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REGISTERED REPORT STAGE 1

Approaches and methods used to bring together Indigenous and Environmental science Knowledge in environmental research: A systematic map protocol

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Abstract

1. The bringing together of multiple knowledge sources, such as Indigenous knowledge (IK) and Environmental science Knowledge (ESK), is a topic of considerable interest and significance in environmental research. In the areas of resource management for example, the bringing together of IK and ESK datasets has raised considerable interest for its potential to increase understanding and provide insights into complex phenomena such as the effects of climate change and variability on wildlife health and distribution.
2. The potential benefits that exist from merging these knowledge sources have been widely acknowledged. However, navigating the complex processes involved in knowledge linking continues to pose significant challenges. This systematic mapping protocol will guide the collection and analysis of literature to examine the approaches and methods used in published studies that aim to bring together Indigenous and Environmental science Knowledge in environmental research. The particular focus of this examination is placed on identification of the types of approaches and methods used to merge IK and ESK datasets at the stages of data analysis, results, and interpretation/discussion in the research process.
3. Through a scoping exercise, a draft search string was developed based on a predetermined list of keywords. Consultation was held with a senior Indigenous scholar to advise on the keywords used and consideration for IK likely to be represented in the collected literature. The final search string will be applied to online bibliographic databases to collect studies published in peer-reviewed journals. The final capture of the search will be screened in two stages: (1) at the level of title and abstract and (2) at full-text.
4. All studies included will be coded using a standardised coding template and a narrative synthesis approach will be used to identify patterns in the evidence, including knowledge gaps and clusters.
5. *Practical implication*: The resulting systematic map, following the outlined procedures in this protocol and considering guidelines from the Collaboration for

Environmental Evidence (CEE) and Reporting standards for Systematic Evidence Syntheses (ROSES), can serve to support and inform future research endeavours engaged in working towards the linking of IK and ESK, with practical implications for communities and policymakers.

KEYWORDS
decision-making, ecological research, environmental management, Indigenous Knowledge, policy, science, systematic map

1 | INTRODUCTION

1.1 | Background

The bringing together of Indigenous Knowledge (IK) and Environmental science Knowledge (ESK) bases has been a topic of interest within academic research, natural resource management and Indigenous communities for some time (Turnbull, 2003). In the areas of natural resource management for example, the bringing together of IK and ESK has raised considerable interest for its potential to increase understanding and provide insights into complex phenomena such as the effects of climate change and variability on wildlife health and distribution (e.g. Gagnon & Berteaux, 2009; Hauser et al., 2021). The recognition of the role of multiple knowledge systems in sustainable resource management and biodiversity conservation has led to various international reports and agreements, such as The Brundtland Report, The Convention on Biodiversity, and Agenda 21, emphasising the importance of engaging and incorporating knowledge held by Indigenous peoples for more informed environmental policy and decision-making processes (Higgins, 1998; Tengö et al., 2017). Effective wildlife and resource management practices require a holistic and accurate understanding of ecosystem dynamics and must also reflect the needs of resource users involved/affected (Gilchrist et al., 2005; Huntington, 2000; Laidler, 2006; Russell et al., 2013). Furthermore, it has long been considered imperative to recognise the role that active and equitable engagement of Indigenous peoples can play in advancing environmental research and decision-making, fostering inclusivity and promoting collaboration between knowledge systems and holders (McGregor, 2000).

Subsequently, there have been numerous articles published in the field of environmental sciences and studies attempting to link both Indigenous and Environmental science Knowledge (see Table 1 for definitions). The processes involved in knowledge linking are complex and should not be viewed with a one-size-fits-all perspective (Bohensky & Maru, 2011; Johnson et al., 2023). This study recognises that there are many levels of knowledge linking; different methods and approaches exist at each level; and that there is overlap between and among linking levels or phases.

Various studies have explored knowledge linking across different stages of research, ranging from project design and collaboration, to research methodology, and data collection (Figure 1a). For example, researchers such as Thornton and Scheer (2012), Castleden et al. (2017), Stefanelli et al. (2017) and Henri et al. (2021) have focused primarily on identifying methods and approaches related to knowledge linking taking place at the level of project design and collaboration. Additionally, Castleden et al. (2017), Stefanelli et al. (2017),

TABLE 1 Definitions of key concepts.

