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Review

Developing a national level evidence-based toolbox for addressing freshwater biodiversity threats

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ABSTRACT

Freshwater biodiversity is in a state of crisis. The recent development of a global emergency recovery plan to "bend the curve" for freshwater biodiversity lacks the necessary details for implementation in a regional context. Using Canada as an example, we describe a toolbox intended to equip decision-makers and practitioners with evidence-based tools for addressing threats to freshwater biodiversity. The toolbox includes two rubric-based scoring tools to inform users about the level of the reliability (e.g., transparent methods, critical appraisal) and relevancy to Canadian freshwater systems (e.g., habitat, species) of an evidence synthesis. Those scoring tools were applied to 259 evidence syntheses, also included in the toolbox, across fifty freshwater management actions. Habitat Creation, Invasive Species Removal, and Revegetation were found to have reliable evidence syntheses but there remain several actions for which the syntheses are not robust and where the evidence base is unreliable. We suggest the need for more rigorously conducted empirical tests of freshwater management actions, further evidence synthesis, and clearer conveyance of implications for decision-makers and practitioners.

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Decision-makers and practitioners should use the two scoring tools on syntheses outside this project and tailor them to their regions. Given the global interest in addressing the freshwater biodiversity crisis and the necessity to engage and empower decision-makers and practitioners on a regional basis, we anticipate this toolbox will serve as a model for regions beyond Canada. Future studies to understand if and how the toolbox is used will be needed to make refinements and ensure it benefits freshwater biodiversity.

1. Introduction

1.1. Global freshwater biodiversity and the need for evidence synthesis

The status quo for freshwater ecosystem management and protection has failed biodiversity, ecosystems, and humans. It is now well accepted that we are in a freshwater biodiversity crisis (Harrison et al., 2018), with the latest Living Planet Index report revealing declines of over 85% in freshwater taxa (WWF (World Wildlife Foundation), 2020). Failure to prevent and reverse threats to freshwater biodiversity is having dramatic effects on many ecosystem services, including human wellbeing, given the extent to which humans rely on freshwater biodiversity (Postel and Carpenter, 1997). There is an urgent need to rethink aquatic ecosystem management and to equip decision-makers, practitioners, and their partners with the evidence needed to make decisions that will not only halt declines in freshwater biodiversity but also reverse them (Maasri et al., 2022). A recent global initiative involved the development of an emergency action plan (Tickner et al., 2020), which intends to 'bend the curve' for freshwater biodiversity decline (sensu Mace et al., 2018). The plan has six themes: restoring natural river flows, reducing pollution, protecting critical wetland habitats, ending overfishing and unsustainable sand mining in rivers and lakes, controlling invasive species, and safeguarding and restoring river connectivity through better planning. The plan is global in scope and focuses on broad strategies (and policy direction) but fails to provide specific tools to achieve these freshwater biodiversity goals, especially on a regional scale (Twardek et al., 2021).

Well-conducted evidence syntheses and systematic reviews provide a valuable resource to enable effective policy and practice (Dicks et al., 2014; Donnelly et al., 2018). Systematic reviews and meta-analyses are considered to be higher in the hierarchy of levels of evidence than primary studies (see Glover et al., 2006). Evidence syntheses are considered more reliable in informing policy and practice because they have a greater inferential strength than primary studies. Syntheses reduce the potential for bias by transparently selecting studies, help to resolve (or at least make sense of) conflicting studies, increase sample sizes used to test particular questions or hypotheses, are replicable (in principle), and provide a reliable basis for decision-making that avoids 'cherry-picking' (Cook et al., 2017; Kadykalo et al., 2021a). Given the extensive literature and resource constraints of decision-makers and practitioners, it can be difficult to identify and synthesize this information. Additionally, previous research suggests that some syntheses may not be reliable given their generally low standards of conduct and reporting (e.g., no review planning/a-priori protocols, searches limited to only one or two databases of conventionally published scientific literature, poor reporting of screening decisions and outcomes (O'Leary et al., 2016). This makes it challenging for decision-makers and practitioners to easily find reliable syntheses when searching for evidence to inform their decisions. However, it has been shown that if high-quality syntheses are made accessible, they will be used by decision-makers (Thomas-Walters et al., 2021). Syntheses (and the databases that are created when generating such syntheses) also serve as collections of empirical studies that can be further explored by those wishing to engage more deeply with the content.

There is also an increased expectation that governments and other organizations engaging in environmental management base their decisions on robust evidence. Yet, decision-makers and practitioners often lack the time and resources to fully and systematically make use of the evidence base (Pullin et al., 2004; Young et al., 2016; Walsh et al., 2019; Kadykalo et al., 2021b). The emergency action plan requires transformative change to current aquatic management and adoption of evidence-based approaches (Díaz et al., 2019). There is a need to ensure that decision-makers and practitioners working to halt and reverse freshwater biodiversity loss have access to such syntheses that will guide on-the-ground actions. Unfortunately, such syntheses specific to freshwater biodiversity, especially those of high quality, remain relatively uncommon (Cooke et al., 2017).

1.2. The Canadian freshwater biodiversity crisis

The land now known as Canada contains more than 25% of the world's surface waters, with more lakes than any other country, over 8500 rivers, and some of the largest wetlands globally (Keddy et al., 2009). Given the vast size of Canada and its substantial heterogeneity in geology, climate, and biogeography, it is not surprising that Canada also has rich and diverse freshwater ecosystems that span from small Arctic ponds to the massive Laurentian Great Lakes. These freshwater ecosystems support a wide variety of organisms that contribute to human nutrition, wellbeing, spirituality, identity, livelihoods, and recreation for a range of populations and cultures. The ecosystem services (or nature's benefits or gifts to people; Díaz et al., 2015a, 2015b) provided by Canadian fresh waters are substantial, though there are limitations associated with assigning monetary values to these services (see Ludwig, 2000). Nonetheless, examining the monetary value of ecosystem services alone demonstrates the tremendous value of freshwater for human populations. For example, recreational and commercial freshwater fisheries in Canada are valued at over $5 billion annually (DFO (Department of Fisheries and Oceans), 2015). In the Peace River watershed, British Columbia's 2012 annual value $/hectare/year of ecosystem services were estimated for water supply ($32.60 CAD), wetland soil carbon storage ($715.24 to $2453.85 CAD), wetland flood control ($245.67 CAD), and recreation ($215.97 CAD) among others (Wilson, 2014). In Canada's boreal region, valuable services provided by wetlands including flood control, water filtering, and biodiversity, are valued at $3.4 billion (Anielski and Wilson, 2005). People travel from across the globe to experience and interact with fresh waters in Canada.

