterize the status of fish populations using non-lethal fisheries?	Survey
208	Also of concern is what are the fisheries impacts when an area is OVER sampled. what are those threshold. Asian Carp maybe seeing a decline in some species that they catch in the trammel nets, 3 times a year.	Survey
209	Why don't we have routine monitoring requirements for commonly applied offsetting projects? How many years should they be monitored to demonstrate success?	Survey
209	A clear direction on duration of monitoring of any habitat alteration	Survey
210	limited large scale monitoring in Canada	Survey
212	lack of decision support tools for different spatial and temporal scales.	Survey
212	more quantitative decision making tools for how much offsetting or restoration is required, given mitigation measures and residual impacts - tools to make this more quantitative and less up to individual judgement.	Survey

212	Cumulative effects tools and models should be developed and shared to be transparent with agencies, proponents and the public	Survey
212	Policy and risk assessment tool does not provide comprehensive interpretation on what level triggers an authorization.	Survey
212	riparian habitat and loss - how valuable these are to fish and fish habitat and how they should be reviewed and managed.	Survey
212	functions that riparian habitat provides for aquatic species	Survey
212	importance of riparian fish habitat	Survey
212	Many tools rely on science that hasn't been done yet. Need to fund small projects that address each portion of these large questions.	Survey
212	the difference between tools that could be used for decision making that would help with data storage and visualization (e.g. a geospatial platform) vs. tools that provide for the operationalization of science advice (e.g. calculators, checklists etc.). There needs to be better understanding of the differences of these types of platform and feasibility for use.	Survey
212	tools adapted to management (requires tools that are realistic and adapted to often short time frame for decision making; no time conduct a scientific research program and collect data for 15 years).	Survey
212	How can a model be developed which factors in stressors to fish habitat to help develop a decision making tool, and how can this help answer questions regarding cumulative effects?	Survey
212	HEAT is a great example of a decision-making tool for infills in the great lakes. How can we expand the application of it across Canada?	Survey
212	Tool development, such as habitat models and environmental flow determination methods	Survey
212	What other tools similar to HEAT exist that could be expanded nationally?	Survey
212	importance of riparian zone - e.g., if the riparian zone (one or both sides of bank) of an agricultural drain or stream is cleared, how will that affect fish populations (such as brook trout or other cool/cold water species) in the short and long term?	Survey
212	Once mapped, next step would be to develop tools that could quickly assess habitat condition/quality so that spatial coverage can also be linked to condition. Generalized tools that can support rapid project assessment - e.g., productivity-area curves for different habitat types	Survey
212	Tools for consistent assessment of the contribution of riparian habitat would be useful. Factors to be considered would include the relative value of riparian habitat based on stream size, aspect, location, etc.) and consideration of how much riparian removal might not affect the suitability/productivity of the habitat for the fish species present.	Survey
212	heterogeneity of decision support tools.	Survey
212	nationally consistent decision making tools	Survey
212	Decision-support tools that integrate policies will always be needed for effective management - existing tools used by FFHPP can be further developed and improved to incorporate the latest science and improve consistency in decision making	Survey
212	Transparent and data-driven decision making is always desirable. Not sure what tools are in use though.	Survey
212	practical easy to use tools that make Quantitative methods accessible	Survey
212	How can decision support tools be modernized and include modern technologies?	Survey
212	development, testing and application of a range of decision-making tools should be an on-going enterprise among DFO research and management staff, academia and the private sector.	Survey
212	Require scientifically defensible habitat pressure state indicator benchmarks to support the development of decision making tools	Survey

213	Essentially the development of tools that allow for looking at multiple stressors to a single watershed or population, all in one place, would be beneficial to develop.	Survey
213	There is no system in place to track areas which are designated as offsets and which should hence be considered permanent conservation reserves- the overall benefits of such reserves should be assessed	Survey
213	mapping of advice and authorizations that DFOs FFHPP has given to proponents (e.g. map of pre and post- shoreline/lake infills) to get an idea of habitat lost/gained	Survey
213	access to information on physical and environmental qualities of freshwater habitats and watersheds.	Survey
213	How can fish and fish habitat data be incorporated into a centralized, secure database?	Survey
213	mapping tools for offsetting projects (to calculate how much has been gained)	Survey
213	national or regional maps of project approvals, including species (including species at risk) and any offsetting requirements	Survey
213	An easily accessible, centralized database integrating georeferenced information on species distributions, habitat use, habitat conditions, stressors, and environmental features would be most welcome!	Survey
214	How can we avoid placing potentially at-risk species in the purgatory that is the COSEWIC designation of "Data Deficient"?	Survey
214	how to make decisions in data poor areas	Survey
214	Several tools that are available south of 60 do not apply north of 60 due to lack of baseline information...i.e. HEAT tool.	Survey
214	Data poor tools that may include qualitative modelling (loop analysis, fuzzy logic models etc..).	Survey
215	More work needs to be done to refine the precautionary approach for Atlantic salmon - the current approach is good, but doesn't work well for all rivers that are assessed.	Survey
215	How can we improve the use of quantitative assessments of management practices using No Net Loss, and how can the precautionary principle be more heavily implemented in these scenarios?	Survey
215	more precautionary approach (towards conservation) in decision-making	Survey
216	Accuracy and refinement of decision-making tools over time	Survey
217	More info needed on anadromous fish and fish lower on the trophic level.	Survey
217	Some Great Lakes (e.g. Lake Ontario, Lake Michigan) have undergone declines in offshore nutrients and primary production over the past several decades. Bottom-up ecosystem processes and interactions need to be better understood.	Survey
217	is current decline in offshore production in Great Lakes impeding production and health of key fish species and fisheries?	Survey
218	What biological structures are most important for supporting function, and how are these structures linked to habitat?	Survey
219	Multiple species and ecosystem models that different management measures or strategies can be applied to.	Survey
219	Adequate modeling of fish responses to altering habitat	Survey
219	a predictive approach to the impacts of habitat stressors	Survey
219	Tools that incorporate ecosystem feedback, direct and indirect effects.	Survey
220	time series data. for many ecosystem elements we don't have a great idea of how they are changing over time or what type of variability is normal. Environment Canada's CABIN program is a good start for monitoring water quality and fish habitat but, last I checked, didn't have much time series information to understand how systems are changing over time.	Survey
220	How does fish habitat change through space and time.	Survey

220	time series information is lacking (especially for the fish themselves).	Survey
220	Are there general ways that communities or food webs respond to change.	Survey
226	There is also a lack of knowledge about northern aquatic ecosystems (environment with permafrost)	Survey
226	Lack of knowledge about northern species and habitats	Survey
232	landscape level wildfire terrestrial and aquatic alteration and multi-decadal recovery of habitat	Survey
233	population dynamics and community structure	Survey
233	Historical data of brook trout are non-existent, although anecdotal references exist.	Survey
233	Current and historical population abundances	Survey
233	The life history of most fish in Canada does not allow for meaningful determination of changes for most sport, commercial, aboriginal or species at risk that live 10-100 years.	Survey
233	Historical trends in abundances or population trajectories	Survey
234	accurate measures of total and species-specific biomasses and population size structure	Survey
235	What's the accepted level of uncertainty in field observations?	Survey
236	It is especially important to understand the size of small salmon populations on the Lower Fraser River (Coho, Chinook) that are struggling to survive because DFO's conservation Units mask their numbers and expose them to over harvest.	Survey
236	How can stock sizes be estimated at a finer resolution to prevent aggregation of strong and weak stocks, and enable greater protection for weak stocks such as prevention of by-catch?	Survey
238	blasting and effects on fish - the tools are outdated	Survey
238	It is my belief especially in southern Ontario on what is an appropriate buffer. Cold water habitats need stronger buffers as well as headwater protection	Survey
238	Better understanding of cumulative effects (of multiple development projects, ecosystem impacts, climate change) and thresholds (if they exist) for negative effects on productivity of fish communities	Survey
238	Thresholds for various ecohydrological flows	Survey
238	When using explosives in or near the aquatic environment, what is the maximum amount of overpressure that should not be exceeded if we want to prevent harm to or mortality of fish (currently, the lethal distance corresponds to an overpressure of 100 kPa, i.e., a distance within which half of the fish are likely to be injured or killed)?	Survey
238	If the FFHPP triage process is a policy, the establishment of thresholds of impacts could benefit from scientific rather than arbitrary values.	Survey
238	As always, the gaps are related to the thresholds or the range in the metric of stressor as an indicator of the potential or probability of stress to fish to occur (DFO 2012). The stressors were identified in DFO (2014).	Survey
238	What percentage of a habitat can be altered or destroyed before the situation becomes critical for a population?	Survey
238	determine quality and quantity of riparian habitat necessary for survival and recovery of species, populations and communities, and therefore constitute critical habitat	Survey
238	Offsetting and restoration (the term rehabilitation should be used instead) should be a last resort and should not be calculated separately for individual projects. There should be a very simple rule of thumb for calculating habitat loss, that is, all encroachments are considered habitat loss. There should be clear-cut rules on cumulative impacts for all categories of works and for specific ecosystems: for	Survey

	example, maximum of ten docks per 50 ha of lake habitat, one crossing/x km of river, maximum of 15% degraded banks, etc.	
238	Thresholds for flow changes associated with development.	Survey
238	How can a model be developed that estimates the pollutant thresholds for various species and the resultant impact on these species' abundance?	Survey
238	improve understanding of link between critical habitat for species at risk and when a biological impact is seen from critical habitat destruction	Survey
238	thresholds of changes in habitat that are critical to effects on fish	Survey
238	In projects where there is a potential presence of species at risk, what overpressure limit should be set to ensure that no fish are harmed or killed?	Survey
238	Are there thresholds at which cumulative effects are unacceptable, and how can these thresholds be determined?	Survey
238	Effects of noise and overpressure associated with human activities (e.g., blasting) on fish and effective means of mitigating them.	Survey
238	One of the knowledge gaps relates to the thresholds that should not be exceeded to allow us to limit the negative impacts of projects on fish populations and their habitat, with the ultimate goal of maintaining populations and good habitat quality. Considering species and habitat variability, it is probably impossible to establish general thresholds; however, specific criteria and the importance (weighting) that should be assigned to them could be established.	Survey
239	the means to assess the needs related to the restoration of degraded freshwater fish habitats (e.g., degradation thresholds).	Survey
239	Overall there should be an on-going process to assess the state of all fresh water fish habitat as a reference point for gauging the success of management. This would require establishing a national classification system, regular random sub-sampling in all regions and on-going monitoring at a network of reference sites,	Survey
239	Need to identify new measures of "reference" for prairie streams due to long-term impacts and general lack of true headwaters.	Survey
239	quantification of habitat 'norms' or benchmarks of productivity to provide a basis for comparison if no controls are monitored.	Survey
239	Targets (e.g. area of habitat, productivity benchmarks) for protection or restoration set by management biologists that inform policy and management	Survey
239	Means of estimating fish productivity for compensation projects	Survey
240	Almost all stressors require some work, anything that works towards a threshold type approach will be useful.	Survey
240	Thresholds and indicators for various stressors to fish and fish habitat. For example, setting limits for darkened areas and hardened surfaces, shoreline hardening, sediment thresholds for various species, etc.	Survey
242	tipping points and thresholds related to cumulative effects	Survey
242	How do we determine cumulative effects on small-scale development (e.g., road crossings) and their impact on fish and fish habitat? When do we determine the breaking point and do not allow further development when the previous project was allowed?	Survey
242	We do not know tipping points or thresholds for when we might expect a particular response to occur (for example, at what point does the cumulative amount of agricultural land lead to a tipping point in water quality)	Survey
245	effects of stocking on fish communities	Survey
251	DNA database for species nationally	Survey
253	no publicly available centralized and continually updated database for dams, road, rail, pipeline crossings	Survey
253	substrate maps, dynamic environment (upwellings, storm discharge (temperature, sediment, road salt / pollutants) relative to fish response (avoidance vs tolerance)	Survey