Indigenous Knowledge
Indigenous Knowledge, as part of a larger system of knowledge, can be defined as 'a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relation of living beings (including humans) with one another and with their environment' (Berkes et al., 2000). According to Battiste (2019), Indigenous Knowledges are 'diverse learning processes that come from living intimately with the land, working with resources surrounding that land base, and the relationships that it has fostered over time and place' (p. 33). Indigenous Knowledge has also been commonly referred to in the academic literature as Traditional Ecological Knowledge and Indigenous Science (Cajete, 1999).
Environmental science Knowledge
Environmental science Knowledge, a field of science, which is part of a broader system of knowledge that can be traced back to the philosophical traditions of ancient Egypt, India, China and Greece, as well as the more recent Renaissance (Mazzocchi, 2006). This knowledge is represented by various models of inquiry, such as classical, hypothetico-deductive and pragmatic approaches. Although it is often associated with Eurocentric worldviews and epistemologies (Aikenhead & Ogawa, 2007) and commonly referred to as "Western Scientific Knowledge" within the environmental studies and sciences literature, the authors acknowledge that science is not inherently Western (Raju, 2009) and will use the term "Environmental science Knowledge" throughout.
Knowledge linking
Knowledge linking has been commonly referred to in the academic literature as Knowledge bridging, merging, weaving and braiding (Johnson et al., 2016) and can occur at one or more stages of the knowledge production process. For the purposes of this study, knowledge linking can be broadly defined as any planned and/or purposeful undertaking of the bringing together of Indigenous and Environmental science Knowledge as represented by data generated through epistemological processes accepted within each knowledge system. This definition is inclusive of that put forth by Johnson et al. (2016) on co-production of knowledge, including Indigenous Knowledges, and by Alexander et al. (2021) when speaking of knowledge bridging. The focus in this paper is more specific than each of these though in that we examine this phenomenon at the stage of interconnected analysis of data originating from the two knowledge systems and therefore clarify our use of the term "linking" here.

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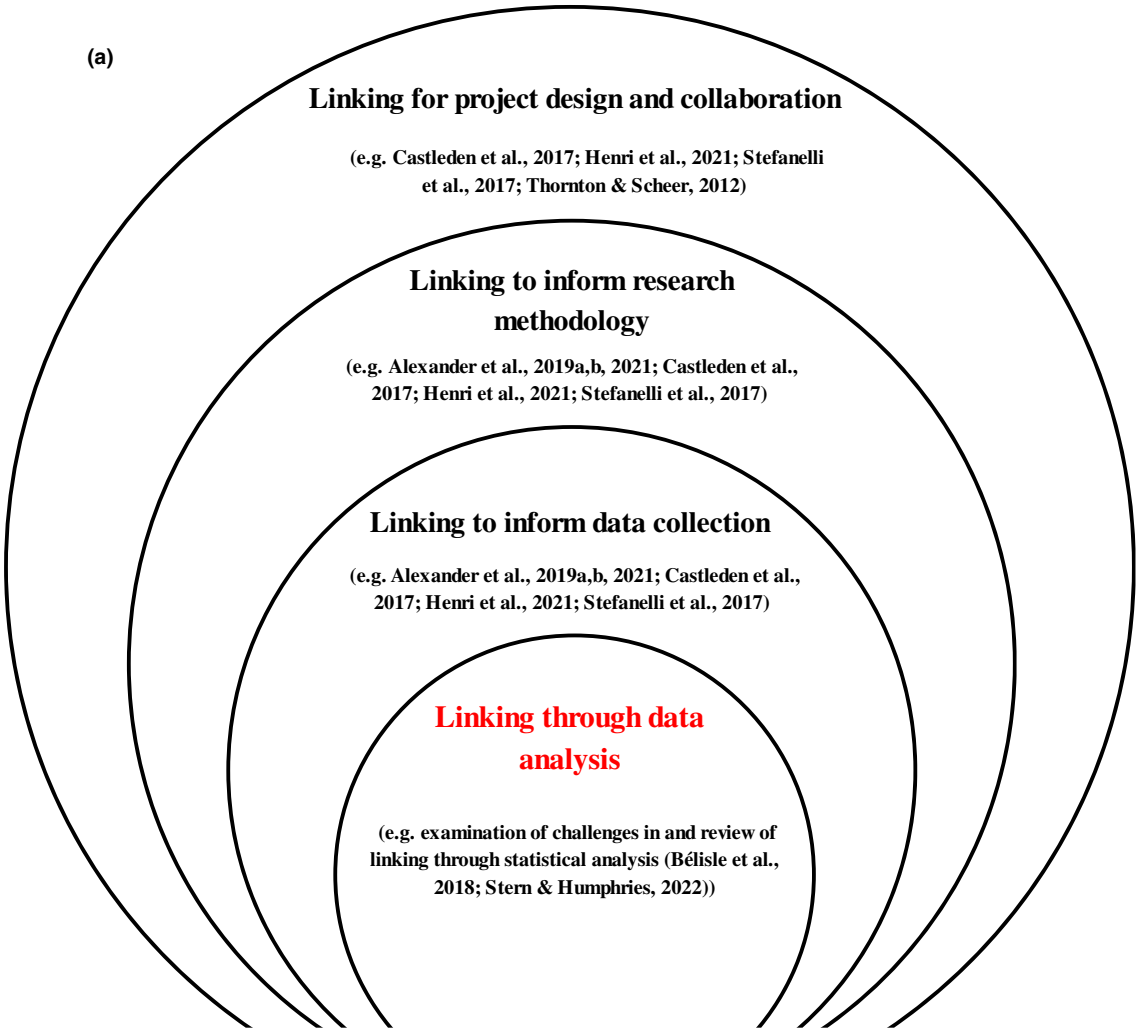