Despite vast freshwater systems, even the most remote areas in Canada have been impacted by human activities. A state of emergency for freshwater in Canada was declared 20 years ago as the result of various individual and cumulative stressors (Schindler, 2001) and was recently reaffirmed (Desforges et al., 2022). For instance, the thousands of dams in Canada put in place predominantly by settler populations have fragmented rivers and rendered species that rely on natural flows such as the American eel (*Anguilla rostrata)* vulnerable (Haro et al., 2000). These declines have serious implications for Indigenous peoples who have long lived in relationship with various migratory fishes. Acid rain, driven widely by mining activities in some areas, was already affecting lakes at the turn of the 20th century (Dixit et al., 1995), leading to a sharp decline in biodiversity in freshwater systems (Schindler et al., 1989). Invasive species are considered a key driver of freshwater biodiversity declines, and in Canada Eurasian milfoil (*Myriophyllum spicatum*), the zebra mussel (*Dreissena polymorpha*), and the spiny waterflea (*Bythotrephes longimanus*) have profoundly changed many aquatic ecosystems resulting in substantial shifts in ecosystem function and structure (Dextrase and Mandrak, 2006). Layered on top of these threats is climate change, "the big threat multiplier" (Smol, 2010), which is contributing to a wide range of outcomes including Pacific salmon (*Oncorhynchus* spp.) declines (Healey, 2011; Crozier et al., 2021) and harmful algal blooms across Canada (Winter et al., 2011; Taranu et al., 2015). A recent assessment of the state of freshwater biodiversity in Canada revealed that 11.7% of plants and animals assessed were found to be "at risk" (i.e., listed as "Threatened", "Endangered", or "Extirpated") and 17.9% identified as "Special Concern" (Desforges et al., 2022). The implications for biodiversity and human well-being are serious.

Threats to freshwater biodiversity are not unique to Canada and occur because of persistent and emerging stressors (Dudgeon et al., 2006; Reid et al., 2019). However, for decades, Canada has had considerable scientific capacity and knowledge about these ecosystems within academic and non-government organizations (NGO), as well as the numerous regional, Indigenous, provincial/territorial, and federal bodies, to address and act on these threats (Cooke et al., 2016). Despite that capacity, freshwater biodiversity threats are ever-present in Canada and there is evidence that these threats are accelerating. Quite simply, the freshwater biodiversity crisis in Canada demands solutions that align with our various governance structures (e.g., federal, Indigenous), geography, ecology, culture, and collective values. The same can be said for other regions, and so the approach outlined here can be adopted elsewhere and at various spatial scales.

1.3. Objectives

Here, we conducted a review of evidence syntheses and created a database that lists the most relevant syntheses regarding freshwater management actions (hereafter "interventions", as commonly used in the evidence synthesis literature [CEE (Collaboration for Environmental Evidence), 2018]) for any knowledge user or generator of freshwater sciences, including decision-makers and practitioners. Recognizing that there is an inherent regional aspect to such toolboxes given differences in biogeography, threat landscapes, cultures, economics, and governance systems, we focus on Canada - a single large country with diverse aquatic ecosystems. To develop the toolbox, we assembled evidence syntheses describing various freshwater interventions, including direct freshwater species (e.g., fishes) and freshwater-dependent species (e.g., waterfowl). Next, we focused our efforts on scoring evidence syntheses to assess their overall reliability (based on aspects related to methodology and conduct) and relevance (spatial and temporal similarity) to Canadian freshwater systems. The two scoring tools are included in full so that they may be employed by others in their own work. The resulting toolbox, composed of evidence syntheses, their associated scores, and the two scoring tools, ensures that decision-makers and practitioners have access to the latest, most comprehensive, and reliable evidence syntheses – information that they may otherwise not have time to compile and distill. Given the global interest and urgency in addressing the freshwater biodiversity crisis and recognition that it will be necessary to engage and empower decision-makers and practitioners on a regional basis (Tickner et al., 2020), the approach we describe here can serve as a model for other regions outside of Canada.

2. Material and methods

2.1. Identification of interventions

To identify relevant interventions to collect syntheses on, we first drafted a list of interventions currently used or proposed in Canada for restoring freshwater biodiversity. The list was informed by initial exploratory searches (see below) and by examining the Canadian *Species at Risk Act* (SARA) action plans. We examined action plans as they detail the specific measures that are to be taken to facilitate the recovery of species at risk on a federal level (SARA (Species at Risk Act), 2002). With this approach, the initial set of actions were those deemed to support the survival or recovery of imperiled aquatic species in Canada, but likely also confer substantial additional benefits to ecosystems and/or non-listed species. On 22 September 2020, a virtual workshop was held with a group of 10 freshwater practitioners representing Canadian provincial and federal governments and environmental NGOs to review and approve the proposed list of interventions based on their feasibility and relevance. Interventions were grouped into broad categories to help recognize gaps based on the emergency action plan (Tickner et al., 2020), and a list of 54 interventions was agreed upon for inclusion in the toolbox (See Table 3 for the final list).

2.2. Searching

We systematically searched sources of peer-reviewed papers, grey literature, and other relevant reports (e.g., government or consulting reports) to identify evidence syntheses (including non-systematic and systematic) that examined the interventions identified for inclusion in the toolbox. For this exercise, we focused on evidence syntheses because they hold great promise for informing management decisions (Walsh et al., 2015; Pullin et al., 2020; Thomas-Walters et al., 2021) and are considered to be the highest-level of possible evidence sources (Glover et al., 2006; Dicks et al., 2014; Kadykalo et al., 2021a). We performed literature searches in three publication databases, including ISI Web of Science Core Collection (WoS CC), Scopus (Carleton University subscriptions), and the Federal Science Library (FSL), and one search engine (Google Scholar). The search string combinations used were intervention-dependent and slightly modified based on the search database or engine to ensure the most relevant articles were included. Full details of the search strings and number of articles found from each source are provided in Appendix A. Only English search terms were used in searches. The first 200 and 100 search results (sorted by relevance) were included from WoS CC and Scopus, and Google Scholar and FSL, respectively. The cut-off number for each database was established through scoping exercises by determining the point at which relevance typically trails off (Livoreil et al., 2017). Although no date restrictions were applied during the searches, we did use language and document type restrictions in WoS CC, Scopus, and FSL to focus search results. Due to project resource limitations, filters were applied to select only English-language articles and articles classified as reviews in WoS CC and Scopus. In Google Scholar and FSL, we used the following search terms to exclude non-review article types: (review* OR synth* OR meta-analy*). Searches were conducted across the 54 interventions from 28 July 2020 to 07 January 2021.

2.3. Screening

The review team consisted of five members (JLR, JNB, AFM, ANK, and ADC). Screening was conducted by two reviewers (AFM, ADC). Search results from all interventions were collated in Microsoft Excel and duplicates were removed across databases and interventions. Articles found by searches were screened by a single reviewer at each of two distinct stages: (1) title and abstract (AFM), and (2) full-text (ADC). All articles were screened at both stages according to established eligibility criteria: 1) the given article must focus on one or more of the targeted interventions and 2) the article must be a review combining the results of multiple primary studies. During screening, reviewers had the opportunity to request a second opinion from another member of the review team if eligibility was unclear. The full text of any article included after the first stage (title and abstract) was found using Carleton University subscriptions or interlibrary loan services. Reviewers did not screen syntheses for which they were an author.