253	Up-to-date GIS layers for freshwater habitat considerations (e.g. forestry ECA, mining, water licenses, forest fires, water temperature, water quality monitoring etc.)	Survey
253	incorporate DFO science knowledge of fish distribution/habitat use into our mapping tools	Survey
253	How can mapping of stressors, fish habitat, impacts, and habitat condition be improved?	Survey
253	accurate quantitative and qualitative mapping	Survey
253	visual GIS communication, reporting, tracking tools (presence / absence or non-detect of aquatic invasive species, overlaid with species at risk information to start etc.)	Survey
254	Managing water scarcity, environmental flows, conservation flows, knowledge gap to inform policy on this, it is absent in the new fisheries act	Survey
254	water quality degradation vs. physical habitat loss - where should the focus for offsetting goals be?	Survey
254	Lack of understanding of how important the chemical attributes of the physical habitat are to fish and invertebrates (e.g. many projects mitigate stream changes by adding limestone rock, but is that really appropriate in the Canadian Shield where the pH is naturally low? Probably doing more harm than good.)	Survey
254	Habitat restoration needs major help. As noted previously, an understanding of what elements of the physical environment impact the chemistry of the waters is integral to successfully restoring habitat.	Survey
258	Can we develop strategies for measuring the adaptive capacity or resilience of an ecosystem area that includes different types of habitat.	Survey
258	Also, a better understanding of where dynamic systems theory can be used i.e., tipping points, early warning signals, transient dynamics, stability and resilience of different systems.	Survey
259	How can the use of citizen science be increased to help monitor and care for streams?	Survey
261	Refining predictive modelling of future aquatic invasive species; further development of rapid response, mitigation, and control measures; refining risk assessment methods.	Survey
264	Remote sensing holds promise as a technique for mapping habitat at this scale, so would need to develop the methods to actually map habitat using this tool	Survey
266	Improved understanding and development of criteria for determining what habitats are significant, where they are located, and how to conserve them. This information/data should feed into a significant aquatic habitat technical guide/compendium to help assist in the identification, measurement, and monitoring of these features.	Survey
266	It is hard to acquire robust data on habitat types and have one standard accepted way of measuring habitat and monitoring too is not consistent across agencies, ministries, university based projects etc.	Survey
266	homogeneous classification of fish habitat, including spatial mapping	Survey
266	A comprehensive Canadian national habitat classification system at a useful scale (1:200) is needed for major hydrographic systems.	Survey
266	GIS based tools would be beneficial	Survey
266	National habitat classification definitions (R.L.L. in AB has a fantastic fish habitat mapping protocol)	Survey
266	A fish habitat classification is desperately needed for aquatic habitats in Canada	Survey
266	habitat classification is lacking,	Survey
266	National-level classification schemes to allow for national mapping and quantification of habitat types	Survey

266	need habitat classifications that are based on functional habitat attributes instead of correlational observations	Survey
266	Readily available and up-to-date stream classification mapping in Ontario is either outdated or non-existent in parts of Ontario.	Survey
266	no detailed mapping tool of fish habitat by species available	Survey
266	the selection of spatially nested ecological units within which to describe the past and present state of fish habitats and even to predict their future state. The ecological units selected should extend beyond provincial boundaries in Canada and there should be consensus.	Survey
266	tools for the spatial management of fish habitats across Canada.	Survey
266	How can mapping of fish distributionsand habitat type be made more consistent at a national level?	Survey
267	Yes, we have a need for more information on critical habitat for a variety of species. For example, Coho salmon are intensively harvested in sport and commercial fisheries but in most cases and in most places we have no idea where they spawn, rear, and migrate. Nor do we know how many there are.	Survey
267	Defining critical habitat remains a knowledge gap.	Survey
268	There are no comprehensive freshwater habitat classification for the Fraser River watershed in relation to all life stages of Pacific Salmon.	Survey
268	How do we classify habit in a rapidly changing world were what constitutes habitat is changing is space and time?	Survey
269	a lack of knowledge of the spread and distribution of invasive habitat-altering species (i.e. Canary Reed Grass)	Survey
270	In many cases, we do not know how effective mitigation strategies are	Survey
270	validation of mitigation measures	Survey
270	Studies on how to protect fish and fish habitat	Survey
271	concrete information on how fish react to being displaced.	Survey
272	site-specific information is not always known, lack of consistency in the use of decision-making tools across regions	Survey
272	lack of consistency in avoidance and mitigation strategies across regions	Survey
273	Strategies and Best Management Practices that mitigate (prevent) the impacts of urbanization on stream and wetland habitat quality	Survey
273	Approaches to mitigate (compensate) for urbanization impacts (water quality and physical habitat)	Survey
273	What are the best methods for restoring damaged or polluted freshwater fish habitats in urban centers?	Survey
274	municipal drain maintenance projects are completed in the winter months which has impacts that are challenging to mitigate need a review of mitigation for authorizations for cleanouts	Survey
274	What habitat restoration, conservation, and offsetting measures work in winter?	Survey
278	how to integrate long-term sustainable growth of cities and communities and landscape planning with protection of fish habitat.	Survey
279	How can we prevent the introduction of invasive species in restored habitats?	Survey
280	How can we compensate for the losses of a large area of freshwater?	Survey
280	Way more studies on effectiveness of offsetting projects. How to offset humongous impacts such as mines?	Survey
280	As the scale of the ecosystem gets larger, the link between fish and habitat is more difficult to identify, and which makes classification and monitoring more difficult.	Survey
280	Uncertainties in all of these areas exist related to large-scale development projects.	Survey

281	how much and type of offsetting is required to counterbalance the HADD	Survey
281	A "common currency" when assessing impacts on fish and fish habitat. A standardized list of habitat components supporting key habitat functions for different fish species would be extremely valuable and could be used across programs.	Survey
281	reasonable expectations of equivalence, offset ratios and monitoring plans.	Survey
281	How do we monitor offsetting projects to assess their adequacy (e.g., habitat credit in a habitat bank).	Survey
282	How can all fish species present in an ecosystem be considered when evaluating ecosystem wellbeing, as opposed to only commercially important or charismatic species?	Survey
282	should restoration activities be fish species specific or ecosystem based approach?	Survey
282	Consideration of a more ecosystem approach to management.	Survey
282	should offsetting not be aimed at the forage-fish base instead of the top 5 sportfish in a fishery i.e. if you feed them they will come	Survey
284	Limited understanding of the effectiveness of small scale offsetting and restoration projects.	Survey
284	A large scale evaluation of offsetting.	Survey
284	the evaluation of mitigation measures should be evaluated	Survey
285	From my understanding, we do not effectively monitor offsetting programs to know whether they are successful	Survey
285	more research into offsetting methods and what has been successful, what offsetting should entail	Survey
285	summary of offsetting projects in Canada and whether they have been successful	Survey
287	Carving fictitious commodities from the splintering of nature for additional profit over and above the development and the benefits of maintaining Canada's fledgling habitat banking system where the owner of the habitat harm is also the owner and maintainer of the compensation/offset habitat for the life of the harm	Survey
287	The commodification of fish habitat to support development and the practice of developing 3rd party for profit habitat banking systems as they have in the USA and formerly in the Europe Union	Survey
288	Appropriate scale of habitat measurements relative to fish species and objective	Survey
290	does applying the natural channel principles counterbalance the HADD of lost channel length and infill of existing channel footprint	Survey
291	Criteria that has been vetted through Science for small lakes and rivers is needed to identify ecologically significant areas	Survey
291	ecologically significant areas	Survey
293	Better guidance is required on what constitutes high quality habitat across the country	Survey
293	What is the value of habitats that are currently presumed to have no value to fish productivity (in a regulatory context, i.e., that they are afforded little to no protection). Examples include riparian zones and harbour bottoms that can be dredged without compensation under new codes of practice.	Survey
294	Which habitats are limiting factors to fish productivity and therefore in greatest need of protection or remediation, particularly from an ecosystem or multi-species context?	Survey
294	The identification of areas that can be used for offsetting appears to be a challenge that we are currently facing.	Survey
294	Locations of unique, rare, highly productive areas, as well as degraded areas that used to have these qualities is lacking. Knowledge of these areas will allow for the prioritization of restoration projects.	Survey