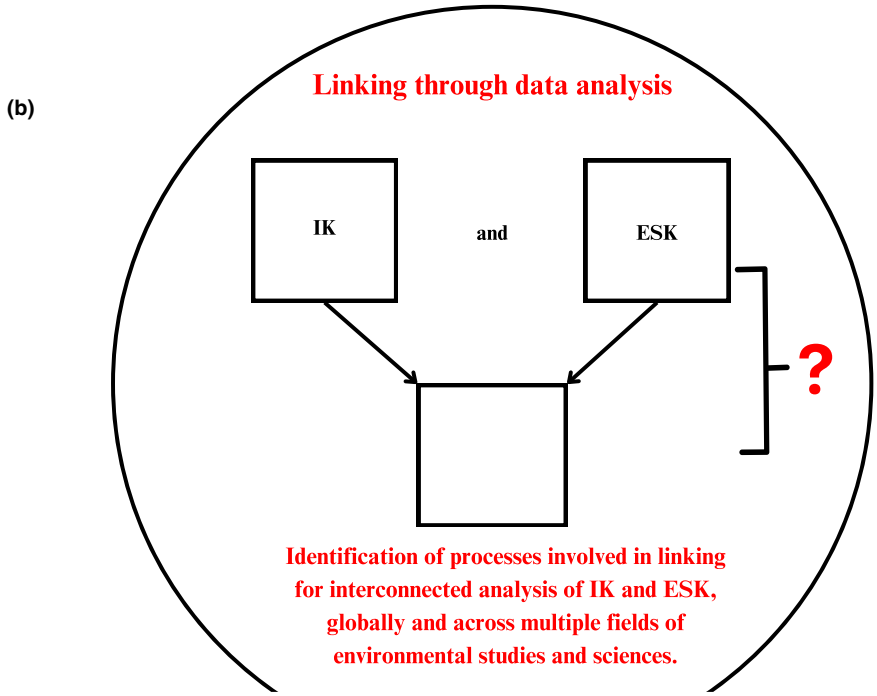

FIGURE 1 (a) Examples of work that have explored and examined aspects of knowledge linking at various stages of the research process. (b) Focus of the proposed review and its intended contribution to the literature.