2.4. Data extraction

Following screening, syntheses that met all inclusion criteria were processed by two reviewers (JNB and JLR). Metadata were extracted from all syntheses and used to populate a database template in Microsoft Excel (see Appendix B). Reviews were organized in the database in rows by intervention. In some cases, syntheses included multiple interventions (e.g., mechanical methods to remove invasive fish AND chemical methods to remove invasive fish), which resulted in some syntheses populating multiple rows in the database as we used one row per intervention.

Extracted metrics included bibliographic information (e.g., authors, DOI, journal name, abstract), study information (e.g., habitat, country, species), and the applied intervention(s). We also gathered brief key messages and/or concluding statements from each synthesis. For example, a brief concluding sentence would state, "We conclude that, in order to recover macroinvertebrate communities in channelized lowland rivers, a variety of restoration methods stabilizing substrates should be implemented" (see Nakano et al., 2008 in Appendix B), while brief key messages were bulleted points as summarized by the authors (see Wild et al., 2011 in Appendix B). Study location was extracted where possible, but in some instances only broad statements were given, such that the study was a "global review" or only continents were listed. Relevant species included both fully aquatic species (i.e., fish, freshwater mussels, macrophytes) and species that used freshwater habitats for some activities or life stages (e.g., waterfowl, beavers, amphibians). When species were not specified, a general taxonomic classification was used (e.g., "Fish" rather than "Brook Trout"). Syntheses that contained information from studies performed in zoos, hatcheries, or aquariums were included within "Laboratory Settings" in habitat classifications. If a synthesis was published multiple times in different formats (e.g., as a government report and commercially published), data were extracted from the most comprehensive source, and others were excluded as supplementary.

2.5. The Collaboration for Environmental Evidence Synthesis Appraisal Tool (CEESAT)

Like primary studies, evidence syntheses can vary widely in methodological validity (i.e., internal validity). Internal validity can be defined as how confident one can be that the variable of interest is truly responsible for the observed effects. Internal validity depends largely on the methodological procedures of a study and how rigorously it was performed. For evidence syntheses, internal validity depends on the level of rigour of the methods used by the review (susceptibility to/magnitude of bias), transparency with which those methods are reported, and the limitations imposed on synthesis by the quantity and quality of available primary data. To assess the internal validity, or the reliability, of syntheses on freshwater biodiversity interventions, we independently and objectively assessed each synthesis that met inclusion criteria using The Collaboration for Environmental Evidence Synthesis Appraisal Tool (CEESAT) (see Konno et al., 2020). Appendix C contains a copy of the complete CEESAT tool, which is a rubric providing descriptions for each criterion of CEESAT. CEESAT was developed by the Collaboration for Environmental Evidence (CEE; https://environmentalevidence.org) in 2013 (Woodcock et al., 2014) as an independent assessment tool for evidence users with limited time to review the literature themselves and with the goal of identifying the most robust and reliable reviews of evidence relevant to the user's needs (e.g., for integration into policy and practice). CEESAT can also identify gaps and limitations in data and reviews. CEESAT questions cover seven review criteria (review question, method/protocol, searching for studies, including studies, critical appraisal, data extraction, and data synthesis) consisting of 15 elements (Table 1). For each of the 15 elements, an evidence review is rated along a 4-point colour scale from most reliable to least reliable, as either: Gold, Green, Amber, or Red.

2.6. Relevance and Applicability of Evidence Syntheses to Canada Appraisal Tool (RASCAT)

Evidence syntheses also vary widely in their external validity. External validity is the relevance and applicability of the study findings to users in other contexts. For example, external validity considers how relevant and applicable the study findings are to the particular setting, population of management, or policy interest. To assess external validity, or the relevancy, of syntheses on freshwater biodiversity interventions, we developed a complementary tool modelled after CEESAT; we call this new tool the Relevance and Applicability of Evidence Syntheses to Canada Appraisal Tool (RASCAT). RASCAT employs the same ratings as CEESAT (i.e., Gold, Green, Amber, or Red). Appendix C contains a copy of the complete RASCAT tool which is a rubric providing descriptions for each criteria. The RASCAT checklist provides a point-by-point appraisal of the relevance and applicability of candidate review studies (review 'study sites' and associated findings) to Canadian ecosystems, based on criteria such as climate, habitat, and species. Thus, relevance in this context is based on spatial and temporal similarity between the study context and the context of policy interest (in this case, freshwater biodiversity in Canada).

Relevance may also include considerations of a) the level of similarity between the interventions and treatment conditions and b) statistical validity, especially the precision of estimates of effects, with low precision within-study suggesting lower predictive value in different contexts. However, both of these considerations were not included in the RASCAT tool. Regarding the level of similarity between intervention and treatment conditions, the relevance of interventions and treatment conditions were addressed during the scoping - eligibility screening and data extraction phases. Regarding statistical validity, syntheses that collect and analyse secondary data may be qualitative, or in the case where data are quantitative, many syntheses do not employ systematic meta-analyses producing effect sizes, making it difficult to rate the majority of syntheses for statistical validity.

RASCAT was refined by co-authors during two virtual workshops (22 September 2020; 01 October 2020) in which inclusion of review component questions into the tool were informed by discussion among expert (co-author) opinion. For several review components, whereby not clearly reporting on a particular review component (e.g., climate, species) should not be penalized (considered a fault), we added an additional rating to the colour-coded ratings, 'NC — Not Clear'. See Table 2 for a summary version of RASCAT and Appendix C for the full version of

Table 1
Elements of the Collaboration for Environmental Evidence Synthesis Appraisal Tool (CEESAT) criteria and corresponding review components. Adapted from Konno et al. (2020).

Review components	15 elements of CEESAT criteria
2. Method/protocol	2.1 – Is there an a-priori method or protocol document?
3. Searching for studies	3.1 – Is the approach to searching clearly defined, systematic, and transparent? 3.2 – Is the search comprehensive?
4. Including studies	4.1 – Are eligibility criteria clearly defined? 4.2 – Are eligibility criteria consistently applied to all potentially relevant articles and studies found during the search? 4.3 – Are eligibility decisions transparently reported?
5. Critical appraisal	5.1 – Does the review critically appraise each study? 5.2 – During critical appraisal was an effort made to minimize subjectivity?
6. Data extraction	6.1 – Is the method of data extraction fully documented? 6.2 – Are the extracted data reported for each study? 6.3 – Were extracted data cross-checked by more than one reviewer?
7. Data synthesis	7.1 – Is the choice of synthesis approach appropriate? 7.2 – Is a statistical estimate of pooled effect sizes (or similar) provided together with a measure of variance and heterogeneity among studies? 7.3 – Is the variability in the study findings investigated and discussed?
8. Limitations	8.1 – Have the authors considered limitations of the synthesis and evidence base?

