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Environmental Evidence

SYSTEMATIC MAP PROTOCOL

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Evidence of effect of riparian attributes on listed freshwater fishes and mussels and their aquatic critical habitat: a systematic map protocol

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Abstract

Background: Habitat that is necessary for the survival and recovery of a species listed as threatened, endangered or extirpated (i.e., Critical Habitat) is protected in Canada. For freshwater aquatic species, Critical Habitat may include the riparian zone, however, it is unclear how much of this riparian habitat needs to be protected to support the survival and recovery of a listed species. The riparian zone mainly affects aquatic species through its indirect effect on aquatic habitat according to five main processes: erosion, filtration, infiltration, shading, and subsidization. To provide quantitative evidence to support the delineation of riparian Critical Habitat, a systematic map will be used to create a searchable database containing the current state of knowledge regarding the relationships between the riparian zone attributes (e.g., size, vegetation) and fishes and mussels, aquatic features, and riparian processes.

Methods: We will search for primary research articles in bibliographic databases and relevant organizational websites for primary literature, theses, preprints, and grey literature including reports, along with models using a search string specific to riparian habitat. The results will be screened at title and abstract, and full text levels against predefined inclusion criteria and consistency checking will be performed to ensure the inclusion criteria are consistent across multiple reviewers. Quantitative and qualitative data including study details and methods, the riparian habitat, and the waterbody and upland habitat use will be extracted. The findings of the systematic map will be provided in a manuscript and a searchable database accompanied by a decision tree to support biologists in providing scientifically defensible delineation of riparian Critical Habitat for aquatic species at risk in Canada.

Keywords: Erosion, Filtration, Infiltration, Shading, Subsidization, Decision tree, Riparian

Background

When freshwater fishes and mussels are listed as threatened, endangered or extirpated, Fisheries and Oceans Canada (DFO) is required to identify and protect the habitat that is necessary for the survival and recovery of the species (i.e., Critical Habitat). The identification of Critical Habitat is based on a biophysical description of the habitat required to fulfill species life-cycle functions (e.g., reproduction, survival, growth) [1]. To determine Critical Habitat, the biophysical elements are broken down into features (e.g., pools, littoral zone) and attributes (e.g., substrate size, water depth, prey species) that are key in supporting a species' functions necessary to achieve the species' population and distribution objectives. Features are defined by attributes, which provide the greatest level of information about a feature, the quantity and quality of the feature, and the mechanism by which the feature

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is able to support particular life-cycle requirements of a species [1].

Some features designated as Critical Habitat may support functions indirectly by supporting or reinforcing other features. These features may be outside of the aquatic ecosystem, i.e., in the riparian zone, which is defined by the Species at Risk Program (SARP) as the area located between a waterbody's high-water mark and the upland area. The riparian zone supports aquatic Critical Habitat by mediating the impact of natural disturbances and land use on the aquatic habitat and by providing inputs via riparian processes. Hence, the riparian zone should be considered Critical Habitat if riparian attributes support aquatic Critical Habitat features or if the riparian features directly support the species' functions [3].

Currently the protection of the riparian zone as Critical Habitat is not applied consistently by the SARP [3]. Critical Habitat designation needs to be based on scientific evidence and legally defensible. One of the main reasons mentioned when the riparian zone is not included in the Recovery Strategy of an aquatic species at risk is the lack of species-specific data [3]. Since the importance of the riparian zone is, for the most part, due to the indirect effect of the riparian zone on aquatic features and attributes designated as aquatic Critical Habitat, we argue that designation of riparian Critical Habitat does not hinge on species-specific data. What can be substituted, is an understanding of the relationships between the riparian zone and aquatic features.