294	How can sensitive systems and rare features be better identified for protection in freshwater systems?	Survey
295	We need standards to identify core habitat areas that are off-limits to development, or a guiding document that outlines the threshold of what development is acceptable based on the habitat that will be destroyed. This would include more money for higher value habitat damage.	Survey
296	more information on critical habitat policies and what can and cannot be done in these areas	Survey
296	critical habitat and what they means for regulators and development.	Survey
298	Indigenous Knowledge	Survey
298	How to increase the input from indigenous peoples as partners in the management and research of freshwater fish habitat?	Survey
298	How can indigenous people and organizations have greater input into the operations of DFO?	Survey
298	How to increase the use of local knowledge in Species at Risk assessments	Survey
298	insufficient First nation participation	Survey
298	Traditional Knowledge and Natural Knowledge systems	Survey
298	The main knowledge gap is the Indigenous and western science interface.	Survey
299	How can officials from the science sector have greater input into freshwater fish habitat policy development?	Survey
299	How can regional expertise and knowledge be better incorporated into policy drafting through consensus?	Survey
299	A key knowledge gap is that regulators, policy-makers and proponents lack sufficient knowledge of fish habitat to develop systems to adequately protect it	Survey
299	Lack of communication of policy and management with science	Survey
299	How do we build a channel of communication to get the general needs of Fish Habitat to high level policy makers?	Survey
299	Scientific research appears to often be conducted but not translated into ready-to-use management tools, that can be used in decision making. In particular at the academic level, the work is disconnected from resource managers and the onus is on the scientist, though they do not often realize this.	Survey
300	Localized management objectives based on stakeholder engagement with agencies and the public.	Survey
300	Canada is a diverse country with diverse landscapes. In my professional experience, there is a lack of on-the-ground, local experience with the different landscapes in Canada and even within Ontario.	Survey
301	An establishment of appropriate co-management principles with First Nations peoples and Indigenous Groups and a better understanding of reconciliation vis a vis habitat protection / promotion - especially within historic Treaty areas.	Survey
301	principles of co-management with First Nation peoples and Indigenous Groups	Survey
302	How can First Nations and Indigenous Groups participate in monitoring? Including DFO legal obligations	Survey
303	How can the knowledge of seasoned employees be incorporated into improvements and modernization of management programs?	Survey
304	Frameworks for restoration	Survey
304	Habitat restoration is something that has received more research, and a review of work to date would be valuable for particular systems and species	Survey
304	how to identify the habitats to be restored and how to select appropriate restoration measures	Survey
304	Increase knowledge and monitoring on habitat restoration projects to better develop Best Management Practices and determine what, if any, methods provide the best long-term outcome of habitat restoration.	Survey

304	Fisheries offset plans often involve the creation of aquatic habitat, however, our ability to replicate natural systems is underperforming and resulting in habitat losses. A research priority should include enhancing our understanding and ability to restore and rehabilitate aquatic habitat (what works and what doesn't).	Survey
304	Impacts of restorative measures in degraded, channelized streams that also satisfy agricultural needs.	Survey
307	Using sediment eDNA to help guide restoration efforts in impacted ecosystems	Survey
308	integrated planning	Survey
308	The scope of integrated planning, Ecologically Significant Areas and cumulative effects assessment must be determined ensuring that there is no duplication between the Oceans Management Program, that of other sectors within DFO and other federal and provincial departments.	Survey
308	In my opinion, the main gap to effective policy and management strategies for freshwater fish habitat in Canada is related to the lack of integrated approaches to managing.	Survey
308	We are using 100 year old assumptions in fisheries assessments, that have not been revisited to review whether these assumptions are valid. Given our ability to deal with large datasets, this would be critical to development of accurate assessments of fish habitat quality.	Survey
309	Economic benefits of protecting fish habitat	Survey
309	research on scarcity and allocation of fish for entertainment (recreation), sustenance, economic opportunity and restrictions on these activities by SARA , COSEWIC, recovery plans or lack of abundance	Survey
311	Standardize of enforcement needs to occur at the DFO level with Indigenous environment issue management leading not being repressed	Survey
312	How can the consistency of habitat and stock monitoring at all life stages be improved to allow for the evaluation of trends in habitat and stock condition?	Survey
312	variables and monitoring protocols that are homogeneous and science based, but also realistic in terms of cost and time. Monitoring measures may need to be adapted depending on the resilience of the habitat/species.	Survey
312	Standardized national protocol for a monitoring program covering all human activities found in Program Activity Tracking for Habitat (PATH) in relation to the definition of fish habitat, migration, spawning grounds, rearing, growth and food. In the marine, estuarine and river environment.	Survey
312	Develop functional monitoring programs for different habitats (i.e., rapid monitoring protocol to assess condition and function of a freshwater habitat types)	Survey
312	Information submitted to DFO as well as information collected by DFO needs to be organized in a way that enables broader use and limits the need for repeated electrofishing / fish sampling	Survey
312	Lack of coordinated monitoring across Canada: monitoring is done is such an ad hoc way that any data or information collected can't be compared across the country, and therefore can't be used for a national-scale assessment (like WWF-Canada's Watershed Reports).	Survey
312	For the last three points (stressors, habitat and distribution), better coupling of field measurements, including sampling design, and advanced modelling efforts, would help close the gaps	Survey
312	Yes, there is no national-scale database for fish distribution information, limited guidance on best practices on collecting fish information (there is no fish equivalent of CABIN for benthic inverts) which leads to inconsistent data.	Survey
312	Without a consistent approach to collecting the information the quality of the fish distribution and habitat use is poor too.	Survey
312	It is currently difficult to compare projects in order to assess the effectiveness of the offsetting work since no standard method of data collection and storage is currently applied under the FFHPP.	Survey

312	There is a lack of standardized data and even data collection across watersheds.	Survey
312	Also I believe there is a vast amount of knowledge relevant to fish habitat in possession by ECCC and NRCAN. If branches shared data and info we could significantly reduce the amount of required field work and redundant activities.	Survey
312	retirement of knowledgeable staff can be a significant drain to an agency. We need to find better ways to document and transfer information to younger generations.	Survey
312	Standardization of data collection and maintenance of data, as well as the access to clean and organized data	Survey
312	Lack of centralization and easy accessibility of fish distribution data as well as fish habitat data	Survey
312	Baseline information needs to be compiled in a format that is more user friendly for the far north.	Survey
312	We don't know how to roll-up data collected at finer spatial scales (sites, reaches) to make assessments of at the larger scale (e.g. watersheds).	Survey
312	Difficulty in accessing standardized data on species distribution and abundance across Canada, particularly for rare species	Survey
312	Data gathering within the department needs to be aligned so that various sectors in DFO can make use of information collected by other sectors	Survey
312	Many organizations have fish habitat data from long term monitoring programs but there is no central hub to access.	Survey
312	Better monitoring programs should be a priority but they will need some standardization to allow comparisons.	Survey
312	Lack of uniformity in sampling methods across geographical areas	Survey
312	How can knowledge transfer between organizations and departments be improved?	Survey
312	Monitoring is not standardized across the Grand River watershed and tends to focus on watersheds with development pressures.	Survey
312	Limited surveys, only find fish if one trips over them	Survey
312	A common data base shared between the different sectors of DFO	Survey
312	Standardized methodologies for monitoring the performance of management measures and the state of habitat components.	Survey
312	I am unaware of any database or source where I can find the data on fish distribution and habitat use in any given watershed in my region.	Survey
312	We don't know how to evaluate habitat status at larger spatial scales.	Survey
312	Shared GIS data base.	Survey
312	Currently, in the Quebec Region, one gap relates to the limited dissemination of knowledge and decision support tools developed by scientists in other regions, which could assist with decision making by FFHPP staff.	Survey
312	there is a trend in assuming fish presence, distribution, etc. rather than confirming which species and habitat exist (which takes more time than those in industry would like)	Survey
312	Yes, everyone needs to share their data within DFO working groups, would limit getting information from OMNR and other less than ideal sources. We need a all encompassing database that has species found, habitat type and gaps coordinates.	Survey
312	Shared spatial and temporal data base (e.g. GIS) between the various DFO sectors (habitat, stock assess, restoration, fish mgmt., science, etc.).	Survey
312	how to combine assessments at multiple sites to develop an index of habitat status at aggregate spatial scales.	Survey
312	Our department has a large amount of data, yet this data is often in inaccessible, scattered formats. There is a need to create centralized, vetted, accessible	Survey

	databases that can be used to better formulate questions to Science and inform decision-making.	
312	We need to develop standardized protocols and train partner agencies on methods and of assessing habitat. All the conservation authorities in Ontario are doing things differently to each other, as well as to us. We cant compare any of it!	Survey
312	means (e.g., national database, national observatory, etc.) to integrate the different habitat monitoring data from various sources, provided that the data are collected in a fairly consistent manner.	Survey
313	What works in terms of restoration	Survey
313	Long term offsetting doesn't appear to be successful based on current research but this seems to continue forward. How can we improve on this?	Survey
313	Ecosystem process are not monitored	Survey
313	Many habitat restoration projects usually only had photo monitoring and there was no way of knowing if there was an actual improvement (or decline) as a result of the project.	Survey
313	long term offsetting and rehabilitation monitoring	Survey
313	What works in terms of restoration	Survey
313	Improved climate and ecosystem monitoring and invasive species surveillance and prevention	Survey
313	How can follow-up of restoration studies be improved?	Survey
313	understanding how created or restored habitats become functional. This will include addressing issues about timing, time lags, and sustainability.	Survey
313	How offsetting and restoration performs over the long term.	Survey
313	the value of offsetting and habitat restoration over the short and long-term is unclear. Offsetting may be "effective" in the short-term but how does the value of the habitat age. The value of restoration is also unclear in most cases. One key challenge is how to monitor these projects so that over time their value can be appropriately characterized. Knowing the future value of offset or restored habitat also feeds into the habitat banking system.	Survey
313	Offsetting and to some extent restoration have not been extensively monitored either. There is an urgent need for restoration planning processes that are watershed based.	Survey
314	lack of a risk management framework for the department, clear direction, scope and interpretation of the new Act.	Survey
314	a science-based, risk-management framework that can be consistently and effectively applied on a national scale.	Survey
314	How can risk management and risk aversion be better balanced in management decisions related to freshwater fish habitat?	Survey
314	Tools can help in develop science-based consistency in decision making, but require an awareness of risk management in the decision process. The use of tools is sometimes resisted because the risks of using the tool are perceived to be too great. This suggests there is a need for a greater awareness of risk-based management approaches by those charged with habitat management decision-making.	Survey
314	lack of knowledge and/or desire by the decision makers at the higher levels to actually implement the risk management and ecosystem approaches	Survey
314	adopt a science-based risk management framework	Survey
315	Death of Fish (not covered by Draft Risk Assessment tool)	Survey
315	Additional scientific advice on Death of Fish and Offsetting Death of Fish is required. This is particularly important for hydroelectric operations, fish species that have high fidelity to native rivers, species at risk, and for circumstances where freshwater habitat is not limiting productivity.	Survey

