Systematic Map Protocol

Title
Collating existing evidence on cumulative impacts of invasive plant species in riparian ecosystems of British Columbia, Canada: a systematic map protocol

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Cumulative impacts, British Columbia, Invasive species, Impacts, Riparian ecosystems, Plant invasions, Foreshore ecosystems, Protocol, Systematic maps

Background
Globally, the structure and functioning of foreshore and riparian ecosystems are being dramatically impacted by non-native invasive plant species. Invasive species can outcompete and replace native species, modify geochemical and hydraulic cycles, alter trophic processes, and change the composition and structure of communities above and below ground. However, these impacts are often investigated in isolation, even though one invasive species might increase or mitigate the impacts of others (i.e. cumulative impacts), potentially with cascading effects. Although cumulative impacts have long been studied within other environmental contexts, research on the cumulative impacts of invasive species is comparatively scarce. We aim to develop a protocol to systematically identify and collate evidence on the individual and cumulative impacts of a set of plant species invasive in foreshore and riparian ecosystems of British Columbia, Canada. Our primary question is: What evidence is available on the individual and cumulative impacts of invasive plants in the riparian and foreshore ecosystems of British Columbia, Canada? In addition, our systematic map will identify the strengths and gaps in knowledge pertaining to invasive plant species impacts in foreshore and riparian ecosystems, with the ultimate goal of facilitating the development of evidence-based management strategies.

Theory of change or causal model
See above.

Stakeholder engagement
Stakeholders provided a list of 10-15 plant species that are invasive in the target ecosystems and geographic areas, thereby aiding in the identification of specific research questions and objectives. Input from practitioners and other researchers helped refine the approach and the methodology. In addition to quantifying the cumulative impacts of plant species invasive to riparian ecosystems, stakeholders have identified two additional aspects as essential. First is the development of a reproducible protocol that can be employed in future systematic studies of invasive species impacts. Second is the investigation of how the cumulative impacts of invasive species will vary under current climate change scenarios.

Objectives and review question
Objective: We aim to systematically collate and map evidence on the individual and cumulative impacts of a selection of plant species invasive to riparian ecosystems in British Columbia, Canada. Primary question: What evidence is available on the individual and cumulative impacts of invasive plants in the riparian and foreshore ecosystems of British Columbia, Canada? Secondary questions: We will describe variations in the research effort with regard to geography, time, invasive species, impacts and their directionality, impacted ecosystem components, type of study, and time.

Definitions of the question components
• Population: Riparian and foreshore ecosystems in British Columbia • Exposure: non-native plant species invasive to riparian and foreshore ecosystems of British Columbia • Comparator: No impact or absence of invasive plant species • Outcome: A synthesis of both the individual and collective cumulative impacts of the selected invasive plant species Secondary questions: We will describe variations in the research effort with regard to geography, time, invasive species, impacts and their directionality, impacted ecosystem components, type of study, and time.

Search strategy
We will conduct multiple systematic searches, one for each of our focus species. For each search, we will use as keywords the scientific name of a species and "impact", formatted for Web of Science (WOS). For example: Elaeagnus angustifolia AND impact* The selected search string is purposely broad. Searches including keywords associated with the target ecosystem (riparian, foreshore, freshwater, wetland, aquatic, etc.) and geographic area (British Columbia, Canada, North America, etc.) were deemed to be too restrictive. A broader search allows for capturing additional studies that either use different keywords or investigate impacts in different circumstances and yet might be relevant to the target ecosystem.

Bibliographic databases
We will conduct searches in WOS, accessing the core database using an institutional licence (University of British Columbia). The core database assigns metadata to a study based exclusively on the information provided by the publisher and journal. Since other databases assign additional metadata to a study, some material might go undetected despite meeting our criteria. We will expand our search to all databases and then refine it to the core collection. This will identify studies that match our keywords across all databases but are only present in the core collection, and thus accessible to the authors. Additionally, we will screen all references in the CABI Invasive Species Compendium factsheet for each species, except for references in the Distribution References section. Review studies that fit the criteria for inclusion will be used as sources as well, and references extracted and screened. We will also scope organization websites across North America at different administrative levels. We will assess international (outside Canada), federal (Canada), provincial (British Columbia) and local (within British Columbia) organizations, searching for the focus species name and the word "invasive". We will conduct the same query in searchable catalogues of government documents. These sources will allow for capturing also the grey literature. WOS identifies dissertations and conference proceedings, especially if expanding searches to all databases, while the CABI, review papers and organizational websites will identify technical reports. Accessing multiple databases will help reduce location and index biases (i.e. not all journals are indexed in all databases, incomplete or poor indexing).

Web-based search engines
Web of Science. See 8 for the search string.

Organisational websites
• CABI compendium • Canadian Weed Society • British Columbia Inter-Ministry Invasive Species

Working Group • Canadian Council of Invasive Species • Invasive Species Centre • Okanagan Basin Waterboard • North American Invasive Species Management Association (NAISMA) • The National Environmental Coalition on Invasive Species (NECIS) • United States Department of Agriculture (USDA) • National Invasive Species Council • All local associations in British Columbia (e.g. Boundary Invasive Species Society, East Kootenay Invasive Species Council, Okanagan and Similkameen Invasive Species Society, etc.) • Canadian Federal Science Library Network • Legislative Library of British Columbia

Comprehensiveness of the search
We tested the comprehensiveness of searches using two pilot species, the Russian Olive (Elaeagnus angustifolia) and the Canary Reed Grass (Phalaris arundinacea). For each species, we selected 5 primary articles, which used a variety of keywords (e.g. impact, effect, alter, change, consequence, see Appendix 1 for the full list). Then, we used the search strings to extract studies from WOS and we extracted references from CABI and review studies for pilot species. All studies were detected by search strings. These two species aided the iterative development of the protocol and will be included in the systematic map.