The riparian zone is an important component of the ecological functioning of a healthy ecosystem [2]. The main processes by which the riparian zone affects aquatic features include: erosion, filtration, infiltration, shading, and subsidization [3] (Table 1). Stable banks are required to maintain stream channel geomorphology and aquatic features such as undercut banks, shoals, and backwater [4]. Filtration prevents contaminants, excess sediments and nutrients from surface and subsurface water in the riparian zone from entering the waterbody [5]. Infiltration affects flow and water level through the amount of water that enters the waterbody by runoff or groundwater [6]. Shading maintains natural variation in evaporation and temperature of water entering, and within, the aquatic habitat [7]. A functional riparian zone subsidizes energy, food, and structural components from the terrestrial habitat into the aquatic habitat [8].

It might be expected that the larger the riparian zone, the greater the benefits for the adjacent aquatic ecosystem, however, the reality is much more nuanced. There is no amount of riparian habitat that can provide the natural levels of processes needed to maintain aquatic features if the riparian attributes do not exist to support those processes. For example, an altered riparian vegetation community, such as a lawn or cultivated field, may not provide key functional processes like provision of large woody debris inputs or shade [3]. In addition, the relationship may not be linear, and an increase in the size of riparian zone may reach a threshold after which any increases in size would provide minimal benefit to the aquatic features [9].

Many primary research studies and reviews have been conducted, and models developed, regarding the effect of riparian attributes on aquatic attributes and on riparian processes. However, there is no framework on how to use this available information to identify Critical Habitat for aquatic species at risk. To designate riparian Critical Habitat for the conservation and recovery of a species at risk, biologists are required to turn the information on riparian attributes and processes into a

Table 1 The main processes by which riparian features support aquatic features defined. Adapted from [3]

Process	Description
Erosion	Soil gradually wearing away by wind, water or gravity. When erosion is occurring within a natural range of variation, it controls sedimentation and siltation; supporting aquatic attributes such as aquatic vegetation and interstitial spaces, and channel forming processes at the longitudinal scale (i.e., meandering of a stream)
Filtration	Removing matter or sound from air or water. When filtration is occurring within a natural range of variation it prevents contaminants, excess sediments, and excess nutrients in surface and subsurface water in the riparian zone from entering a waterbody
Infiltration	Surface water entering the soil. When infiltration is occurring within a natural range of variation it maintains natural water levels and flow in the aquatic habitat by maintaining natural levels of surface and sub-surface water entering the waterbody
Shading	Adjusting the amount of light admitted onto a surface. When shading is occurring within a natural range of variation it provides cover and maintains the photic environment and water temperature in the aquatic habitat and maintains natural variation in the temperature of water entering the aquatic habitat
Subsidization	Transferring energy, food, and structural components from the terrestrial habitat to the aquatic habitat. When subsidization is occurring within a natural range of variation it provides provide food for fishes (e.g., terrestrial insects), mussels (e.g., organic matter), and their aquatic prey (e.g., nutrients and organic matter); subsidization of wood and other structural components provides cover and maintains natural flow dynamics in the aquatic habitat

These processes are dynamic and occur within a range of natural variation that needs to be considered when defining riparian areas as Critical Habitat

mappable geo-physical area. Critical Habitat is described for the current and future distribution of the species at risk, which in some cases may have biologists dealing with an expansive and heterogeneous area. In addition, to be able to provide Critical Habitat designations within a restricted timeline, SARP biologists are limited to data that is readily available or easily collected. Therefore, this knowledge needs to be compiled into an easy to use, comprehensive database with a clear framework that will allow SARP biologists to consistently apply the correct level of protection to riparian areas.

A systematic map of the current knowledge on the effects of riparian attributes on fish and mussels functions, aquatic features, and riparian processes will be performed to create a searchable database of relevant research. Specifically, the map will be used to determine the evidence base for the amount of riparian habitat required to support fishes and mussels and their aquatic Critical Habitat, and if evidence is adequate for further synthesis or if more evidence needs to be collected. A decision tree (Fig. 1), that may evolve during the process of creating the systematic map, will guide biologists' use of the database towards a scientifically defensible Critical Habitat designation that utilizes the appropriate primary research and models.

