Collaboration for Environmental Evidence

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Systematic Map Protocol

Title
What evidence exists on the measures and outcomes of ecological restoration for areas impacted by mining activity in Canada? A systematic map protocol

Citation:
Sonia Andreea Voicescu, Jimmy Clifford Oppong, Larissa Bron. What evidence exists on the measures and outcomes of ecological restoration for areas impacted by mining activity in Canada? A systematic map protocol: a Systematic Map Protocol. PROCEED-24-00230 Available from: https://proceedevidence.info/protocol/view-result?id=230
https://doi.org/10.57808/proceed.2024.12

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Keywords
Mining, ecological restoration, Canada, monitoring, systematic map protocol

Background
Increased pressures from a changing climate have highlighted the need for more pragmatic approaches to restoration of industrial landscapes. In Canada, the mining industry has left a large footprint on the landscape, which continues to grow as the demand for mining products increases worldwide. Federal and provincial regulatory requirements call for mining companies to have a program in place to recover land that has been affected by mining activity. While these programs have been operating for decades, not much is known with regards to what constitutes successful or failed restoration outcomes in mined landscapes. Information provided by mining companies is often dispersed through provincial databases, and published research has not been synthesized. A lack of consensus within the restoration field on what constitutes successful (or failed) ecological restoration further challenges the identification of actions that can lead to successful recovery. Barring two review papers on restoration success conducted by Ruiz-Jean and Aide (2005) and Wortley et al. (2013), and a systematic map on Canadian ecological restoration research (Alamenciak et al., 2023), no attempt has been made to systematically assess the breath and distribution of evidence on the measures and outcomes of ecological restoration at mined sites, specifically for the Canadian context. A lack of synthesized knowledge can prevent decision-makers within the Canadian mining industry to plan and prepare for long-term closure activities at mined sites. The goal of this study is to compile evidence on the outcomes of restoration activities at mined sites and the indicators that have been used to measure the recovery of those areas. As mining will continue to be an important sector within the Canadian economy, this systematic map can assist stakeholders and policy-makers in the management of mined landscapes by providing them with a data repository relevant to their context.

Theory of change or causal model
Mining activities, by nature of their operations, inherently impact the land and resources in which they are undertaken. In order to allow for multiple land uses post-mining, it is important to plan for effective restoration strategies throughout the life cycle of a mining project. Canada is a leading country in terms of extraction and processing of mineral and metal resources (NRC, 2023). Information on the outcomes of restoration activities and the indicators used to measure recovery can help decision-makers in this country plan for long-term sustainable use of mined landscapes (see

Figure 1 for a visualization of the impact pathway).

Stakeholder engagement

The motivation for this synthesis stems from the review team lead's PhD dissertation project. The research seeks to map the state of the knowledge on measures and outcomes of ecological restoration in Canada, as it applies to mined landscapes. The main review team (SAV, JCO, LB) collaborated in formulating the review question, constructing the search strategy, and developing eligibility criteria. Three Canadian academics in the fields of ecological restoration, environmental management, and mining policy were consulted in the identification of benchmark articles and refining the search strategy. The search strategy was also reviewed by a research librarian and a team of seven graduate students. It is expected that consultation with academics and graduate students will continue throughout the review process. Further stakeholder engagement is anticipated via conference presentations and meetings with interested parties. Feedback from these consultations will be incorporated into project outputs and dissemination of results.

Objectives and review question

The objective of this systematic map is to search the evidence base in order to identify, summarize, and map the measures and outcomes of ecological restoration activities at mined areas in Canada. The review question is : What evidence exists on the measures and outcomes of ecological restoration for areas impacted by mining activity in Canada?

Definitions of the question components

Population: Canadian mined areas. For this evidence synthesis, mining is defined as the extraction, refining, or processing of mineral and metal resources, and a mine is considered to be the physical location associated with mining activity. Intervention(s): Ecological restoration activities. In the context of this systematic map, ecological restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004, Gann et al., 2019). This includes active and passive restoration, and activities that aim to recover both ecological and social components of an ecosystem, as well as ecological functions and services (Miller and Bestelmeyer, 2016). This definition encompasses the full spectrum of practices that fall under the “big tent” of restorative activities (Murphy 2018). Comparator(s): Different ecological restoration activities for the same mined area with or without a control, Before-After-Control-Impact activities. Outcome(s): Any measure or outcome of ecological restoration activity.