RASCAT. We acknowledge that the delineation of rating categories (i.e., what should constitute as Gold, Green, etc.) for several questions (e.g., 2.2, 3.2, 4.2, 4.3) was somewhat subjective, as was the actual rating of some questions, but in developing RASCAT we emphasized clear definitions for each rating category of criteria for easier and more transparent categorization. Thus, we are confident in the precision and directional accuracy in overall scoring, despite some inherent subjectivity. Additional review components (e.g., socio-demographic indices) were considered but were not included into the final RASCAT due to tenuous pertinence to the external validity of evidence syntheses, low reliability, too much within-Canada variation, or redundancy with selected review components. Appendix C also provides a list of considered but excluded review components.

There may be a trade-off between the reliability of an evidence synthesis and its relevance and applicability. Users therefore must decide whether reliability (CEESAT) or relevance (RASCAT) is more important when considering an evidence synthesis. As indicated, CEESAT and RASCAT uses colour coded ratings ranging from most reliable to least reliable (Gold, Green, Amber, or Red). For this paper, we used the numerical ordinal equivalents for CEESAT ratings from high reliability to very poor reliability (4, 3, 2, 1), and for RASCAT, high relevancy to very poor relevancy (4, 3, 2, 1). CEESAT scoring was completed by JNB and JLR, while ANK completed RASCAT scoring.

3. Results

We present here the results of our review of evidence syntheses on freshwater management interventions and how they scored in their overall reliability (CEESAT) as well as their relevance to Canadian freshwater systems (RASCAT). These results are static and only relevant for the timeframe we searched the literature (i.e., updated to early 2021). This toolbox can also be found in an interactive format hosted by Aquatic Habitat Canada (https://aquatichabitat.ca/) under the "Resources" tab where syntheses may potentially be updated every 5–10 years. Our use of the CEESAT and RASCAT tools was independent of the CEE; therefore, any review or syntheses that are present in both our database and the CEE database may have slight variations in their scoring.

3.1. Interventions

Workshop discussions identified 54 freshwater management interventions of interest. Of the 54, searches for four of the interventions did not recover any relevant syntheses and thus were not included in the final tally (i.e., Aquatic Environmental Regulations - Regulation of combustion motors in water bodies; Habitat Creation - Creation of turtle basking sites; Irrigation Management - Screening of irrigation and water intakes; Stormwater Management - Stormwater ceptors). Three interventions (i.e., Chemical methods to remove invasive plants; Chemical methods to remove invasive crayfish; Mechanical methods to remove invasive crayfish) were added during the data-extraction stage based on their appearance in the literature. In total, 53 interventions were included (Table 3).

Broad-scale intervention groups with the most syntheses included Wildlife Passage (n = 65) and Invasive Species Removal (n = 47). The individual intervention with the most syntheses was Freshwater Biodiversity Conservation & Monitoring (n = 25). Interventions that were included, but that had few relevant syntheses, included Habitat Creation - Bird nest/box creation, Invasive Species Regulations - Bait bucket releases, Managing Riverine Aggregates, and Salvage of Stranded Organisms.

3.2. Literature searches and screening

Our literature searches and screening efforts returned 13,433 records from three databases and one search engine. After title-and-abstract screening followed by full-text screening, 351 syntheses related to freshwater management interventions remained. An additional 92 articles were excluded during data extraction. Exclusion decisions included syntheses that were deemed irrelevant to the selected interventions (e.g., no link to freshwater habitat or species), articles that were primary literature or focused on a marine ecosystem or species, or management plans/protocols that did not have a direct conservation intervention. A total of 259 syntheses were included for data extraction, generating 417 data sets, because some syntheses included more than one intervention.

3.3. CEESAT

Most syntheses (within and across interventions) had very low reliability (i.e., scored 1) according to CEESAT criteria (Fig. 1). For most CEESAT criteria, the median score was 1 indicating that most syntheses did not provide detailed, transparent, and systematic methods or reports of limitations. Few criteria (4.1 [Are eligibility criteria clearly defined?], 6.2 [Are the extracted data reported for each study?], 7.3 [Is variability in the study findings investigated and discussed?], and 8.1 [Have the authors considered limitations in the synthesis and evidence base?]) also had a large proportion of low reliability (i.e., scored 2), indicating that their specific criteria were broadly apparent but not explicitly identified or described in a systematic manner (Fig. 1). Five syntheses (2%) had very low reliability for every criteria of CEESAT, whereas 205 syntheses (79%) had low or very low reliability in only one criterion. At least one CEESAT criterion was given a moderate reliability evaluation in 47 syntheses (i.e., 19% syntheses scored 3). Only six syntheses (2%) had high reliability in at least one CEESAT criterion (i.e., scored 4). The majority of studies (73%) were unable to adequately describe the search strategy used in the synthesis in relation to specific search terms,

Table 2
Elements of the Relevance and Applicability of Evidence Syntheses to Canada Appraisal Tool (RASCAT) criteria and corresponding review components.

Review components	9 elements of RASCAT criteria
1. Publication date	1.1 When was the review published?
2. Spatial factors	2.1 – In which habitat types are the review findings extracted from? 2.2 – What is the latitude of the study site(s) included in the review?
3. Climate	3.1 – In which climate classification(s) are the review findings extracted from? 3.2 – How well does the climate of the country/counties sourced in the review match the climate of Canada
4. Species	4.1 - Are all species included in the review found in Canada?
5. Environmental performance and level of democracy	5.1 – What is the environmental performance index (EPI)[a] of the country/countries the review findings are extracted from? 5.2 – What is the polity score[b] for the country/countries the review findings are extracted from?
6. Applicability to decision-makers and practitioners	6.1 – Have the authors considered implications for decision-makers or practitioners (e.g., resource managers in government, industry, or conservation organizations, as well as NGOs, community groups, private landowners, or farmers) or policymakers in the synthesis? The implications can include practical advice, actionable messages, recommendations, or guidance.

[a] EPI: The 2018 Environmental Performance Index (EPI) ranks 180 countries on 24 performance indicators across ten issue categories covering environmental health and ecosystem vitality. These metrics provide a gauge at a national scale of how close countries are to established environmental policy goals.

[b] The Polity data series is a widely used data series in political science research. The latest version, Polity IV, contains coded annual information on the level of democracy for most independent states with greater than 500,000 total population and covers the years 1800–2018.

Table 3
Number of syntheses included in the toolbox for each intervention. Broad categories are indicated in bold with specific interventions listed below. Note in some cases all syntheses found related directly to the broad category itself, in which case there are no interventions (sub-categories) listed below.