Stakeholder engagement

Fisheries and Oceans Canada's (DFO) SARP is responsible for carrying out the Department's mandate under the *Species at Risk Act* (SARA) to protect, recover, and conserve all listed aquatic species at risk in Canada. When an aquatic species is listed on Schedule 1 of SARA as threatened, endangered or extirpated, DFO is required to identify and protect the Critical Habitat, which is linked to the population and distribution objectives established in the Recovery Strategy [10].

DFO's SARP requested advice to ensure a more rigorous and systematic approach to identify Critical Habitat in the riparian zone for freshwater fishes and mussels. An evidence-based approach was required to guide the identification of features in the riparian zone as Critical Habitat. Therefore, a literature review was undertaken to identify current scientific evidence regarding the effect of riparian features on aquatic habitat features [3]. This systematic map builds upon the initial request for advice by providing a database of available evidence to support the delineation of Critical Habitat in the riparian zone.

As the stakeholder, DFO's SARP will provide members of the advisory committee that will be regularly updated on the progress of the systematic map and analysis the final report. In the end, it will be SARP biologists that will be responsible for integrating the findings of the systematic map, using the decision tree (Fig. 1), into Critical Habitat designations.

Objective of the review

The objective of this systematic map is to provide a manuscript, report, searchable database, and decision tree, that will allow biologists to use the best current knowledge on how riparian attributes affect aquatic Critical Habitat in order to provide scientifically defensible Critical Habitat designations.

Primary question

What evidence exists on the effect of riparian attributes on listed freshwater fishes and mussels and their aquatic Critical Habitat?

Secondary questions

Riparian zone defined

The definition of riparian zone used by the SARP and in this map (i.e., from the high water mark to the upland area) is rather arbitrary, and may add to the uncertainty in the geo-physical area that should be protected as riparian Critical Habitat.

How is the riparian zone defined in the different studies?

What are the different riparian zone habitat types (e.g., forest, grassland) that have been studied in Canada?

Riparian zone and fish and mussels' functions

A feature is Critical Habitat if the species relies on the habitat to perform life cycle functions. There may be studies that directly test the effect of the riparian attributes (e.g., geo-physical area, vegetation, slope) on a species' functions. For this systematic map, we will examine studies that have been performed for the purpose of determining the effects of riparian attributes on fish and mussel functions (e.g., reproduction, survival).

What is the current state of knowledge (i.e., number of studies per species, range of study design, range of study years, functions studied) regarding the effects of riparian attributes on fish and mussel functions?

Riparian zone and aquatic features

When direct studies on a species' functions do not exist, studies that examined the effect of the riparian attributes on aquatic features that a species relies on to perform their life cycle functions may be substituted (Fig. 1). For this systematic map, we will examine studies that have been conducted with the aim to determine the effects of riparian attributes on specific aquatic features using a standardized list of aquatic features [11].

What is the current state of knowledge regarding the effect of riparian attributes on aquatic features?