Search strategy

This search strategy is based on methods outlined in Guidelines and Standards for Evidence Synthesis in Environmental Management version 5.1 (Collaboration for Environmental Evidence, 2022). Only sources in English will be considered, as the review team is not fluent in French, the other official language in Canada. This will create limitations to data representation from sources in that language. An exploratory search was performed in May 2023 by the team lead through Google Scholar to select a diverse set of benchmark publications. This list was finalized through discussions with the main review team and academic experts (see "Benchmark articles" document). Ulrich’s Periodicals Directory (2023) was used to determine which databases index the journals that published all benchmark articles. After eliminating redundancies, it was determined that Web of Science, Scopus, and Environment Index provided full coverage for all identified benchmark articles. A series of search strings were designed and tested with these databases from August to October 2023 until all benchmark articles were captured (see “Search strings” document). Other sources of information include: ProQuest Dissertations & Theses (through the Web of Science interface) to identify relevant theses and dissertations, Google Scholar for supplementary researching (up to first 300 results, as per Haddaway et al., 2015), Canada Commons, OAIster, Government of Canada related websites, and other organizational websites (see sections 8.2. and 8.3.). Reference back-

checking will be performed for all included studies, and additional sources that result from this process will be screened by the main review team.

Bibliographic databases

Four bibliographic databases will be searched as described below: 1. Web of Science Core Collection : This includes Science Citation Index Expanded (1900-present), Social Sciences Citation Index (1900-present), Arts & Humanities Citation Index (1975-present), Conference Proceedings Citation Index-Science (1990-present), Conference Proceedings Citation Index-Social Science & Humanities (1990-present), Book Citation Index-Science (2005-present), Book Citation Index-Social Sciences & Humanities (2005-present), Emerging Sources Citation Index (2018-present). Subscription provided by the University of Victoria. Search performed in English and search options include title, abstract, and author-supplied keywords. 2. ProQuest Dissertations & Theses Citation Index (1637-present). Search performed through Web of Science interface. Subscription provided by the University of Victoria. Search performed in English and search options include topic (title, abstract and subject). 3. Scopus: Subscription provided by the University of Victoria. Search performed in English and search options include title and abstract. 4. Environment Index: Subscription provided by the University of Victoria. Search performed in English and search options include title, abstract, author-supplied keywords and subject headings. See attached "Search strings" document for detailed database search strings.

Web-based search engines

Three web-based search engines will be used for this systematic map: 1. Google Scholar: Given limitations (Boeker et al., 2013) Google Scholar will only be used for supplementary researching. Search performed at the title level in English. First 300 articles will be examined as per Haddaway et al., 2015. 2. OAIster: Open-access search engine used for grey literature searching. Search performed in English and search options include title, subject, and keyword. 3. Canada Commons: Government of Canada search engine, used for grey literature searching. Search performed in English and search options include title and summary. See attached "Search strings" document for detailed search strings.

Organisational websites

38 organizational websites will be searched as part of this systematic map. Details pertaining to websites names and language searches are provided in the attached "Organizational websites list" document.

Comprehensiveness of the search

A list of 24 benchmark articles known to be eligible for this systematic map was determined through an exploratory search in Google Scholar and discussions with the main review team and academic experts. Key search terms were mined from these articles and included in the search strategy. The search strategy was then tested iteratively between August and October 2023 and revised with each identified database until all benchmark articles were returned through the search. Search string variations were discussed with the main review team and a research librarian, which improved and refined the search strategy until the final search combinations were shown to capture all benchmark articles. The 100% retrieval rate of benchmark articles was chosen to ensure comprehensiveness of the search and determine that search strings were optimized to capture the most relevant articles.

Search update

As per Collaboration for Environmental Evidence (2022) guidance, there is a plan for a search update if the time between the initial search and submission of the report for publication exceeds two years.