315	Risk documentation form should incorporate fish passage and death of fish concerns.	Survey
315	Fish passage and flows (not covered by Draft Risk Assessment tool)	Survey
315	Death of Fish Offsetting (advice for species at risk, species that have high fidelity to native rivers, areas where freshwater habitat is not limiting productivity)	Survey
316	What impact will Artificial intelligence and the underlying algorithms have on freshwater fish - restoration prioritization, emergency measure fish or human conflict, water for hydro or water for fish, decision tools and machines	Survey
316	what emerging or perceived but undeveloped technologies can benefit fish and fish habitat	Survey
316	How can we improve protections for species (both common and elusive) whose habitat is threatened by human development?	Survey
317	no report on the state of fish habitat	Survey
317	Need to be able to report on the state of fish and fish habitat.	Survey
317	consensus on descriptive and predictive models of the state of and change in fish habitat. These models should be able to use data available for provinces and data that are homogeneous and collected in a consistent manner across the various provinces.	Survey
317	The lack of a national-scale assessment limits the possibility of having national-scale policies	Survey
317	Knowledge on the state of fish and habitat	Survey
318	it has been very difficult to gain access to agricultural lands to measure and monitor fish habitat	Survey
318	How can simple and clear practices be introduced to ordinary people for use on private property that helps maintain freshwater fish habitat?	Survey
318	How can habitat offsetting efforts be maintained for longer periods of time and be less subject to the whims of landowners, while standardizing habitat measurements?	Survey
318	Much of the research we need to do revolves around the human dimension - What drives people to want to develop in riparian zones? What are the nudges that work to make citizens make good decisions?	Survey
319	Understanding how variation in fish activity can impact encounter rates in passive survey gear, thus potentially biasing catch rates away from relationships developed in calibration datasets	Survey
319	Poor metrics to relate to abiotic parameters to fish encounter with a gear type.	Survey
321	When are local physical changes to fish habitat harmful (in terms of works undertaking and activities) or beneficial (restoration and offsetting), and when are they either a hindrance in the context of ecosystem-scale habitat-forming processes? When do these processes rapidly erase or replace local activities?	Survey
321	When is habitat alteration harmful (requires offsetting) or beneficial (may be viewed as remediation), and when does this depend on fisheries management objectives (e.g., trade-offs among habitats that are valuable for different species).	Survey
322	Too little of the knowledge that is available is put to best use in guiding the actions to manage fresh water fish habitat.	Survey
323	How can we reduce conflict between economic activities such as commercial fisheries and angling, and freshwater fish species at risk? For example, the introduction of largemouth bass in the Algonquin region has had immense impacts on native fish communities.	Survey
323	How can historic distributions of extirpated species be restored, despite human interactions and economic activities? For example, efforts to restore the Lake Ontario salmon are likely hindered by competition from stocked Chinook salmon which support anglers.	Survey
325	More counting facilities for Arctic char populations in Labrador	Survey

325	In the Atlantic Canada region, more counting fences are required for Atlantic salmon. More (and better) counts would significantly improve the stock assessment for salmon in the region.	Survey
326	Clear goals and objectives to achieve a net environmental gain from a policy implementation perspective.	Survey
326	net environmental gain as a policy objective	Survey
328	How can we improve our knowledge of fish habitat data in the Maritimes region, and how can we improve the frequency of surveys, especially for non-commercial species?	Survey
331	Lack of knowledge about current and pending impacts to First Nation rights and title related to habitat impacts.	Survey
332	Broadly, scaling up scientific studies to the spatio-temporal scope needed by managers is a challenge for science to help develop evidence-based policies.	Survey
333	increased guidance on aquatic species at risk listing process for economically important fish	Survey
334	How can the timeline regarding providing protections to species at risk be streamlined to ensure that once a decision is reached by COSEWIC, protections are afforded to the species under SARA in a more timely manner?	Survey
NA	invasive spp.	Survey
NA	The new (OLD) Fisheries Act habitat provisions and how they will actually (not idealistically) be implemented in the real world.	Survey
NA	Water supply and availability	Survey
NA	Habitat value of "High" vs. "Low" salt marsh in terms of fish habitat and productivity (value for offsetting proposals in coastal areas)	Survey
NA	importance and promotion of avoidance first before willingness to authorize	Survey
NA	fishery management objectives that are useful and why blanket high-level statements are nice but not helpful	Survey

APPENDIX D

The list of 334 candidate priority research questions created by collating and refining the initial list of 1903 knowledge gaps, identified through the literature review and expert survey. In addition to the question text, we also show the 5 most common species and regions mentioned in the set of knowledge gaps contributing to each research question

ID	Question	species	regions
1	What is the impact of specific types of development and in-water works on fish and fish habitat?	Atlantic salmon, northern madtom, plains minnow, sockeye salmon, American eel	Fraser River, inner Bay of Fundy, Athabasca, British Columbia, Canadian Maritime provinces
2	What are the ecosystem effects of aquaculture operations and how can they be minimized?	lake sturgeon, northern madtom, channel darter, coastrange sculpin (Cultus population), pugnose minnow	Alberta, Cultus Lake, Great Lakes, Nelson River
3	What are the risks associated with new invasive species and their parasites?	coho, Cowichan (Vancouver) lamprey, Dolly Varden, Atlantic salmon, Atlantic whitefish	central coast of British Columbia, Columbia Basin Rivers, Cowichan Lake, Fraser River, Great Bear Lake
4	What is the rate and impacts of different types of land use change on freshwater habitat?	Dolly Varden, coastrange sculpin (Cultus population), redside dace, rocky mountain sculpin, salmonids	British Columbia, Crown Marsh
5	How is fish productivity impacted by changes in water quality, and are there thresholds for water quality change before impacts are observed?	Atlantic salmon, American eel, black redhorse, c. artedi, nooksack dace	Brunette River, Lomond River, Prince Edward Island, Rondeau Bay, the small estuary at the mouth of Sakinaw Lake Creek
6	What are the direct and indirect effects of invasive fishes?	striped bass, Atlantic sturgeon, canadian speckled dace, chinook salmon, eastern sand darter	Lower Athabasca River, Saint John River, Sakinaw Lake, Shubenacadie
7	How can stressors to fish and fish habitat be mapped in a standardized fashion?	stickleback species pair	Alberta, British Columbia, Lower Fraser, Misty Lake
8	How do weathering, erosion, sedimentation and siltation impact fish habitat, and how can these effects be managed?	anadromous species, Arctic char	Arctic, Maritimes region, north of 60, Northern Systems, the North

9	What are the physiological and behavioural effects of toxic substances on fishes?	spotted gar, eastern sand darter, lake chubsucker, pugnose minnow, pugnose shiner	Long Point Bay, McDougall Drain
10	What are the impacts of noise and light pollution on fish health and behaviour?		
11	How does plastic move through aquatic ecosystems, and what are the impacts on fish and fish habitat?	lake chubsucker, rocky mountain sculpin, spotted gar	
12	What are the current and potential stressors acting on focal aquatic systems?	white sturgeon, American eel, Umatilla dace	
13	What are the levels of reported and unreported harvest on focal fish populations?		
14	How important is flooding to fish and fish habitat, and how can the negative effects of flooding and flood prevention be mitigated?	bull trout, rainbow trout	Athabasca
15	How can fish mortality be best quantified and considered in management decisions?		Lower Athabasca River, Saskatchewan River
16	How can the impact of stressors on fish and fish habitat be best quantified and assessed?		
17	How does life history and physiology relate to the vulnerability of species to stressors?	eastern sand darter, grass carp	
18	What are the mechanisms by which introduced fish species cause population declines in native species?	channel darter, smallmouth bass	
19	What are the effects of chemical and mechanical removal of aquatic vegetation on freshwater habitat?	Atlantic salmon	
20	What is the impact of escaped fish as competitors and genetic contributors to native populations?	silver lamprey and northern brook lamprey, sympatric or parapatric stickleback species pairs	
21	What is the effect of shoreline hardening (including revetments) on freshwater ecosystems?	Atlantic whitefish, landlock salmon	Hall's Harbour, New Brunswick, Weymouth, Yarmouth Harbour
22	How do various stressors and activities impact water quality?		
23	What are the impacts of pharmaceuticals on fish and fish habitat?	juvenile sockeye salmon	Lower St. Lawrence Estuary, Sakinaw Lake
24	How can we improve, systematize, and validate pathways of effects models?		
25	How can habitat status and vulnerability indicators be developed for individual watersheds?		
26	What are the mechanisms by which habitat changes impact fish populations?	Atlantic salmon, lake sturgeon, white sturgeon, Morrison Creeklamprey, nooksack dace	Anticosti Island, Big Fish River, Brunette River, East Branch of the St. Mary's River, Fraser River Estuary
27	What are the impacts of different agricultural practices on stream habitat quality?	Atlantic salmon, sockeye salmon, black redhorse, Arctic char, mountain sucker	Fraser River, Conne River, Lower St. Lawrence Estuary,

			Nunavut, Rivers of SFA 4
28	What are the impacts of harmful algal blooms on freshwater ecosystems and how can they be avoided or mitigated?	little quarry lake sticklebacks, speckled dace	Northern Ecosystems
29	What are the effects of hydropower generation on fish species and ecosystems?	sockeye salmon, Atlantic salmon, carmine shiner, coho salmon, eastern sand darter	British Columbia, Hecate Strait Lowlands, Lower Athabasca River, Stewiacke River
30	What is the quality of agricultural drains as fish habitat and how do different drain management practices impact fish populations?	lake sturgeon, Atlantic salmon, Arctic char, ciscoes, plains minnow	Great Bear Lake, inner Bay of Fundy, Qasigiyat Lake
31	How can death of fish be defined and what is the likelihood of death of fish from different types of works?	coho salmon, sockeye salmon	Interior Fraser watershed
32	How does boat traffic impact fish behaviour and health?	Atlantic salmon, Arctic char, chinook salmon, pink salmon, sockeye salmon	Dunk River, Hecate Strait Lowlands Cu, Sakinaw Lake, Trout River
33	What are the impacts of incidental baitfish harvest on populations of small-bodied fishes?	carmine shiner, lake chubsucker, mountain sucker, rocky mountain sculpin, speckled dace	
34	What are the impacts of fishing gear to aquatic habitat?	Atlantic salmon, sockeye salmon, Pacific lamprey	British Columbia, Kitwanga Lake, Miramichi River, Pacific Region, Skeena River
35	What are the effects of dredging on freshwater fish habitat in terms of habitat quality and susceptibility to the spread of invasive species?		Crown Marsh, Long Point Bay
36	What are the best mechanisms to eradicate or control invasive fishes, and what new technologies could improve eradication and control programs?	sockeye salmon	British Columbia, Skeena River
37	What are the densities of invasive species at different sites and how do differences in density modulate their impacts?	plains minnow, silver shiner	EB Campbell Hydroelectric Station
38	What native and introduced fish species are present in each waterbody in Canada?	speckled dace	
39	How can we ensure that Canadian freshwater ecosystems have a natural resilience towards invasive species?	lake chubsucker, Quagga mussel	
40	What is the current distribution and extent of suitable habitat for invasive freshwater plants?	white sturgeon	
41	What are the effects of underwater cables on fish behaviour and health?	salmon	
42	How do invasive plants and algae influence habitat quality for native fishes?	Atlantic salmon	Lake Ontario, Lake Ontario Tributaries
43	What is the magnitude of habitat loss and degradation in focal systems?	Atlantic salmon	Baddeck Rivers, Middle
44	How do pathogens affect fish health and behaviour, and will the impacts be more pronounced under environmental change?		