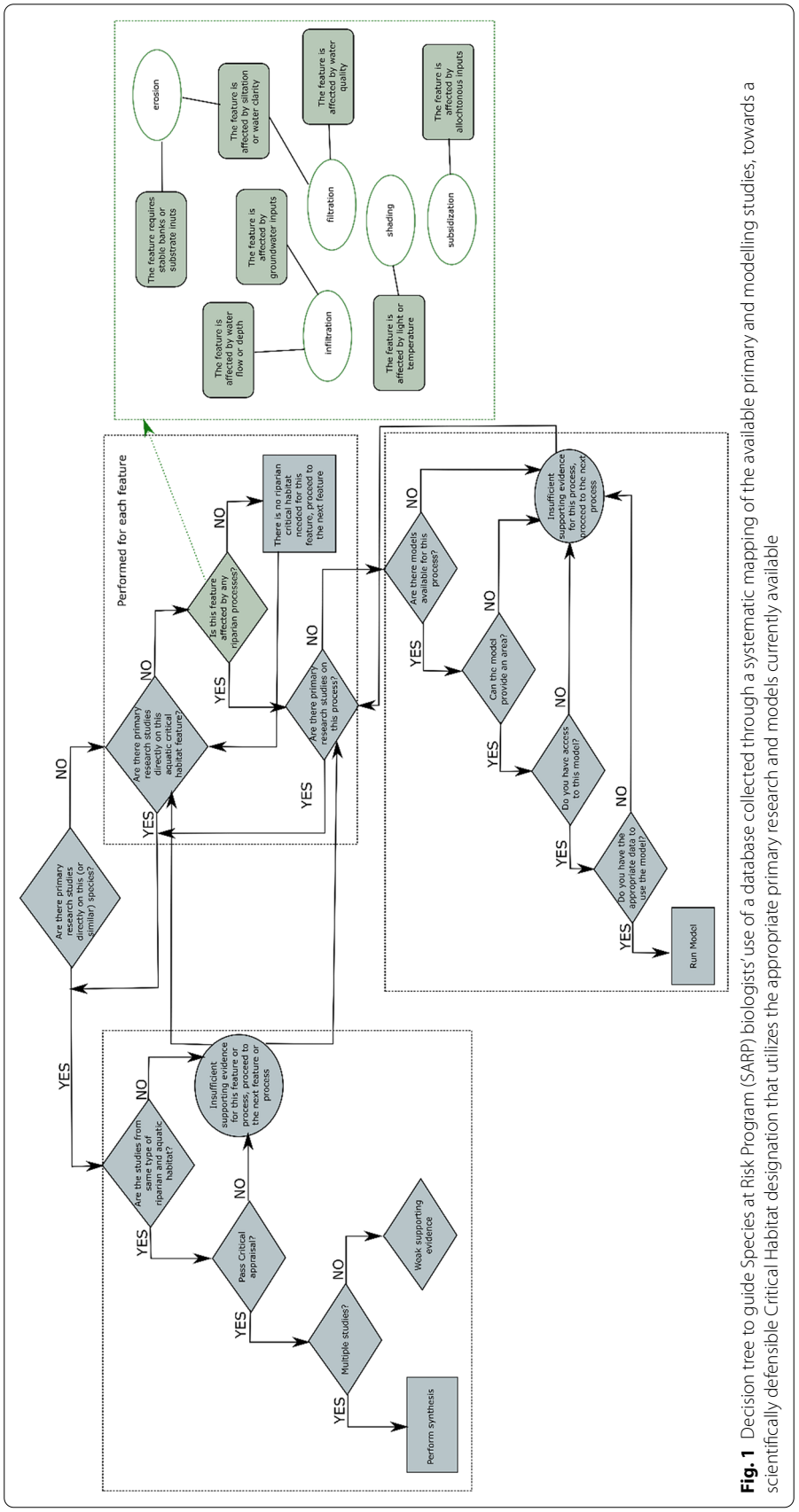

Fig. 1 Decision tree to guide Species at Risk Program (SARP) biologists' use of a database collected through a systematic mapping of the available primary and modelling studies, towards a scientifically defensible Critical Habitat designation that utilizes the appropriate primary research and models currently available

Riparian zone and riparian processes

Where direct studies on aquatic features do not exist, studies that examined the effect of riparian attributes on riparian processes may be substituted (Fig. 1). There are five main processes by which the riparian zone affects aquatic features: erosion, filtration, infiltration, shading, and subsidization [3]. For this systematic map, we will examine the studies that have been performed for the purpose of determining the effects of the riparian attributes on riparian processes.

What is the current state of knowledge regarding the effect of riparian attributes on erosion, filtration, infiltration, shading, and subsidization?

What are the current models available for the effects of riparian attributes on each process and what are their data requirements?

Methods

This systematic map will follow the Collaboration for Environmental Evidence guidelines [12] (https://bit.ly/2WyqxbB) and conform to the Reporting Standards for Systematic Evidence (ROSES) [13] (Additional file 1).

Searching for articles

Relevant studies exist in peer reviewed and grey literature; therefore, an extensive search will be performed across several databases, search engines, and websites of relevant organizations. Packages litsearchr, metagear, and synthesisr in R [14–16] will be used to reduce the search terms, collect search results, and to remove duplicates.