Screening strategy
Dual screening of all sources for this systematic map will be completed by three independent researchers (SAV, JCO, LB) in two steps: 1) Title and abstract screening 2) Full-text screening All three researchers will perform title and abstract screening as well as full-text screening. Screening will be completed in the following order: primary literature, grey literature, web-based search engines, organizational websites. When multiple versions or iterations of a same study exists ("linked articles" as per CEE, 2022), all sources will be kept until full-text screening, if relevant. Linked articles will be grouped together, and the most up-to-date information will be extracted. True duplicates will be manually removed. Screening of all sources will be conducted through the Covidence platform for review management (https://www.covidence.org/). More information on screening methodology is provided in 9.1-9.3 below.

Eligibility criteria
Publications will be screened according to specific PICO and study design criteria as detailed in the attached "Eligibility criteria" document.

Consistency checking
A team comprised of three independent researchers (SAV, JCO, LB) will perform the screening. All studies will be independently screened by at least two reviewers in the following proportions: -JCO and LB will each screen 50% of sources -SAV will screen 100% of sources Any conflicts that arise between two reviewers will be resolved through discussion and consensus, where possible. If the conflict persists, the third reviewer will be consulted for a final decision. To test consistency at the screening stage, three pilots were conducted in which a total of 150 articles (50 articles/pilot) were screened at the title and abstract level. Pilot screening was performed until agreement levels reached 75% between each reviewer pair and Cohen's Kappa (κ) values were greater than 0.4 (Altman, 1991, JBI, 2020, Cochrane, 2023). A series of pilots (10 articles/pilot) will also be undertaken for full-text screening prior to engaging with that level of screening. Pilots will be completed until 75% agreement is reached between each reviewer pair and Cohen's Kappa is greater than 0.4 (Altman, 1991, JBI, 2020, Cochrane, 2023).

Reporting screening outcomes
The outcomes of the screening process for this systematic map will be reported through a ROSES flow chart diagram (Haddaway, 2020). This diagram will provide a record for the number of sources assessed, accepted, and rejected at each stage. A list of articles included for full-text screening will be provided as supplementary material in the final publication. This list will highlight all included articles for data extraction as well as excluded articles along with reasons for exclusion.

Study validity assessment
A study validity assessment is not planned for this systematic map.

Consistency checking
N/A

Data coding strategy
A data coding spreadsheet was developed by the main review team. Metadata from each evidence source that meets inclusion criteria will be extracted and reported into this form (see attached "Data extraction form"). Two pilots will be conducted as part of the data coding strategy. The first pilot was completed before protocol submission by all members of the main review team, on three randomly chosen benchmark articles (JBI, 2020). The goal was to refine and finalize the data extraction sheet and identify any disagreements. The second pilot will be finalized prior to data coding by all members of the main review team, on three randomly chosen included articles (JBI,

2020). The goal is to ensure proper implementation of data coding and verify coding consistency. Following this pilot, data coding will be performed by at least two independent reviewers from the main review team on 10% of all included publications. Disagreements will be discussed and resolved through consensus, and the coding form may be revised as a result of this process. Metadata from the remaining included sources will be extracted and coded by the review team lead (SAV). Accuracy checks will be performed periodically on an additional 10% of those solo-coded sources by another member of the main review team (JCO or LB). If a high level of inconsistency is revealed either through initial dual coding or through accuracy checks, coding will pause and further pilots will be implemented until agreement levels between reviewer pair reach 75% (JBI, 2020).

Meta-data to be coded

Metadata from each evidence source that meets inclusion criteria will be extracted and coded into a data extraction spreadsheet. Coded data will include bibliographic information (e.g. publication type, year, author, title, etc.), PICO-related elements (type of mine/mineral, location of mine, type of restoration treatment, measured restoration variables, etc.), as well as information required to answer the study question (target restoration goals, type of restorative activity, time since recovery, etc.). For complete details on metadata components that will be extracted, please see the "Data extraction form" document in supplementary materials.