45	When should the removal of invasive species be considered an effective offsetting or restoration measure?		
46	How do various stressors and habitat changes impact the abundance and type of aquatic invertebrates?		Great Lakes
47	Which species are exposed to pollutants and other stressors during migration?		Lake Ontario
48	What physical, chemical and environmental factors influence how diluted bitumen will interact with aquatic habitat, and how do these factors determine the vulnerability of systems to diluted bitumen spills?		
49	What are the sublethal impacts from catch-and-release fishing during both summer and winter?		
50	How can we predict the response of focal fish populations to new invasive species?	Atlantic salmon, lake sturgeon, Dolly Varden, pugnose shiner, bull trout	Anticosti Island, Cambridge Bay, Designatable Unit 4, Firth River, Lake Ontario
51	How will diluted bitumen spills influence aquatic habitat in low temperature and ice conditions?	redside dace, rainbow trout, black redhorse, channel darter, eastern sand darter	Athabasca, Ontario, Saint John River
52	How prevalent are fish species-at-risk in piscivore diets?	plains minnow, pugnose minnow, Atlantic salmon, channel darter, silver shiner	Prince Edward Island, Tidal Estuary of the Fraser River
53	How often and where are invasive fishes released into natural waterbodies in Canada?	Atlantic salmon, black redhorse, carmine shiner, plains minnow, rocky mountain sculpin	
54	What is the impact of accumulation of hydrated lime in bottom sediments on benthic communities?	copper redhorse, chinook salmon, sockeye salmon	Cowichan River, Crown Marsh, Fraser River
55	Are invasive parasites a significant threat to fish populations?	Atlantic salmon, lake chubsucker, plains minnow	Lake Ontario
56	How do some ecosystems function and remain healthy under conditions of intense human use?	American eel, eulachon, pink salmon	Hecate Strait Lowlands Cu, Ontario
57	Which areas in large lakes are most susceptible to eutrophication?	mountain sucker, sockeye salmon	Fraser River
58	What is the extent to which modifications to aquatic habitat are conducted without permits and permissions?	American eel, northern brook lamprey and silver lamprey	
59	What is the impact of lowering winter water levels on species that burrow and hibernate?	Atlantic salmon, pugnose minnow, black redhorse, channel darter, mountain sucker	Anticosti Island, Eastern Cape Breton Region, L Lake, Labrador, Lake St. Clair
60	What are the impacts of discharging large volumes of water into aquatic systems?	Atlantic salmon, rocky mountain sculpin, striped bass	Lake Ontario, Saint John River
61	How can early detection of invasive species be improved such that management strategies can be implemented in time to reduce invasion?	Atlantic salmon	Inner Bay of Fundy Region, New

			Brunswick, Nova Scotia
62	How can decision making tools and codes of practice improve outcomes for small habitat alterations?	Dreissenid mussels, New Zealand mud snail	
63	What are the impacts of lampricide on early life stages of native fishes?		
64	What is the impact of ultraviolet radiation on juvenile fishes?	chinook, coho, small salmon populations	lower Fraser River
65	What are the patterns of dissolved gas supersaturation related to hydroelectric dams?	Atlantic whitefish	Petite Riviere
66	What are the impacts of invasive aquatic mussels on nutrient cycling?	pugnose shiner	Great Lakes, Lake Huron, Lake Ontario, Bay of Quinte, Great Bear Lake
67	What is the abundance, distribution and behaviour of seals, and how do they impact fish populations?	coho salmon, cutthroat trout, sockeye salmon	British Columbia, Fraser River
68	How has the intentional introduction of gamefish impacted other ecosystem components?		Nova Scotia
69	What are the risks posed by invasive aquatic invertebrates?	Atlantic salmon, carmine shiner, speckled dace, Umatilla dace	
70	What are the current and potential impacts of aquatic invasive species on large water bodies?	common carp and Umatilla dace, smallmouth bass and Atlantic salmon, sockeye salmon	British Columbia, Lakelse Lake
71	What are the biological and chemical responses to various stressors in freshwater systems, and how can these responses be used to assess the level of stress in a system?		Far North
72	How can biological control be best used to manage aquatic invasive species and other stressors?	eulachon, pikeminnow, salmonids, seal, sockeye salmon	
73	What is the availability, distribution, and quality of habitat for a given species, and how can this habitat be better mapped?		
74	What are the habitat requirements for different life stages of freshwater species?		
75	What are the patterns of habitat use and distribution for freshwater fishes?	sockeye salmon	Cultus Lake
76	What is the life history and habitat use patterns of fishes in winter?	seal, salmonids	estuaries in Newfoundland, Labrador, Salmonid Rivers
77	What is the relationship between habitat availability and habitat use for focal species?	Atlantic salmon	Bay of Fundy Rivers, Gulf Region, Lake Ontario Tributaries
78	What are the traits of good and sub-optimal spawning habitats for anadromous fishes?		
79	How can the spatial resolution of fish and fish habitat data be improved?	northern pikeminnow, salmon	
80	How can habitat use, habitat requirements, and fish distributions be better understood in northern and remote areas?	white sturgeon	Fraser estuary

81	Where do populations of freshwater species at risk continue to persist?		
82	How can habitat suitability models be used to classify habitat quality and quantity?	Atlantic salmon	
83	How can we measure habitat availability and sensitivity for remote and northern locations?	Atlantic whitefish	Conquerall Mills dam
84	How do habitat requirements and fish distributions change throughout the year?	redside dace	
85	What fish species have individual home ranges and what are the ecological characteristics of those home ranges?	Atlantic salmon, mountain sucker, redside dace	Crown Marsh, Great Lakes, Labrador, Labrador Sea, Long Point Bay
86	What are the distributions and life histories of small-bodied fishes?		Ontario
87	What is the area-per-individual requirements for focal species and how does it change with latitude?		
88	How do measures of habitat suitability and connectivity relate to the movement of fishes during biologically significant periods?	American eel, Atlantic salmon	
89	How important is habitat variability for ecosystem resilience and how can habitat variability be incorporated into decisions?	Morrison Creek lamprey	
90	What are the depth preferences for various fish species?	American eel, grass carp	
91	What are the life history differences between lacustrine and riverine populations of freshwater fish?		
92	How does the quality of freshwater habitat relate to the long-term viability of fish populations?		
93	What is the niche differentiation and competitive relationship between closely related fish species?	sympatric stickleback species pairs and the Misty Lake stickleback species pair	
94	What is the source of fish found outside of their historical ranges?	American eel, Atlantic salmon, lake sturgeon	Inner Bay of Fundy
95	What is the importance of substrate to aquatic flora, fauna, and ecosystem functions?	Atlantic salmon	
96	What characteristics make certain pelagic areas important habitats for fish populations?		
97	What are the best metrics for quantifying habitat availability and status?		
98	Can the area-per-individual for fishes be estimated from life history and ecological characteristics?		Big Bar, Fraser River
99	How can we predict where fish species might occur based on spatial data?	American eel	Great Lakes, Lake Ontario
100	Does migratory behaviour systematically varying with latitude?	Atlantic salmon, Pacific lamprey	
101	What are the human caused and natural factors limiting population growth for focal species?		
102	How does the quantity and quality of habitat relate to fish productivity?	eulachon	
103	What is the carrying capacity for various habitats and which populations are limited by habitat availability?		
104	How do habitat changes impact fish population vital rates?		

105	How can we develop standardized indicators or proxies for habitat health and fish productivity?	Umatilla dace, American eel, anadromous salmonid, Atlantic salmon, Pacific salmon	Arctic, coastal regions, EB Campbell dam, Interior British Columbia, Pacific
106	What is the mechanism and form of density-dependence acting on freshwater fish populations?	Atlantic salmon, salmon, eulachon, native salmonids, sea lice	Inner Bay of Fundy, Labrador, Maritime Provinces, Newfoundland
107	What is the productivity of focal fish populations?	pugnose minnow, rocky mountain sculpin, western silvery minnow, black redhorse, carmine shiner	Athabasca, Ontario
108	How does productivity vary among different habitat types for a given freshwater species?	Atlantic salmon, channel darter, eastern sand darter, little quarry lake sticklebacks, plains minnow	Bonilla Lake, British Columbia, Curtis Lake, Devon Lake, Inner Bay of Fundy
109	What should the targets be for recruitment and escapement for various anadromous fish populations?	smallmouth bass, grass carp, black carp, *Neoergasilus japonicus*, northern pike	British Columbia, Great Lakes
110	What is the capacity of fish populations to adapt to habitat change?	round goby, Atlantic whitefish, brown trout, channel darter, eastern sand darter	
111	What are the water temperature niches for native and invasive species, across all life stages?	sockeye salmon	Lake Huron Basin, Lake Superior, Sakinaw Estuary
112	What is the role of larval drift for freshwater fish species?	western silvery minnow, northern madtom, Salish sucker, silver chub, silver shiner	Lake Huron
113	How does the cumulative effect of catchment modification impact hydrology and fish productivity?	Pacific salmon	Oil sands region
114	Are egg deposition rates a good indicator for population productivity and can they be applied across systems?	eastern sand darter, pugnose shiner, spotted gar, stickleback species pair	EB Campbell dam, Misty Lake
115	What buffer area around a waterbody or watercourse should be protected to ensure the conservation of an aquatic ecosystem?	channel darter, copper redhorse, eastern sand darter, salmonids, white sturgeon	
116	What factors drive recruitment and productivity in large, complex aquatic systems such as the great lakes?	northern madtom	Arctic, Great Lakes basin
117	What is the survival and productivity of fishes in artificial habitats such as municipal drains and hydropower reservoirs?	eulachon	
118	How does nearshore coastal habitat contribute to the function of large lakes?		Great Lakes, Lake Ontario
119	How can the total pool of limiting nutrients be estimated for focal systems?	channel darter, American eel, eastern sand darter, lake	