Bibliographic databases

Citation databases will be searched using English search terms for English language studies, and the search string will be adapted to the specific syntax in each database (Table 2). The adapted search strings and matching results will be published with the final systematic map.

Specialist and supplementary searches

In addition, searches of: Google Scholar (https://scholar.google.ca/), bibliographies of all relevant reviews identified, preprint servers, and websites of relevant organizations will be screened to retrieve any additional potentially relevant studies, including grey literature (Table 2).

Primary search string

First, a base set of search terms, generalized from a recent agriculturally focused meta-analysis on riparian buffer strips with a very extensive list of search terms for the area, defined here as the "riparian zone" [5], was stripped of agricultural specific qualifiers. It was then expanded by including unique words and phrases commonly used in primary research and review articles collected by the authors during a previous literature review [3] (Additional file 2). After the primary search string was adapted through estimating the comprehensiveness of the search (see below) the R package litsearchr [14] was used to find common phrases with the screened results from the first 1500 abstracts (sorted by relevance) found in "Web of Science" to create a reduced set of search terms. This resulted in the following search string: "filter strip*" OR "riparian area*" OR "riparian forest*" OR "riparian zone*" OR "riparian buffer*" OR "buffer strip*". There were 10,044 results located in Web of Science using this search string, the search will be re-run once the protocol is accepted.

Estimating the comprehensiveness of the search

Benchmark studies, found in a literature review performed to provide evidence in support of assigning riparian habitat as critical habitat for freshwater species and mussels [3] and Google Scholar searches specific to each riparian process, were used to test the comprehensiveness of the search and were sorted based on the riparian processes (Additional file 4). The bibliographic database "Web of Science" was used to test whether the benchmark studies were found. The search string was adapted to include any benchmark studies that were missed. Both, the search string in Additional file 3 and the refined search string, (above) were able to locate all the benchmark studies.

Article screening and study eligibility criteria

Screening process

All identified articles will first be screened for relevance at the abstract level, then at full text level using predefined eligibility criteria (see below). To determine whether the screening is consistently performed across reviewers, the application of the eligibility criteria will be compared across all possible pairs of reviewers at the abstract level screening for 100 abstracts. A kappa test will be used to formally test agreement levels, with a minimal agreement score of 0.6 for each pair [17]. If the kappa score falls below 0.6, an additional 100 abstracts will be reviewed, and this will be repeated for all reviewers until the kappa score reaches 0.6 for all pairs of reviewers. The abstract screening will provide a list of potentially relevant articles to screen at the full text level following the same eligibility criteria. The eligibility criteria will be refined after discussion between all reviewers if there are disagreements. If one of the reviewers is given an article they have authored; they will forward the article to another reviewer to be screened.

Reporting of the screening process will include presentation of: (1) the total number of unique articles

Table 2 Databases to be searched to locate primary research articles from the peer reviewed and grey literature

Type	Database/website	Subscription (databases, citation indices)	Search parameters	Search Terms
Bibliographic databases	Directory of Open Access Journals (http://www.doaj.org/)		All fields	Search string
	Microsoft Academic (https://academic.microsoft.com/home)		All fields	Search string
	Scilit (https://www.scilit.net/)		All fields	Search string minus the "*"
	Web of Science (Web of Science Core Collection) (http://webofknowledge.com)	Fisheries and Oceans Canada subscription (Web of Science Core Collection)	Topic, abstract, and keywords	Initial list and search string
	ProQuest (https://search.proquest.com/)	Fisheries and Oceans Canada subscription (Biological Science Collection, Earth, Atmospheric & Aquatic Science Collection, Publically Available Content Database)	All fields except full text	Search string
Theses	DART-Europe E thesis (https://www.dart-europe.org/basic-search.php)		All fields	Search string
	Library and archives Canada – Theses Canada (https://www.bac-lac.gc.ca/eng/services/theses/Pages/search.aspx)		All keywords	Each phrase in search string separately then results combined
	EThOS (British Library) (https://ethos.bl.uk/AdvancedSearch.do?new=1)		Any word	Search string
	EBSCO Open Dissertations (https://biblioboard.com/opendissertations/)		Abstract, keywords, title	Search String
Preprint databases	bioRxiv (https://www.biorxiv.org/)		Full Text or Abstract or Title	Each phrase in search string separately
	arXiv (https://arxiv.org/)		All fields	Each phrase in search string separately then just "riparian"
	ARPHA Preprints (https://preprints.arphahub.com/)		All fields	Each phrase in search string separately then just "riparian"
	EarthArXiv (https://eartharxiv.org/)		All fields	Each phrase in search string separately then just "riparian"
	ESSOAr (https://www.essoar.org/)		Anywhere	Search String