Consistency checking

To verify coding consistency, a pilot test will be implemented prior to data coding on three randomly chosen screened-in articles. These articles will be coded by all members of the main review team. Any inconsistencies that may arise at this stage will be discussed, and the data extraction form will be modified based on resulting consensus. Inconsistencies will be represented by the number of fields in the data extraction sheet, aside from bibliometric information, in which a change was required by a second reviewer. Piloting will continue until 75% agreement is reached between each reviewer pair (SAV and JCO, SAV and LB). Once piloting is completed, dual coding will be performed on 10% of all included publications by the main review team. Coding of these articles will be completed in the following proportions: -LB and JCO will each code 50% -SAV will code 100% The remaining 90% of included publications will undergo extraction and data coding by the review team lead (SAV). Accuracy checking will be performed periodically on an additional 10% of those solo-coded sources by another member of the main review team (JCO or LB). In all cases where disagreements arise from this process, they will be discussed and solved through consensus. If high inconsistencies are revealed at any stage of this process, data coding will pause, and the data extraction sheet will undergo further piloting until 75% agreement is reached between reviewer pair (JBI, 2020).

Type of mapping

Coded metadata resulting from this systematic map will be presented in tabular and graphical formats. This will include tables and charts created via Microsoft Word and Excel programs, graphs and figures generated through data visualization and analysis software such as R, and maps developed through the integration of Geographical Information Systems (GIS) platforms such as Google Maps and QGIS. Key characteristics based on PICO elements (section 7.1) from each included publication will be summarized and displayed within these visualizations. A written manuscript will be provided along with the systematic map, detailing the methods, results, discussion, and implications derived from this evidence synthesis. Data from this project will be uploaded onto Borealis, a Canadian Dataverse Repository, accessed through the University of Victoria (https://webapp.library.uvic.ca/databases/details.php?id=1213). An Open Science Framework (OSF, https://osf.io/) page will also be created for this project, and a link to the Borealis project page will be provided, along with other study materials and visualization products.

Narrative synthesis methods
Narrative synthesis for this systematic map will be presented through tabulation of the coded variables from included studies. As suggested in James et al. (2016), descriptive statistics will be employed to describe the main characteristics of included publications and provide a context for the distribution and abundance of collected evidence. Examples of variables expected to show trends include geographic parameters (province, mine location, etc.), mining-related data (type of mineral/metal mined, type of mining, size of disturbance, etc.) and restoration-based information (type of restorative activity, indicators measured, etc.). The evidence base will also be displayed via graphs, figures, and maps as stated in section 12 above. A narrative report that includes the rationale behind the systematic map, the detailed methodology at all stages of the process, recommendations based on identified knowledge gaps, and implications for policy and decision-making, will be produced alongside data visualizations.

Knowledge gap identification strategy
Mapping the evidence base on this topic will allow for the identification of knowledge gaps to emerge through the various presentations and analyses of data as described in sections 12 and 12.1. These gaps can take the form of underrepresented geographical areas in Canada in which there is a lack of research on the topic, or underrepresented restoration parameters or treatments, as well as underrepresented mine types or mineral/metal mined. Identifying these knowledge gaps will be of use to decision-makers, policy developers, and stakeholders in the mining industry in Canada, by providing information on areas and topics that may require additional research and support.

Demonstrating procedural independence
None of the review team members have authored articles that will be considered for this systematic map.

Competing interests
The authors of this evidence synthesis declare that they have no competing interests.

Funding information
There are no sources of funding to declare for this systematic map.

Author’s contributions
SAV conceptualized the study and led data management. SAV, JCO, and LB collaborated on the search strategy: SAV led the development of search strings, JCO and LB reviewed and provided feedback on additional key terms to include. SAV, JCO, and LB all contributed to pilot screening. SAV prepared the first draft of the data extraction form, JCO and LB assisted with reviews and modifications. SAV, JCO, and LB all contributed to data coding piloting. SAV prepared the first draft of this protocol, JCO and LB reviewed it and provided revisions. All authors read and approved the final version of this protocol manuscript.

Acknowledgements
The review team would like to acknowledge Dr. Zahra Premji, Health Research Librarian at the University of Victoria, for her assistance in reviewing search strings and providing valuable feedback to this protocol.

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Submitted: May 1, 2024 | Published: May 22, 2024