Conservation intervention	Number of syntheses
Agricultural best management practices	**38**
Agricultural runoff (fertilizer, pesticide) control	22
Fencing or exclusion of livestock and farm animals	16
Barriers to restrict invasive species	**19**
Intentional barriers	4
Electric barriers	5
Bubble curtains/nets	5
Screens or selective gates	5
Bycatch reduction strategies	**4**
Fishes	2
Turtles	2
Captive breeding	**37**
Frogs	12
Amphibians	12
Fishes	9
Mussels	4
Conservation introductions	**14**
Effluent management	**18**
Wastewater management	18
Fire-risk management	**6**
Freshwater biodiversity conservation & monitoring	**25**
Habitat creation	**33**
Bird nest/box	1
Woody debris to lotic	24
Woody debris to lentic	8
Invasive species regulations	**3**
Bait bucket releases	1
Boat cleaning	2
Invasive species removal	**47**
Chemical methods to remove fishes	11
Mechanical methods to remove fishes	8
Chemical methods to remove plants	9
Mechanical methods to remove plants	15
Chemical methods to remove crayfish	2
Mechanical methods to remove crayfish	2
Irrigation management	**7**
Regulation of irrigation and water-taking	7
Managing riverine aggregates	**1**
Natural channel design	**6**
Pollution	**5**
Non-point source	3
Point-source	2
Protected areas	**15**
Hotspots	4
Freshwater Protected Areas	5
Targeted land protection	3
Riparian Buffer strips	3
Revegetation	**12**
Macrophyte planting	6
Tree planting	6
River regulation	**20**
River basin management	8
Environmental Flows	12
Salvage of stranded organisms	**1**
Sediment & erosion control	**24**
Silt fencing	2
Riparian buffers	22
Source water protection	**1**
Stormwater management	**5**
Stormwater retention	2
Impervious surface management	3
Wetland conservation	**11**
Protective actions	3
Restorative actions	8
Wildlife passage	**65**
Culverts	12
Dam removal	15
Re-establishment of lateral connectivity	20
Provision of passage at natural barriers	2
Provision of passage at dams and hydropower	16

Boolean operators, or the databases used and thus had very low reliability. Only 21 studies (8%) demonstrated a systematic, detailed, and repeatable search strategy, scoring a 3 or higher. Almost all (98%) included syntheses did not conduct a critical appraisal. Over half of the included syntheses (57%) did not demonstrate any consideration of limitations in the conduct or in the primary research they used in their review and 39% of syntheses briefly described limitations in the primary literature used but did not discuss limitations of review methods in sufficient detail (i.e., sources of bias).

There was a wide range of interventions in which all reviewed syntheses had low or very low reliability for CEESAT criteria: Bycatch Reduction - Fishes, Bycatch Reduction - Turtles, Captive Breeding - Mussels, Invasive Species Regulations - Bait bucket releases, Invasive Species Regulations - Boat cleaning, Invasive Species Removal - Chemical methods to remove invasive plants, Chemical methods to remove invasive crayfish, Mechanical methods to remove invasive crayfish, Protected Areas - Buffer strips, Salvage of Stranded Organisms, Wetland Conservation - Protective actions, and Wildlife Passage - Provision of passage at natural barriers. The two highest rated syntheses that had moderate or high reliability across CEESAT criteria synthesized multiple interventions including Habitat Creation - Addition of woody debris to lotic systems, Addition of woody debris to lentic systems, Invasive Species Removal - Chemical methods to remove invasive fishes, Mechanical methods to remove invasive fishes, and Revegetation - Macrophyte planting.

3.4. RASCAT

In general, most syntheses scored well (i.e., 3 or 4) according to RASCAT criteria (Fig. 2). For most RASCAT criteria, the median score was 4 indicating many elements of the included syntheses, and therefore the syntheses themselves, were relevant and applicable to freshwater biodiversity in Canada. The greatest variation in responses was detected with the question 4.1. [Are all species included in the review found in Canada?]. In contrast, the question with the lowest ratings on average was 6.1. [Have the authors considered implications for decision-makers or practitioners or policymakers in the synthesis?].

Just over half of the syntheses scored “4” for the RASCAT publication date criteria (i.e., were published in the last 10 years). About 19% were published between 2006 and 2011, 17% between 2001 and 2006, and 10% before 2001. Syntheses also scored high relevancy in criteria related to habitat, latitude, and climate classification. Ninety-two percent of syntheses were conducted in freshwater inland surface waters and water bodies or freshwater wetland habitat types, with 8% in agricultural or urban systems. The majority of syntheses study sites were at latitudes of >41°N (86%), or in polar or continental/microthermal climates (83%). This resulted in 68% of syntheses study sites being an excellent climate match for Canada as assessed by Climatch (https://climatch.cp1.agriculture.gov.au/climatch.jsp). Twenty-one percent of syntheses included species found in Canada, 31% included species with the majority found in Canada, 34% included species with the minority being found in Canada, and 13% included species not found in Canada. Most syntheses included study sites in countries that were ranked in the top 30 countries in the 2018 Environmental Performance Index. The majority of syntheses (71%) included study sites in countries considered full democracies and 28% in countries considered partial democracies. Only 2% of syntheses had an explicit section or identifiable passage of text devoted to the authors’ consideration of implications for decision-makers and practitioners of their review including an associated manual or protocol, whereas 30% had an explicit section or identifiable passage of text devoted to the authors’ consideration of implications for decision-makers and practitioners but did not contain an explicit manual or protocol. Twenty-seven percent of syntheses had some consideration of implications for decision-makers and practitioners but were not explicitly stated or were not the focus of a specific section, while 41% had no evident consideration of implications in any way.