Table 2 (continued)

Type	Database/website	Subscription (databases, citation indices)	Search parameters	Search Terms
Organizational websites and databases	Canadian Institute of Forestry (https://pubs.cif-ifc.org/doi/10.5558/tfc2016-009)	Fisheries and Oceans Canada subscription	All fields	Search String
	Canadian Forestry Service (https://cfs.nrcan.gc.ca/publications)		All fields	Each phrase in search string separately
	U.S. Forest Service (https://www.fs.usda.gov/treesearch/)		All fields	Search String
	Aquatic Commons (http://aquaticcommons.org/)		Keywords (all fields) or title	Search String
	Agricola (https://agricola.nal.usda.gov/)		All fields	Each phrase in search string separately
	European Environment Agency (http://www.eea.europa.eu/)		All fields	Each phrase in search string separately
	European Soil Portal (https://esdac.jrc.ec.europa.eu/content/european-soil-portal)		All fields	Riparian or Buffer
	GRACEnet, USDA Agricultural Research Service (https://www.ars.usda.gov/anrds/gracenet/)		All fields	Each phrase in search string separately without "" or *
	Rothamsted Research (http://www.rothamsted.ac.uk/)		All fields	Search string
	UC Davis, Agricultural Sustainability Institute (https://asi.ucdavis.edu/publications)		All fields	Search string, individual phrases, and individual words

All text fields will be searched in each database where possible. Search string: "filter strip*" OR "riparian area*" OR "riparian forest*" OR "riparian zone*" OR "riparian buffer*" OR "buffer strip*"

found during the searches after removal of duplicates and the number excluded at each stage of the screening process (in a flow diagram), (2) a list of articles excluded at full text with reasons for exclusion of each article/study considered at full-text (in an additional file), and (3) a list of eligible articles/studies (in an additional file).

Eligibility criteria

Articles will be screened based on the following set of eligibility criteria to determine inclusion into the database. Only studies presented in English will be included. The screening process will continue until all studies have been reviewed or one calendar year has passed. To remove any possible bias that may be introduced if all articles cannot be screened within the one year cutoff, the results will be reviewed in a randomized order before review at the abstract level, and then again at the full text level.

Eligible populations or subjects

The focus of this systematic map is on Critical Habitat for freshwater fishes and mussels in Canada, therefore the search will be limited to studies performed in riparian zones and associated waterbodies in Canada or in areas outside Canada with similar climate. Specifically, eligible locations include Boreo-temperate regions as defined by the Köppen-Geiger climate type classification: EF (Ice-cap), ET (Tundra), Dfc (Subarctic), Dfb (Warm-summer humid continental), Dfa (Hot-summer humid continental), Dwc (Subarctic), Dsc (Dry-summer subarctic), Dsb (Warm-summer Mediterranean continental), Cfc (Subpolar oceanic), Cfb (Oceanic), Csb (warm-summer Mediterranean), Bsk (Cold semi-arid) (Fig. 2). Since the study is focused on freshwater species at risk, articles that include research in brackish or salt-water ecosystems or waterbodies affected by tides will not be included. Many studies will not list a

climate zone, therefore geographic locations will be cross-referenced against a map of climate zones [18].