Search update
The two pilot species will be used for the iterative development of the protocol and will be included in the systematic map.

Screening strategy
The screening process will include two stages. First, we will screen titles and abstracts. If the information is insufficient to make a decision, we will assess the full manuscript as well. These steps will be applied to all studies, regardless of the source they were extracted from.

Eligibility criteria
We will include studies if they: (1) Refer to the non-native invasive plant species searched. We defined as invasive widespread, impactful non-native species (2) Focus on its abiotic and biotic impacts. We defined impacts as measurable changes caused by non-native species on a target ecosystem (3) Investigate such impacts in riparian and foreshore ecosystems. Riparian ecosystems are defined as areas adjacent to streams or rivers (flowing water), while foreshore ecosystems are defined as the land adjacent to still (non-flowing) water bodies (4) within North America (i.e. Canada & U.S.A.) We will include all studies in North America because many environmental conditions and invasive species will be shared between British Columbia and other regions within Canada and the U.S. However, including all studies in North America might capture information not relevant to British Columbia. Such cases will be excluded, and exclusions justified. Similarly, we will justify all other exceptions. We will consider only material in English. To minimize language bias, we will assess the title and abstract if translated into English. Studies were included irrespective of the magnitude, type or directionality of the impact (negative, positive or neutral), and irrespective of the statistical significance of reported results. This will help reduce the prevailing paradigm bias. The time span includes all studies up to the day the search will be conducted, countering temporal bias. Finally, we will include studies regardless of study design.

Consistency checking
A single reviewer will conduct the screening (FM). A random subset of studies will also be assessed by a second reviewer (JP) at both stages (Stage 1 = 5%, Stage 2 = 10%). We will appraise consistency using Cohen’s kappa statistics and set 0.6 as a threshold. If consistency is below the cut-off limit, screening and inclusion criteria will be adjusted for clarity. All disagreements will be discussed and resolved.

Reporting screening outcomes
For each species, we will provide a first database with all studies included at the full-text screening and a reason for exclusions at this stage. A second database with the studies included in the map, along with a ROSES diagram. Included studies will be available also as a public Zotero library of studies included.

Study validity assessment
We assessed the validity of each study based only on the eligibility criteria. We will code the study design.

Consistency checking
We will appraise consistency using Cohen's kappa statistics and set 0.6 as a threshold. If consistency is below the cut-off limit, screening and inclusion criteria will be adjusted for clarity. All disagreements will be discussed and resolved.

Data coding strategy
We will code metadata by compiling them in a distinct data sheet for each species assessed.

Meta-data to be coded
For each study at the full-text screening stage, we will provide the following information: 1. Bibliographic information a) Authors list b) Article title c) Publication year d) Bibliographic source 2. Inclusion criteria a) Exposure: Focuses on target species (Y/N) b) Exposure: Focuses on abiotic and biotic impacts (Y/N) c) Population: Focuses on riparian and foreshore ecosystems (Y/N) d) Population: Within North America (Y/N) 3. Screening stage a) Excluded at full-text stage b) Included c) Exceptions 4. Additional information a) Duplicate (Y/N) b) Notes For included studies only, we will provide also the following information: 1. Bibliographic information a) Authors list b) Article title c) Publication year 2. Information on impacts a) Impact description b) Ecosystem component impacted (e.g. species, soil, etc.) c) Magnitude of impact (more details on this at https://doi.org/10.32942/X26G6K) d) Impact direction (negative, positive, neutral) 3. Additional information a) Geographic region b) Study Design (i.e. field or laboratory experiment, correlation or direct observation) c) Notes We will compile subsection 3c. Exceptions on a case-by-case basis. For included studies, we will provide information by impact so that if a study investigated more than one, there will be a number of entries equivalent to the number of impacts assessed.

Consistency checking
We will appraise consistency using Cohen's kappa statistics and set 0.6 as a threshold. If consistency is below the cut-off limit, screening and inclusion criteria will be adjusted for clarity. All disagreements will be discussed and resolved.

Type of mapping
For each species, we will provide a first database with all studies included at the full-text screening and a reason for exclusions at this stage. A second database with the studies included in the map, along with a graphical representation of the screening process. Both databases will contain corresponding coded metadata (see Data Coding section). We will import studies included in the review into a reference manager and share them as a public library to facilitate accessibility. We will develop a graphical representation of riparian ecosystems, representing identified impacts and their magnitude and directionality for each species. Then, we will create a matrix combining multiple species (as rows) and impacts (as columns) to illustrate the collective impacts of the focus species.

Narrative synthesis methods
Descriptive statistics will be used to answer secondary questions. We will provide the geographic

distribution of studies, visualize publication trends over time, and illustrate differences in species and impacts research efforts. We will use co-occurrence matrices to identify research effort biases (64). Lastly, we will provide a narrative synthesis of results for both main and secondary questions. The narrative synthesis will focus on (i) species and impact prioritization, (ii) clusters and gaps in present knowledge, (iii) predicted variations in impact magnitude and direction under current climate change scenarios, and (iv) avenues for future research.

Knowledge gap identification strategy
We will use co-occurrence matrices to identify research effort biases. See point 12.

Demonstrating procedural independence
Any study authored by one of the systematic reviewers that meets the criteria for inclusion will be assessed by the other reviewer at every stage of the process.

Competing interests
N/A

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Author's contributions
FM drafted the protocol with input from JP and CM. All authors read and approved the final manuscript.

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References
Please, see the full list of references at https://doi.org/10.32942/X26G6K

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