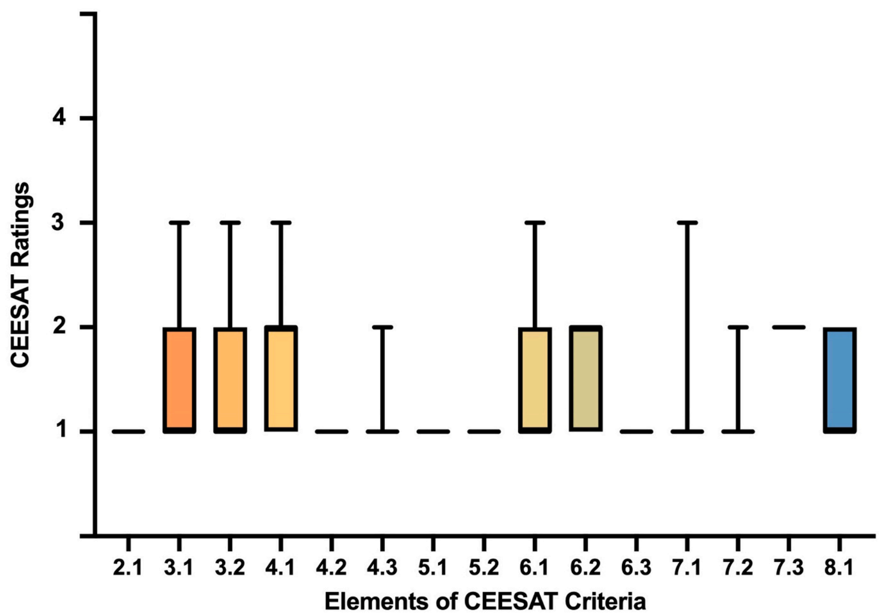

Fig. 1. Boxplot showing the Collaboration for Environmental Evidence Synthesis Appraisal Tool (CEESAT) ratings (4 being high reliability, 1 being very low reliability) across 15 CEESAT criteria. See the list below for complete CEESAT criteria. Median indicated by thickest and widest horizontal bar with surrounding box representing 25th and 75th percentiles and whiskers represent 5th/95th percentiles.
2.1 Is there an a-priori method or protocol document?;
3.1 Is the approach to searching clearly defined, systematic, and transparent?;
3.2 Is the search comprehensive?;
4.1 Are eligibility criteria clearly defined?;
4.2 Are eligibility criteria consistently applied to all potentially relevant articles and studies found during the search?;
4.3 Are eligibility decisions transparently reported?;
5.1 Does the review critically appraise each study?;
5.2 During critical appraisal was an effort made to minimize subjectivity?;
6.1 Is the method of data extraction fully documented?;
6.2 Are the extracted data reported for each study?;
6.3 Were extracted data cross-checked by more than one reviewer?;
7.1 Is the choice of synthesis approach appropriate?;
7.2 Is a statistical estimate of pooled effect sizes (or similar) provided together with a measure of variance and heterogeneity among studies?;
7.3 Is the variability in the study findings investigated and discussed?;
8.1 Have the authors considered limitations of the synthesis and evidence base?

4. Discussion

Using Canada as a case study, we described the development of an evidence-based toolbox for addressing threats to freshwater biodiversity. Recognizing the importance of using evidence syntheses to guide conservation and management actions, we focused our efforts on scoring such syntheses to assess their overall reliability as well as their relevance to Canadian freshwater systems. We conducted a review of syntheses and created a database that lists all the most relevant syntheses regarding freshwater management interventions for Canadian decision-makers and practitioners. As mentioned above, our hope is for all freshwater knowledge users and generators – including academics, government scientists, NGO and/or other researchers – to use this toolbox in informing conservation and management strategies of fresh waters. The approach we used here could be easily adapted to other regions by, for example, modifying the RASCAT tool to include regionally-relevant scoring criteria. Several notable patterns emerged. First, most evidence syntheses that are included in the toolbox had overall low reliability scores. Second, and in contrast, most evidence syntheses retained scored well in terms of their relevance to Canada. The evidence base we have gathered here is considerably large, covering over 250 syntheses on 53 different interventions. While many articles are of low reliability, this toolbox is nonetheless a promising starting point towards meaningful action on the freshwater biodiversity crisis.

4.1. The CEESAT tool and findings

The finding that most existing evidence syntheses related to freshwater biodiversity interventions have low reliability is not entirely surprising given that, in general, most evidence synthesis methods contain bias (Peters et al., 2006) and the quality of the studies underpinning these reviews varies. Overall low reliability is troubling given that these resources are often the "go to" sources of information for what works and what does not. Selective inclusion of different studies in a synthesis can lead to bias (discussed in Rothstein et al., 2005). Moreover, critical appraisal is an important part of systematic reviews (Konno et al., 2020); when systematic reviews lack critical appraisal of individual studies the low-quality evidence emanating from poor experimental designs of flawed analyses may skew findings. Thus, if decision-makers and practitioners do seek out such information (rather than managing based on status quo), they may unknowingly be basing strategies off lower-quality evidence. Our results suggest that evidence syntheses related to freshwater biodiversity interventions are of low reliability to inform decision making because they lack rigour, transparency, and replicability at both the planning and conduct stages. Some of the factors that caused low reliability scores were a lack of a-priori protocols, or even replicable method sections in the evidence synthesis itself, and a lack of reporting of screening decisions on what primary research is included or excluded and why. Further, it is extremely rare for an evidence synthesis to have more than one person in the conduct of an evidence synthesis to screen studies for inclusion, critically appraise, or extract data from the same primary study. Our findings demonstrate that most authors do not report this information. Employing more than one person to do these steps to cross check appraisal or extraction decisions greatly reduces the susceptibility to bias of an evidence synthesis. Shortcomings of evidence syntheses in the environmental sector have been known anecdotally for at least 20 years (Pullin and Knight, 2001) and have been studied empirically more recently (Roberts et al., 2006; Woodcock et al., 2014; O'Leary et al., 2016). Adopting a precautionary approach, coupled with adaptive management, may be needed when there are no syntheses and/or the evidence base is small or unreliable given the urgency of the freshwater biodiversity crisis (Cooney, 2004).

Gathering and summarizing evidence syntheses may perpetuate biases (Christie et al., 2021), but understanding the current conservation evidence base (even if it is poor) supports our call for future efforts to improve the rigour and reliability of the primary conservation research. Systematic reviews (a type of evidence synthesis) represent a rigorous and transparent approach intended to control for bias (Pullin, 2012; Cook et al., 2017), yet we found very few systematic reviews evaluating freshwater management interventions. We found two evidence syntheses that had moderate or high reliability across CEESAT criteria covering multiple intervention groups including Habitat Creation, Invasive Species Removal, and Revegetation. Toolbox users will be able to consult these syntheses for reliable information on these topics, but a more