Eligible exposures

For a particular study to be included into the systematic map, it must provide a measure of the size (e.g., width or area) of the riparian zone along with any other riparian attribute. The minimum requirement for a measure of size of the riparian zone is due to the fact that the information will be used to define a geo-physical area, which requires information about the amount of habitat required.

Eligible outcomes

For a primary research study to be included, the effect of riparian attributes on one of the following needs to be addressed: fish or mussel species' functions (e.g., survival, recovery, reproduction), an aquatic feature's attributes,

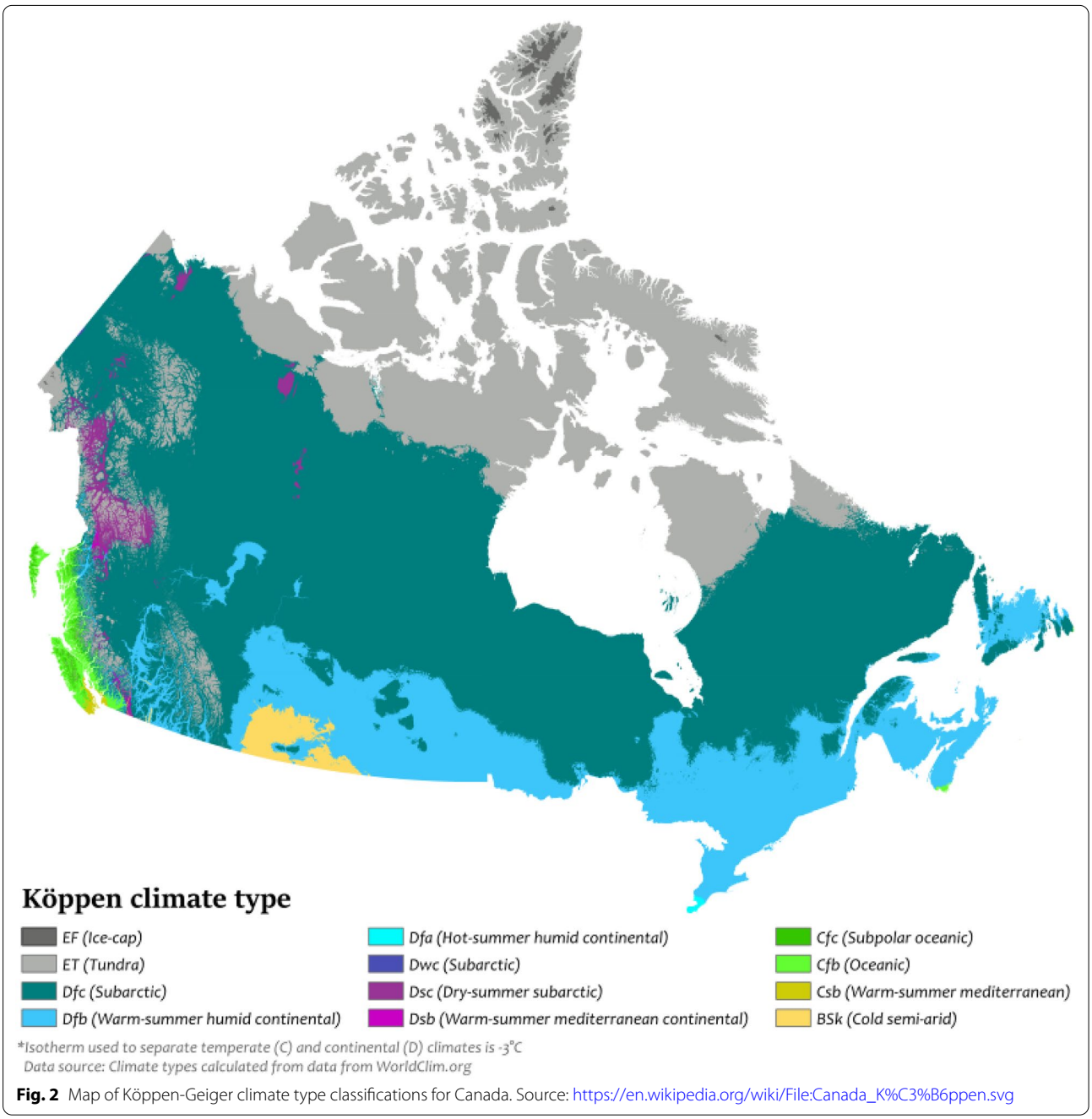

Fig. 2 Map of Köppen-Geiger climate type classifications for Canada. Source: https://en.wikipedia.org/wiki/File:Canada_K%C3%B6ppen.svg