		chubsucker, plains minnow	
120	What are the vital rates for all life stages of freshwater fish populations?	lake sturgeon, American eel	Hudson Bay, Nelson River, Saskatchewan River
121	How do fish habitat use, life history, and physiological tolerances differ throughout a species' range?	salmonids, salmonid	British Columbia, interior of British Columbia
122	How do vital rates vary among populations of the same species, and what factors drive that variation?		
123	What are the basic life history details for freshwater fishes?	salmon	
124	Can vital rates be estimated from life history characteristics and local environmental traits?	bull trout, carmine shiner, mountain sucker, smallmouth bass	
125	What is the reproductive behaviour for freshwater fishes, and what environmental factors trigger reproduction?	New Zealand mud snail, nooksack dace, walleye	British Columbia
126	What is the life history and abundance for early life stages of freshwater fishes?	pugnose shiner, spotted gar	
127	What are the feeding habits of freshwater fish species and how do these affect habitat use?	finfish	
128	What is the fecundity for freshwater species and what is the quantitative relationship between fecundity and body size?	redside dace	British Columbia
129	What is the relationship between natural and total mortality for freshwater fishes?		Great Lakes
130	How does the reproductive success of stocked populations compare with natural populations?		
131	Under what conditions will fish find and use new spawning habitats?		
132	What is the migratory phenology of Canadian fish populations?		
133	Why do some species have eggs that are mobile in river systems, and does this mobile incubation confer a selective advantage?		
134	What are the barriers to movement in freshwater systems for each species and life stage, and how can they be mitigated?	Pacific salmon, redside dace	
135	How do physical parameters in rivers impact the spatial distribution of fishes?	salmonids	Prairies
136	How do flow regimes impact freshwater habitat and fish population dynamics?	American eel, *Cladophora* sp.	
137	What are the movement patterns and capabilities of different fish species?	American eel	Ottawa River
138	What is the connection between groundwater and surface water in focal systems, and what guidelines should be used to avoid impacts to groundwater sources?	American eel	
139	How can knowledge about hydrodynamics and fish swim performance be used to make decisions around fish passage?	channel darter, eastern sand darter, pugnose shiner	
140	What are the best practices for barrier removal when barriers also prevent the movement of invasive species or create headpools with high fish densities?	salmon, steelhead, white sturgeon	Fraser River

141	What is the extent of hydrological connectivity between systems and how does hydrological connectivity impact fish habitat?	American eel	
142	How do different types of barriers impact passage by different fish species?	eurAsian milfoil, starry stonewort	
143	How do reservoir drawdowns and erosion impact fish habitat?	Atlantic whitefish, smallmouth bass	Milipsigate Lake
144	What are the effects of fishways on fish species, and how can they be made more effective while posing less risk?		
145	What is the natural range of hydrological and other environmental conditions for a given system?		Lake Ontario
146	How do nutrients and water flow between terrestrial and aquatic ecosystems?	American eel	
147	What are the effects of periodic low flows on fish community structure?	Atlantic salmon, coastrange sculpin (Cultus population), *Didymosphenia geminata*	
148	How can fish passage around hydropower facilities be improved?	coho salmon	interior Fraser
149	What is the meta-population structure and connectivity among fish habitats?		
150	How should habitat connectivity be considered in offsetting?	Atlantic salmon	
151	What environmental variables impact migration success?	phragmites	
152	How do wetlands impact hydrological and nutrient flows in different sized watersheds, and how do wetland management practices impact these processes?		
153	What is the availability of fluvial habitat in different systems and how applicable are fluvial models across systems?	American eel	
154	Where will fish passage become more difficult as a result of droughts?	chinook salmon, largemouth bass, salmon	Algonquin region, Lake Ontario
155	When should natural barriers (such as landslides) be removed?		
156	How do stocked fishes disperse from their original stocking locations within and around the great lakes?		
157	How can the movement of larval and juvenile fishes be better tracked?		
158	How can flow management be designed with whole ecosystems in mind?	lake trout, white sturgeon	Fraser River
159	Can new technologies be used to evaluate physical conditions experienced during passage through turbines?		
160	How can fish body shape be used to predict entrainment and impingement risk?		Crown Marsh
161	Are water levels in large lakes expected to increase or decrease over time?	bigheaded carps	
162	How will climate change impact habitat connectivity/fragmentation and how can connectivity be maintained despite predicted climatic changes?		

163	How will climate change impact fish physiology, community structure, and population dynamics?	sockeye salmon and lamprey	Sakinaw Lake
164	How and when should freshwater habitat management consider climate change during decision-making?		Lake Ontario
165	How will climate change alter freshwater ecosystems and their susceptibility to establishment of invasive species?		Lake Ontario
166	How will climate impact water temperature, water supply, and water quality in focal systems?		Lake Superior
167	How can we identify and protect thermal refugia?		
168	When should the effects of climate change on water temperature and availability be considered in project reviews?		
169	How can changing baselines be considered and addressed in management decisions?	American eels, frogs and other burrowing aquatic organisms, turtles	
170	How will climate change impact broad patterns of freshwater distribution?		
171	How might climate mediated changes in water quality and flow impact fish sensory systems and modify fish behaviours?	pickerel, smallmouth bass	Maritimes region
172	How can we downscale climate models to understand predictions and uncertainty of effects on specific systems?		
173	How can we operationalize the concept of regime shifts?		
174	How can estuary planning incorporate aquatic habitat concerns given sea level rises?	lake sturgeon	
175	How will climate-mediated changes in flow impact northern waterbodies and species that rely on seasonal flows?	salmonids	
176	How will rapid warming in northern areas impact freshwater fish communities and productivity?		EB Campbell dam
177	When, how, and over what scale, should management decisions consider cumulative effects?		Great Lakes
178	What are the cumulative effects of different types of pollutants on fish and fish habitat?	Atlantic salmon, seals	Labrador, Newfoundland
179	When should we expect multiple stressors to produce additive, synergistic or antagonistic effects on fish populations?	brown trout, silver shiner	
180	What is the mechanism by which different stressors interact to influence fish or fish habitat?	aquatic invertebrates	
181	How can ecosystem or populations models, and landscape-scale data sources, better inform cumulative effects assessments?	smallmouth bass	British Columbia
182	How do the cumulative effects of multiple barriers impact migrating species?		
183	How do ecosystems respond to small, incremental habitat losses?	American eel, bull trout, non-indigenous salmonids, redside dace, salmonids	Lake Ontario, the Ottawa River
184	Can a new framework for cumulative effect review be created or adapted for ffhpp?	Atlantic salmon, cisco, northern madtom, salmon, salmonids	Arctic, Labrador, Minnesota, Newfoundland, Pacific Region

185	When might impacted habitat still be considered to be high value?		British Columbia
186	What is the effectiveness of common avoidance, mitigation, offsetting and restoration methods?		Lake Ontario, Lake Superior
187	What metrics should be used to determine if management measures are achieving their goals?	salmonids	
188	How can data science and data mining improve assessments of management?		
189	How can freshwater habitat data from other sources and jurisdictions be better leveraged to inform DFO's research and management activities?		
190	What are the recovery potentials for various fish populations with and without interventions?		
191	How can ecosystem health be best quantified?		
192	How can management objectives continue to be effective under environmental change?		
193	What processes can support adaptive management practices that are updated based on past results?		
194	Should Larkin benchmarks be considered in assessment of status for anadromous fishes?		
195	What should the target population abundance be for fish reintroductions in various waterbodies?		
196	What are the minimum informational needs to predict the response of a species to harvest?		Arctic, Mackenzie River
197	What management measures can be used to increase connectivity, and how do they perform?	Atlantic salmon, silver lamprey	Great Lakes, Lake Ontario, Saint John River Basin
198	How can we evaluate different ecosystem indicators?		
199	What scientific information is needed to design codes of practice for proponent decision-making?	Salish sucker	
200	Which management measures increase the risk of invasive species introduction?		
201	How can the broad effects of different policies and management practices be assessed and reported?	lake sturgeon	Great Lakes
202	How can we improve and standardize monitoring of mitigation, offsetting, and restoration measures to evaluate the success of management measures?	Atlantic salmon	Inner Bay of Fundy
203	How can we conduct more long term monitoring studies to inform habitat management?		
204	How can existing and new methods, technologies, and tools be used to improve monitoring?		Fraser River
205	How can monitoring for water temperature, hydrology and water quality be improved?	chinook salmon	
206	How can effective monitoring be conducted in the face of limited resources?	pugnose minnow, stickleback species pair	Misty Lake
207	How can eDNA be used to improve research and monitoring in remote areas?		
208	How can non-lethal methods be used to monitor fish populations?		
209	What are the best practices for the length of monitoring following different types of habitat alterations?	Atlantic salmon, Atlantic whitefish, eulachon, northern madtom, channel darter	Newfoundland, Aetna Creek, Cape Breton, Gulf New Brunswick, Inner Bay of Fundy

210	What are the best methods for monitoring large scale projects?	Atlantic salmon, lake sturgeon	Southern Uplregion
211	What is the sampling effort required to identify given species or assemblages in agricultural drain habitat?	Atlantic salmon, westslope cutthroat trout	Inner Bay of Fundy
212	How can tools be developed that are science-based and that integrate multiple policies?	Umatilla dace and speckled dace	
213	How can an accessible, centralized tool be developed to enable the sharing of georeferenced species and habitat data?	Dolly Varden	Rat River
214	How can tools improve decision-making when there is high uncertainty or a lack of data?	grass carp, bigheaded carps, canary reed grass, New Zealand mud snail	Great Lakes, Huron, Lake Huron, Lakes Superior, Ontario
215	How can the precautionary approach be better integrated into decision-making?		
216	How can principles of adaptive management help to refine decision-making tools over time?		
217	How can we better understand the structure and productivity of lower food webs, and their links to upper food webs?		
218	What is the relationship between community composition and productivity?		
219	How can ecosystem feedbacks be better incorporated into models and decision-making tools?		
220	How do fish communities and fish habitats change over time?	Umatilla dace	
221	What are the ecological interactions between focal fishes and other members of the community?		
222	What is the degree of competition between various fish species and how does it impact population dynamics?		
223	What is the effect of natural predation on species of management interest?		
224	What are the vital rates of hatchery and wild fish populations, and how does competition among populations impact these measures?		
225	How does ice chronology impact fish predation by seals, and what local factors impact ice chronology?		
226	What are the basic ecosystem structures and functions in northern aquatic environments?		
227	What is the relationship between trophic richness and nutrient trapping and release by reservoirs?		
228	What are the impacts of predatory fishes on migrating anadromous fishes?	lake chubsucker, silver chub, silver shiner	
229	What is the overlap in habitat requirements between different species of management interest?		
230	What is the link between biodiversity and fisheries productivity?		
231	Are changes in fish community structure a good indicator of changes in habitat quality for keystone species?	salmon	
232	How do aquatic animals modify their habitats?		
233	What is the current population size and trajectory for a given fish population, and how does it relate to historic levels or the carrying capacity?		