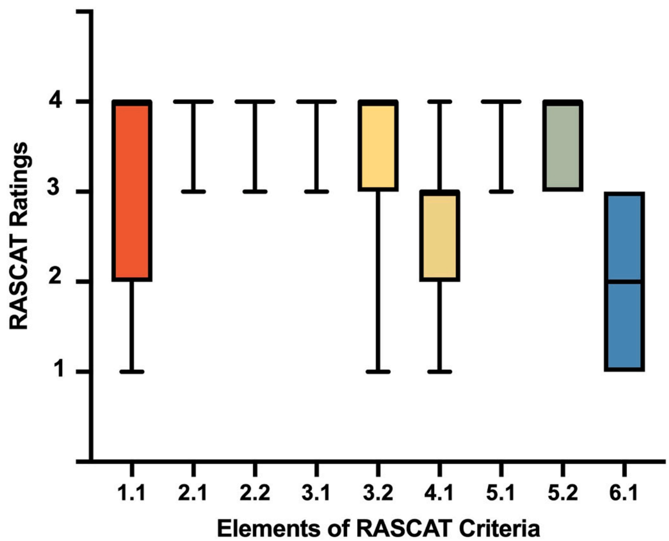

Fig. 2. Boxplot showing the Relevance and Applicability of Evidence Syntheses to Canada Appraisal Tool (RASCAT) ratings (4 being high relevancy, 1 being very poor relevancy) across 9 RASCAT criteria. See the list below for complete RASCAT criteria. Median indicated by thickest and widest horizontal bar with surrounding box representing 25th and 75th percentiles and whiskers represent 5th/95th percentiles.
1.1 When was the review published?
2.1 In which habitat types are the review findings extracted from?;
2.2 What is the latitude of the study site(s) included in the review?;
3.1 In which climate classification(s) are the review findings extracted from?;
3.2 How well does the climate of the country/counties sourced in the review match the climate of Canada?;
4.1 Are all species included in the review found in Canada?;
5.1 What is the environmental performance index (EPI) of the country/countries the review findings are extracted from?;
5.2 What is the polity score for the country/countries the review findings are extracted from?;
6.1 Have the authors considered implications for decision-makers or practitioners or policymakers in the synthesis?

robust evidence base is needed at this stage in the freshwater biodiversity crisis. This can be achieved through more training in evidence synthesis and evidence-based decision making (Downey et al., 2021). We recognize systematic reviews can be time consuming and expensive, however there are also strategies to make other forms of synthesis more reliable (see Haddaway et al., 2015). Given the increasing recognition of the value of systematic reviews by decision-makers (Thomas-Walters et al., 2021), it is our hope that there will be more interest in carrying out high reliability evidence syntheses when suitable funding mechanisms are available.

4.2. The RASCAT tool and findings

The high scores of most syntheses in their relevance to Canadian freshwater systems is promising and suggests that the evidence base, although inherently global in scope, can have strong regional relevance. We anticipate that this likely holds true in other northern hemisphere regions (e.g., Europe) but may be a function of bias in that many evidence syntheses on freshwater interventions have been conducted in North America or Europe, where in general there are similarities in governance, wealth, climate, and habitat. Thus, relevance of freshwater syntheses to other contexts, particularly for regions dissimilar to Canada's biodiversity such as South America or the Middle East, may be more variable. However, we see value in assessing syntheses with RASCAT because it maps the variation in syntheses elements clearly, and it allows decision-makers and users to weight specific elements of syntheses with respect to what they deem important when considering relevancy of findings to their context. During our workshops, co-authors who self-identified as conservation practitioners noted that in addition to syntheses of scientific literature (which may be relevant for policy) future extensions of the RASCAT tool could consider practitioner-focused protocols and manuals to guide intervention implementation.

Importantly, although a synthesis may focus on a specific locale, it may also offer important lessons for other regions. For example, a synthesis that focuses on captive breeding of amphibians in Amazonia may contain content that could be highly relevant or useful to practitioners working in Canada (or elsewhere). However, one area where reviews scored rather poorly in relevance was in their implications for decision-makers and/or practitioners. We strongly encourage future evidence syntheses - not only in freshwater biodiversity - to provide clear, concise, and actionable implications, guidance, and recommendations to decision-makers and practitioners. We recognize that it is not always the priority of academic journals to request and make space (word count) for actionable evidence and recommendations for practitioners (Sutherland et al., 2020). Though such implications, guidance, and recommendations are seemingly becoming more common, more needs to be done to mainstream actionable evidence and messages in peer-reviewed literature for practitioners and decision-makers. Since many decision-makers and practitioners are also limited by time and skills to distill evidence (Kadykalo et al., 2021b), we encourage evidence synthesists to work with Conservation Evidence (https://www.conservationevidence.com/) to produce "subject-wide evidence syntheses" [i.e., searchable synopses (Sutherland and Wordley, 2018], which have already been integrated into several practitioner-focused resources and decision-support tools (Sutherland et al., 2019). We encourage researchers working in other regions to adapt the RASCAT tool to their context and to include diverse knowledge holders and end-users when doing so.

4.3. Other sources of evidence

Community knowledge holders (formerly often referred to as citizen scientists) offer another largely untapped resource of evidence to help support freshwater biodiversity and conservation interventions. The local ecological knowledge that community members hold about population trends and species' spatial usage is widely useful, and community science has also proven to be both efficient and cost-effective for extensive data collection (Ristroph, 2012; Binley et al., 2021). Community knowledge holders, like anglers, hunters, and naturalist groups, can strengthen the knowledge base of species' life history characteristics and changes in distribution and/or abundance (Bergman et al., 2020; Kadykalo et al., 2021c) and are indeed legally recognized and included in planning under Ontario's *Endangered Species Act* (Endangered Species Act, 2007, S.O. 2007, c. 6).

We also acknowledge that most evidence syntheses have failed to consider other ways of knowing such as knowledge held by Indigenous Elders, knowledge holders, and other community members (No'kmaq et al., 2021). The lack of recognition, consideration, and inclusion of multiple ways of knowing needs to be addressed. Multiple ways of knowing provides valuable evidence that is helpful to inform conservation action, and often makes valuable connections and fill knowledge gaps unaddressed by Western science. Indigenous knowledge does not necessarily need to be assessed in these stringent ways to be included/valued in the practice of scientific reviews. Fortunately, there are a number of projects underway that are considering how to weave together different evidence sources and that both adequately and respectfully include them in evidence syntheses (e.g., see Haddaway et al., 2019). Such projects would benefit from cooperation, coordination, and co-design of evidence-synthesis with existing Indigenous and local-led knowledge platforms such as SIKU—the Indigenous Knowledge Social Network and Exchange for Local Organizations (siku.org), which maintain ownership, control, access and sovereignty of the data to knowledge holders. However, it must be emphasized that there is a great deal of knowledge that is not contained within a synthesis nor can be readily integrated into a platform. The mobilization and inclusion of this kind of knowledge in informing conservation efforts will require supporting Indigenous-led conservation efforts, building strong relationships, and collaborating with knowledge holders for other kinds of conservation efforts. Additionally, future extensions of CEESAT and RASCAT should strive to consider Indigenous knowledge systems, including Indigenous knowledge of fresh waters by involving Elders and other knowledge holders in the research process from project inception. Though critical to future work in this area, this was beyond the scope and capabilities of our current toolbox and authorship team.