or one of the processes (i.e., erosion, filtration, infiltration, shading, and subsidization). For a modelling study to be included into the systematic map, it needs to present a model that can provide an estimate of the size of the riparian zone required to perform at least one of the processes.

Eligible types of study design

The systematic map will be restricted to primary research studies that involve either a field-based experimental manipulations or observations. Modelling studies that include primary data will also be included into the systematic map; laboratory studies will not be considered. Modelling studies without primary data will be assessed separately.

Study validity assessment

Study validity will be assessed at the full text level. The results of the study will be applied to freshwater ecosystems in Canada, therefore, external validity assessment will be limited to determining if the study was performed in a freshwater ecosystem in Canada or outside of Canada but in regions with Köppen-Geiger climate type classifications found in Canada. The critical assessment of internal validity will be performed using the Collaboration for Environmental Evidence Critical Appraisal Tool to reduce the risk of misleading conclusions [19]. All studies removed after critical appraisal will be listed in a database along with the reasoning, and will be reviewed by at least one other author to ensure consistency. If they obtain different results, then the two reviewers will go through the tool together and come to a consensus.

Data coding strategy

Description of the study location, methods, and outcomes will be extracted from the included studies (studies deemed relevant at full text) and entered into a searchable database that will be included, along with a refined decision tree (Fig. 1) and help file, in the systematic map. The data extracted from the studies will be compared across at least two reviewers to ensure reliable extraction of data. Where differences occur, all reviewers will be provided with clarification of extraction methods. The extracted data records will be made available as additional files.

The following types of information will be recorded for all included studies: study identifiers, year of publication, publication type, study country, data source, data type, study design, species, population(s), intervention, exposure, outcome(s) assessed, sampling strategy, and length/period of study [20] (see Additional File 4 for a complete list).

Potential effect modifiers that will be incorporated in the database (if available) include: the adjacent waterbody type and size; the adjacent land use; recentness of a disturbance, temporal and spatial extent of the disturbance, and annual precipitation.

Study mapping and presentation

Along with the searchable database, we will provide an interactive report as an html file that accesses the database and will be built using the R packages markdown [21] and Shiny [22]. This interactive report will describe the methods, the database, and will allow users to move through the decision tree to be able to determine for any given species or set of aquatic features, what is the best available primary research or models to perform the appropriate analysis to support their determination of riparian Critical Habitat. The systematic map manuscript will describe the methods and database, and provide case studies where the decision tree is applied to three randomly chosen species.

The systematic map manuscript will also provide summaries of the data for each of the secondary questions. Key knowledge gaps will be identified according to decision nodes. If there is not enough information for any of the decision nodes, they will be prioritized for more primary research. Well represented decision nodes will be presented as amenable for full synthesis via systematic review.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13750-021-00231-1.

Additional file 1. Reporting standards for Systematic Evidence (ROSES) Form.

Additional file 2. The original search string used in Web of Science used to create the final search string in all databases.

Additional file 3. Benchmark studies used to determine the comprehensiveness of the search strings used.

Additional file 4. Data coding tool.

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Authors' contributions

AC wrote the protocol draft, AC and TD searched for benchmark studies, EE secured funding, and all authors will actively participate in the searching and screening of potential studies for the systematic map. All authors provided edits and comments and approved the final manuscript protocol. All authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analyzed during this study will be included in the published article and its additional information files. The database will also be hosted on DFO servers to be updated regularly with new studies.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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