234	What is the demographic structure of a given fish population, and what factors are driving demographic changes?	striped bass	Annapolis River, Saint John River, Yellowknife River
235	How can uncertainty associated with population assessments and predictions be quantified and considered?		
236	How can stock assessments consider the complexity associated with mixed-stock fisheries and the potential for overharvest on small populations?		
237	What factors are driving observed changes in body condition for some fish populations?		
238	Can we define thresholds for acute and permanent habitat modification below which the effects on fish productivity is minimal?		
239	How can we develop appropriate targets or benchmarks that would guide management?		
240	How can thresholds for habitat alteration consider uncertainty and ecosystem complexity?		
241	What are the tolerances and population responses of freshwater fish to changes in dissolved oxygen and nutrients?		
242	When do cumulative impacts on a system lead to tipping points in ecosystem health?		
243	How much genetic diversity is there in fish populations in Canada and is it important to protect?		
244	How should we define populations or management units for freshwater and anadromous species?		
245	How is stocking success impacted by source population genetics and adaptations to local conditions?		
246	What is the population composition in various mixed-stock fisheries?		
247	What is the minimum viable population size for a given population?		
248	What are the risks from genetic introgression in fish populations?	redside dace	
249	What is the taxonomic relationship within families of small bodied fishes?		
250	In populations with variable life histories, what proportion of the population uses each life history strategy?		Lake Ontario
251	How can a national DNA database for aquatic species be maintained and inform habitat management?	lake sturgeon, coastrange sculpin (Cultus population), copper redhorse, silver lamprey and northern brook lamprey	Nelson River
252	What is the frequency and magnitude of catastrophic events in freshwater ecosystems?		
253	How can spatial data from different agencies and sectors be better managed to inform freshwater habitat mapping?		
254	How can ecosystem and habitat models be used to guide habitat restoration and offsetting activities?		
255	How can mixed-effects models be used to improve estimates of fish abundance?		

256	How do life-history or habitat-based models perform in predicting escapement in locations with multiple stocks or stocks with mixed life-histories?		
257	Which freshwater fishes can hybridize with closely related species and under what conditions does hybridization occur?	stickleback species pair	Misty Lake
258	How can dynamic systems theory help inform ecosystem tipping points, early warning signals, stability and resilience?		
259	How can citizen science data be used to improve estimates of fish abundance and habitat quality?	Pacific lamprey, redside dace, summer group of chinook salmon	Lower Fraser
260	How can we best evaluate the tools and predictions produced by proponents?		
261	How can predictive models help identify sites and vectors at risk from invasive species, and how they would respond to management measures?	nooksack dace, silver lamprey	
262	How can we develop mechanistic models relating fish habitat to fish populations and communities?		
263	How can spatial and individual-based models that functionally link habitat to fish populations be used to increase our knowledge of area-dependent survival?		
264	How can habitat mapping be improved through remote sensing?	Pacific salmon	
265	What is the extent of macrophyte coverage in aquatic systems?	Atlantic salmon	Lake Ontario
266	How can spatial tools and mapping technology be better used to classify freshwater habitats and standardize those classifications across Canada?		
267	What is the current availability of critical habitat for species at risk, and what are the vital rates of populations within those habitats?		
268	How can freshwater habitats be classified in a way that is meaningful for managers and fish species?	walleye	Tathlina Lake
269	What is the likelihood of arrival, establishment and spread of various aquatic invasive species?	white sturgeon	
270	How effective are mitigation measures designed to protect fish and fish habitat?		Alberta, Ontario
271	How do pulsed flows impact water quality and fish behaviour, and what are the best methods to mitigate the negative impacts?	speckled dace, white sturgeon, Atlantic whitefish, coho salmon, copper redhorse	Minamkeak Lake
272	How can avoidance and mitigation measures be standardized across Canada?	Pacific salmon	Fraser River
273	What are the best practices to mitigate and compensate the impacts of urbanization on stream and wetland quality?		Maritimes Region
274	What is the effectiveness and best practices for impact mitigation and avoidance in winter?		Prairie Streams
275	How does salvage logging affect flow and freshwater habitat?		Ontario
276	What are the best practices for fish-outs?		
277	Which locations are most suitable to be used for ballast water exchange?		

278	How can long-term sustainable growth of cities be integrated with protection of fish habitat.		
279	How can we prevent the introduction of invasive species in restored habitats?	Asian carp	
280	How can the impact of large scale projects be quantified and offset?		
281	How can a common scale be used to compare project impacts to the result of management measures, and how can this guide decisions around equivalency?		
282	Should management measures focus on fish species or be an ecosystem based approach?		
283	What tools can help prioritize species actions vs habitat actions?		
284	What is the effectiveness of common management measures?		
285	What is the performance of different habitat offsetting methods?		
286	What are the best practices for offsetting measures in different habitat types, regions, and qualities?		
287	How effective are habitat banks and in which situations should they be used?	stickleback species pair	
288	What spatial scale should be used for considerations about offsetting?	walleye, Arctic char, Pacific salmon	Tathlina Lake, Lower Churchill Hydroelectric Generation Project, Northwest Territories, Qasigiyat Lake
289	How does food web structure impact the effectiveness of offsetting?		
290	Does applying the natural channel principles counterbalance the impacts of lost channel length and infill of existing channel footprint?		
291	How can existing frameworks for identifying ecologically and biologically significant areas be applied in various freshwater system?		
292	How does the establishment of aquatic protected areas impact freshwater community structure and modify the impact of stressors?		
293	What methods and tools can improve habitat valuation?	brook trout, Cowichan (Vancouver) lamprey	
294	How can we prioritize habitat types for protection and restoration to maximize productivity and protect rare species?	rocky mountain sculpin	
295	Where should new aquatic protected areas be located to best protected aquatic biodiversity?		north of 60, south of 60
296	What does the designation of critical habitat mean and what activities should be permitted in critical habitat?	Atlantic salmon	
297	How does the distribution of species, habitats and threats relate to current aquatic protected areas?		
298	How can local, traditional, and Indigenous knowledge be better integrated in science advice and management decisions?	rainbow smelt	Far North, Grand River watershed, Lake Superior, Lake Superior Watershed, Lake Utopia

299	How can communication be improved between science, management and policy-makers in relation to fish habitat?	sockeye salmon	Kettle River, Nooksack River Basin, Sakinaw Lake, Southern Ontario
300	How can management objectives incorporate the views of local stakeholders and other agencies?		
301	How can the principles of Indigenous co-management improve the management of freshwater fish habitat?		
302	How can Indigenous communities be involved in habitat monitoring programs?		
303	How can the knowledge of seasoned employees be incorporated into improvements and modernization of management programs?		
304	What are the best practices for habitat restoration projects?		Grand River watershed
305	How does the quality and stability of created wetland habitat compare to that of natural wetlands?		
306	Is it possible to rehabilitate degraded habitat and reintroduce species at risk?		Central Region, Lake Superior, Nunavut, NWT
307	Can sediment eDNA help guide restoration efforts in impacted ecosystems?		
308	How can assessments and decisions integrate multiple goals and multiple types of information?		
309	How can we include social and economic benefits of fish habitat in risk assessment and management?		
310	How can multiple management objectives be considered and addressed?		
311	How can compliance and enforcement be standardized and integrated with indigenous environmental management processes?	walleye	Tathlina Lake
312	How can data sharing between managers, researchers and proponents be increased to improve the management of freshwater fish and fish habitat?	Arctic char, Dolly Varden	Babbage River, Big Fish River, Nunavut, Shingle Point
313	How can we use an ecosystem based approach to understand how the function of restored habitats will change over time?		
314	How can we develop a science-based risk management framework that can be applied at a national scale?		
315	How can decision-making tools include principles of risk assessment and risk management?		
316	What new technologies could help mitigate and recover anthropogenic impacts on fish habitat?		
317	How can we use existing data to report on the state of fish and fish habitat?	Arctic char, Atlantic salmon	Labrador
318	How can engagement with private landowners be improved to encourage responsible land use related to riparian and aquatic habitats, and to conduct research and monitoring on private land?		
319	How does variation in environmental conditions and behaviour impact the encounter rates of fish and sampling gears?		
320	How valid are aging structures and age validation measures of fish species?		

321	When might in-water works improve aquatic habitat?	Atlantic salmon	
322	How can science and other evidence better inform management?		
323	How can species be protected in the face of economic incentives that drive their declines?		
324	What are the interactions between different ecosystem services provided by Canadian rivers?		
325	How can more fish counting facilities be installed in remote locations?		
326	How can policies support the achievement of net environmental gains?	alewife	Lake Ontario
327	How can fishing efforts be managed to maintain sustainable wild fish stocks?		
328	How can we improve knowledge of understudied systems and species through monitoring and research?		
329	How can large scale experiments be leveraged to improve management and policy?		
330	How does the Earth's rapidly shifting magnetic field and increasing anthropogenic electromagnetic fields affect fish migration?		
331	How can issues related to Indigenous rights and title be incorporated into aquatic habitat decisions?		
332	How can the results of focused scientific studies be scaled-up to inform decision making at larger scales?		
333	What are the best practices for species at risk listing for economically important fish?		
334	How can the timeline regarding providing protections to species at risk be streamlined to ensure that once a decision is reached by COSEWIC, protections are afforded to the species under SARA in a more timely manner?		

APPENDIX E

Outline of the prioritization process questionnaires (i.e. step 1-3), as seen by participants.

DEMOGRAPHIC INFORMATION

The following series of questions were presented in all three prioritization surveys:

In order to confirm your participation in this survey and include you as a co-author for the resulting publication, please provide the following information:

- First Name
- Last Name
- Email Address
- Professional Affiliation

In your current position, do you identify as being more strongly involved in freshwater fish habitat research or policy/management. (This data will be used to understand differences in scores provided by researchers and practitioners)

- Research
- Policy/Management

How much experience do you have working in the field of freshwater fish habitat science, management or policy?