4.4. Recommendations for decision-makers and practitioners

Policies pertaining to freshwater biodiversity must also be updated and/or created with the best-available science (with help from evidence-based toolboxes to guide that process) in partnership with those working within the framework of these policies (Leach et al., 2002). Researchers have the critical task of producing and synthesizing relevant information (in partnership with diverse knowledge holders and users; Sunderland et al., 2009) and research funding bodies have the responsibility of prioritizing research that has the greatest likelihood of influencing practitioner actions with respect to freshwater biodiversity. Ample time, funding, and other forms of support must be available to the practitioners that put policies into action (Lapointe et al., 2014). Provision of enabling conditions (i.e., influencing factors that increase the likelihood of enacting an effective policy or management action; Huber-Stearns et al., 2017) is not only the role of policy-makers, but also the responsibility of decision-makers at the organizations that practitioners work within, including various NGOs and advocacy groups, and industry, among others. For groups that focus on freshwater biodiversity objectives, support for freshwater biodiversity and practitioners can be woven into their corporate culture and brand identity (Rattalino, 2018). Professional bodies and societies (e.g., Society for Conservation Biology, Ecological Society of America) can also play an important role in advocating for effective policies and working conditions and in communicating relevant science to practitioners (e.g., through webinars, newsletters, infographics).

Here, we provide clear recommendations to decision-makers and practitioners regarding how to best use this toolbox and the resources it contains:

- **Use the CEESAT tool beyond the scope of this toolbox** - Given the low reliability of many syntheses, CEESAT is a valuable tool for evidence synthesis users to identify the most robust and reliable reviews of evidence suitable and relevant to user needs. The CEESAT tool included in the toolbox contains review criteria that can be applied to any evidence synthesis on any subject, making it a quick and cost-effective strategy to understanding an evidence base without the need for high-level training.
- **Adapt RASCAT to regional contexts** - RASCAT criteria may be tailored to the unique landscape and context of other countries. Several criteria such as latitude, climate, and species can be re-written or re-ordered (i.e., criteria that is considered Red in Canada may be Gold in another region) to be of higher relevance as needed. Resource links are embedded within the tool for criteria such as environmental performance and polity score for users to find information about their country specifically. This allows for the use of RASCAT beyond the scope of this project and empowers users to assess the relevance of any synthesis on topics beyond freshwater biodiversity.
- **Understand the evidence base** – By exploring the database included in this article (Appendix B) or using the website format, decision-makers and practitioners can examine the variety and quality of existing evidence syntheses on freshwater management actions. This also may introduce users to syntheses they are unfamiliar with and provide collections of empirical studies that can be further explored. Decision-makers and practitioners should be aware of the freshwater management evidence base even if it is currently poor. It is important to understand and acknowledge any limitations and biases in justifying the use of these syntheses and ultimately the decisions made and actions undertaken. It is likely many of these syntheses were commonly consulted but without a true understanding of their biases; this toolbox transparently identifies these limitations for users and makes them more aware of criteria to look for in the future.

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Essentially, the creation of an evidence-based toolbox constitutes a critical step in addressing freshwater biodiversity challenges in Canada, but it will take a concerted effort by all actors (including practitioners themselves) to ensure that the toolbox leads to meaningful actions by practitioners in support of freshwater biodiversity.

4.5. The future of the toolbox

An important aspect of this work is sharing the toolbox with end users, which is an important component of effective evidence and knowledge exchange. We have developed a web interface where the toolbox will reside. We have partnered with Aquatic Habitat Canada (https://aquatichabitat.ca/), which is a national network supporting aquatic habitat protection and restoration, to host and promote use of the toolbox. We hope that the toolbox will be consulted regularly by decision-makers and practitioners, and that as they learn more about the process used to generate the toolbox, they will also learn more about evidence-based decision making. We are just beginning our efforts to share the toolbox with the broader community and will be working closely with our non-academic team members on this project to ensure this occurs (i.e., those embedded in various governments and NGOs). It is our hope that this is only the first iteration of this toolbox. More work will be needed to ensure that the web-based toolbox will be updated (e.g., every 5–10 years, or as funding allows) as more aquatic syntheses are published.

Moreover, the toolbox is currently only available in English because it was beyond the scope and capabilities of the current review team to translate other languages, which is limiting given that Canada itself is a multi-lingual nation (e.g., English, French, as well as over 70 Indigenous languages). Non-English studies often contain crucial evidence for global biodiversity conservation, especially for species or regions where no English-language evidence is available (Amano et al., 2021). It is likely the current toolbox is missing valuable syntheses on freshwater management interventions and species performed in non-English languages, and collaborations with global partners. The use of machine translation may help diversify the future evidence base (Amano et al., 2021). We may look to address underrepresented taxa interventions, and non-English studies by adjusting our search strings and methods in future work. For example, many interventions can introduce bias into the evidence base when performed only on large vertebrates. When restoring algal or zooplankton communities, which require long-term, ecosystem wide approaches, practitioners have little to no evidence base or reliable syntheses to draw knowledge and base management decisions from (though where available, paleolimnological data can be used). Studying the ways in which the toolbox is used (or ignored) in the coming years will be helpful for refining the toolbox to be of maximal benefit to decision-makers and practitioners and revealing the extent to which it can and should be expanded to other regions and topics.

5. Conclusions

Though it is clear what is required to "bend the curve" for freshwater biodiversity (i.e., the emergency action plan; Tickner et al., 2020), it is unclear what specific conservation interventions have been successful. Though this finding is troubling, it should not be taken as a sign that we do not have enough knowledge to act. We developed this toolbox to ensure that decision-makers and practitioners have access to the latest, most comprehensive, and most reliable evidence syntheses – something that they would otherwise not have time to do. In this toolbox, we included a database of appraised evidence syntheses regarding freshwater management interventions and a set of appraisal tools for evidence syntheses that informs decision-makers and practitioners of the level of uncertainty in their review conduct and application to, in this case, Canadian freshwater systems. Researchers can consult the toolbox to identify gaps and limitations in the scientific evidence to better inform primary studies in the future. Decision-makers and practitioners are encouraged to download and use the scoring tools provided for syntheses they consult beyond this toolbox, adapting the RASCAT tool to their regional context where applicable. This toolbox provides information on the quality, quantity, and relevance of various interventions, but further work is needed to then evaluate the implications of those interventions for freshwater biodiversity.

While evidence-based selection of interventions is important, monitoring of the effectiveness of these interventions in different contexts is critical so that implementation decisions can be improved in the future. Many of the routine interventions used in Canada and elsewhere to address the freshwater biodiversity crisis lack reliable evidence to support their use which suggests the need for a precautionary approach (Cooney, 2004). There are additionally several clear research gaps that if addressed would improve our ability to halt and reverse freshwater biodiversity decline (Harper et al., 2021; Maasri et al., 2022), though more research alone will not solve this problem (Arthington, 2021). Future studies to understand if and how the toolbox is used will be needed to refine the tool and ensure it benefits freshwater biodiversity. There are other approaches used to share environmental evidence with decision makers that rely more on aggregating individual empirical studies (e.g., https://www.conservationevidence.com/). The reality is that we are in crisis, and we need to try various approaches to ensuring that the best possible decisions are made to restore freshwater biodiversity. Only time will tell whether our toolbox approach will be embraced.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2022.109533.

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