- Less than 10 years
- 10 years or more

STEP 1 SURVEY: INITIAL PRIORITIZATION

Instructions

In the following activity, you will be asked to rate the importance of 48 scientific research questions to the management of freshwater fish habitat in Canada. These data will be used to help identify the most important scientific research questions, which will move on to the next step of the prioritization process. In addition, you will be asked to rate questions based on the amount of existing scientific knowledge and the scientific resources required to answer them:

Importance to management

This metric relates to the whether answering the research question would have an impact on freshwater fish habitat management in Canada. Questions that are the most important are those that would have a direct and transformative impact on freshwater fish habitat management. Questions that would have less impact are those that would have indirect impacts on freshwater habitat management (e.g. fundamental research questions) or those that, even if answered, would not advance freshwater fish habitat management.

Very unimportant – answering the question is not likely to have an impact

Unimportant – answering the question may have minimal impact

Somewhat unimportant – answering the question may have some impact

Somewhat important – answering the question may have moderate impact

Important – answering the question is likely to have important impacts

Very important - answering the question is likely to have transformative impacts

State of existing knowledge

This metric relates to whether there is existing scientific information available to address the question. In some cases, relevant research may have already been conducted but has not been widely communicated with freshwater fish habitat managers

Very limited – very limited or no management relevant scientific knowledge exists

Somewhat limited – limited management relevant scientific knowledge exists

Somewhat known – some management relevant scientific knowledge exists

Well known – sufficient management relevant scientific knowledge exists

Scientific resource requirements

This metric relates to the amount of financial, time, and human resources that would be required to answer the question.

Very low – likely addressable by one or a few people, over a short time frame, and with minimal financial resources

Somewhat low – is likely to require one of: a large team, a long time frame, or a large financial investment

Somewhat high – is likely to require two of: a large team, a long time frame, or a large financial investment

Very high – likely to require multiple or large teams, working over an extended time period with a large financial investment

Step 1 Questions

Participants were presented with individual research questions (listed in Appendix E) and asked to respond to rate questions on 3 separate Likert scales. These scales are as follows:

Importance to management

- Very unimportant
- Unimportant
- Somewhat unimportant
- Somewhat important
- Important
- Very important
- I don't know

Existing knowledge

- Very limited
- Somewhat limited
- Somewhat known
- Well known
- I don't know

Scientific requirements

- Very low
- Somewhat low
- Somewhat high

- Very high
- I don't know

STEP 2 SURVEY: FEEDBACK ON SCORES

Instructions

On the following pages you will see the initial scores collected during Step 1 of this project, for each of the 106 remaining research questions.

You are asked to review the research questions and associated scores. If you believe that your peers should reconsider their scores (i.e. the group has scored a question lower or higher than it should be), please comment on the question in the assigned space. The best comments will briefly (1-2 sentences) outline your arguments for why the group's scores should be revised.

Your comments will be anonymously shared with all participants during the final scoring round (step 3). In addition, comments will be translated into both official languages. Therefore we request that you avoid using ambiguous acronyms and jargon if possible.

You are welcome to comment on any of the three metrics being considered (importance to management / scientific resource requirements / state of current knowledge). However, the final short list of the 'Priority Research Questions' will be based on the importance to management metric alone. Data on scientific resource requirements and the state of existing knowledge will be used to identify questions that could be cheaply addressed (i.e. those with low resource requirements) and questions that require a greater science communication effort (i.e. those that are already sufficiently studied).

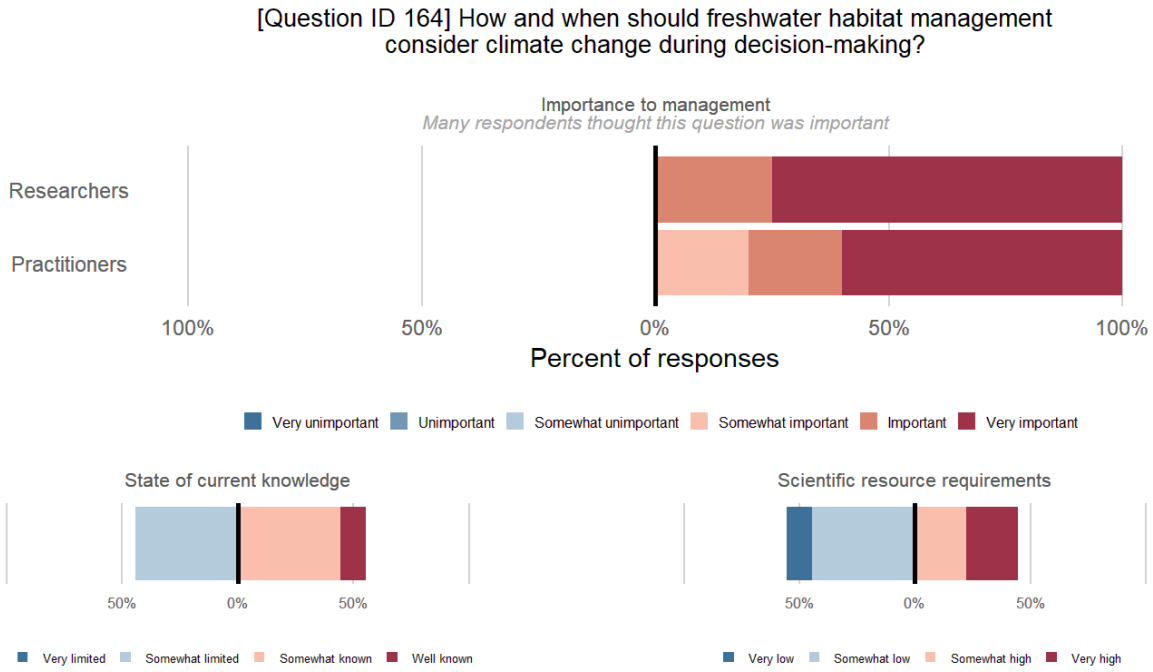
It is not necessary to comment on every question, and comment fields may be left blank should you feel that the scores are appropriate.

In addition to comments on the initial scores given to each question, we are also inviting suggestions for revising a question's wording, if you believe it is poorly specified. Suggestions provided in the assigned space will be considered by the project steering committee. Rewording suggestions should not fundamentally change the question's content.

The remaining research questions have been grouped into the following themes. Each theme is presented on a single page. **Feel free to focus your effort on your area(s) of expertise:**

Theme	*Page*	*# of questions*
Climate impacts on habitat	*1*	7
Flow, fish passage and habitat connectivity	*2*	15
Habitat classification	*3*	6
Habitat management effectiveness	*4*	8
Habitat monitoring	*5*	6
Habitat use	*6*	10
Stressors to fish habitat	*7*	19
Habitat, population dynamics and community structure	*8*	18
Multiple stressors and cumulative effects	*9*	6
Other habitat issues	10	11

Example of prompts displayed in Step 2:



Step 2 Questions

Participants were provided with text fields in which they were encouraged to provide feedback on the wording and scores of each knowledge gap. These text fields were labeled as follows:

- Comments on Scores

- Rewording Suggestions

STEP 3 SURVEY: FINAL PRIORITIZATION

Instructions

In the following activity, you will be presented with the initial scores and peer comments for each of the 93 remaining research questions.

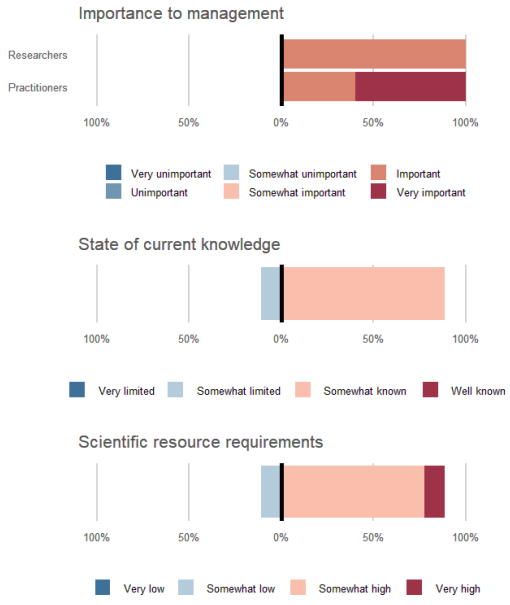
Taking the comments and scores of other participants into consideration, you will be asked to provide a final score for each question. As in Step 1, we will ask you to score each question based on the question's importance to the management of freshwater fish habitat in Canada, the state of existing knowledge, and the scientific resources required to answer each question.

Example of prompts displayed in Step 3:

Based on the comments collected in Step 2, the above question has been revised from the initial version. The scores and comments shown below are based on the initial version of the question.

Scores and comments for the initial question"How will climate change alter freshwater ecosystems and their susceptibility to establishment of invasive species?"

Initial scores



Comments on initial scores

-I wonder if the practitioners also consider range distribution changes as the establishment of invasive species?

-aren't invasive species all part of changing ecosystems? there are many naturalized species that we protect and manage for.... these invasives should be accounted for in biodiversity goals.

-I would argue that the thermal requirements of most potentially invasive species and how that influences their ability to invade systems is not well known from a physiological and genetic level

-I wonder about the current state of knowledge. Are we really that good at predicting establishment when we tend to see/record success, but not see/record failures?

-Some changes in climate may facilitate the establishment of invasive species - with severe consequences for native fauna and productivity. With warmer water, shipping lanes will change, species will establish is areas that were previously inhospitable and AIS may become the predominant problem

-I would argue that the information base for this question is very limited for northern systems. The Arctic is warming, but it is still cold at times. The winter is likely the limiting season for invasive species and there is not a great deal known of the availability of winter habitats or the thresholds for winter survival in invasive species coming from sub-Arctic areas. This question speaks to the establishment of invasive species, or their ability to survive in the Arctic. It does not just ask about than the ability of invasive species to appear in the Arctic, which I would agree is a better known topic.

-An important factor is to know which parameters have the greatest effects on the invasion of aquatic species (water temperature, water level, oxygen-free zone, etc.).

-I think this question is the most important (after question 164) to consider in managing climate change as it relates to fish and fish habitat.

Step 3 Questions

Accompanying the results of step 2, as presented in the plot above, participants were provided with array-type questions in which they were encouraged to provide a final score. These questions and their answer options are as follows:

Importance to management

- Very unimportant
- Unimportant
- Somewhat unimportant
- Somewhat important
- Important
- Very important
- I don't know

Existing knowledge

- Very limited
- Somewhat limited
- Somewhat known
- Well known
- I don't know

Scientific requirements

- Very low
- Somewhat low
- Somewhat high
- Very high
- I don't know