Alexander, Provencher, Henri, Taylor, and Cooke (2019), Alexander, Provencher, Henri, Taylor, Lloren, et al. (2019), Alexander et al. (2021) and Henri et al. (2021) have explored knowledge linking within the context of approaches and methods for data collection as they relate to water or terrestrial research and management. Bélisle et al. (2018) examined how common challenges to local ecological knowledge (LEK) inclusion in ecological modelling have been confronted in the literature, while Stern and Humphries (2022) reviewed the methods used to weave experiential wildlife knowledge into quantitative, mixed methods analyses of population and habitat models.

The current work extends this research to further explore the processes involved in linking IK and ESK, but specifically at the stage of data analysis, presentation and interpretation, and across multiple fields of environmental studies and sciences around the globe (Figure 1b).

Many different methodological approaches, methods and techniques have been developed and used in different regions around the world for the purposes of bringing together IK and ESK at various stages of the research process and this number continues to grow. The diversity highlights the complex nature of IK and ESK knowledge interaction in environmental research. In support of the ongoing importance of fostering meaningful engagement of both Indigenous and environmental science knowledges in research, and in recognition of the existence of multiple levels of knowledge interactions, the aim of this systematic map is to contribute to this existing body of literature and support ongoing research using or further exploring ways to bring together these knowledges to address important environmental challenges. This will be done by using a systematic mapping approach to identify and examine the approaches and methods used in published studies from around the globe that aim to bring together Indigenous and Environmental science Knowledges within the fields of environmental studies and sciences, with particular emphasis on methods and approaches used for data analysis, results and interpretation/discussion stages of the research process.

1.2 | Primary research question and objectives

This work is guided by the question: What approaches and methods do peer-reviewed papers in the field of environmental studies and sciences use to bring together Indigenous Knowledge (IK) and Environmental science Knowledge (ESK) during the data analysis, results and/or discussion stages of the research process? In this study, we will employ a systematic mapping approach to categorise and classify key aspects of existing research papers within the scope of our investigation. It is the intent of this protocol to outline the methodology for the conduct of a systematic map. In contrast to systematic reviews, our methodology will concentrate on organising and thematically describing the available literature, without the need for data synthesis or evaluating the quality or validity of individual studies, as outlined by Collaboration for Environmental Evidence (CEE) (2018). This approach is particularly suited to the broad objectives and scope of our work. This method will allow us to provide a comprehensive overview of the research landscape, identifying general study characteristics (e.g. publication year, geographic distribution, focus of study, etc.) and key approaches and methods used to bring together IK and ESK, specifically those used at the stage of data analysis, results and discussion in the research process.

TABLE 2 Description of eligibility criteria.

Population
In recognition of the growing diversity of literature available and considering the time constraints of this systematic map, our focus will be limited to peer-reviewed studies that focus on any aspect of ecological or environmental research. For the purpose of this review, ecological or environmental research will be defined broadly as any planned and/or purposeful inquiry pertaining to the environment, including those studies examining the environment as a determinant of human health.
Study intent
Articles that purposefully and actively bring together Indigenous Knowledge (IK) and Environmental science Knowledge (ESK) and present empirical results will be included. Specifically, we will consider articles that incorporate both IK and ESK components, offering empirical evidence to support the merging of IK and ESK datasets. Our inclusion criteria will be further refined to include papers that have employed some form of a convergent parallel design. Review papers and articles proposing frameworks for merging IK and ESK without accompanying empirical assessments will be excluded.
Geographic scope
The geographic context for this systematic map will include all geographic areas identified within the final capture.
Language
English.

1.3 | Components of the research question

For this protocol and the resulting systematic map, description of identified and explored articles will include the following components (see Table 2 for more details):

- *Population*: Articles within the fields of environmental sciences and studies.
- *Study intent*: Articles that aim to bring together both Indigenous Knowledge and Environmental science Knowledge.
- *Geographical scope*: There will be no geographic limit applied to this search.

2 | MATERIALS AND METHODS

2.1 | Author positionality

The authors recognise the importance of disclosing their positionality, shaped by their personal, social, cultural and political context, as it can significantly influence their perspective, interpretation and

analysis of the research topic (Creswell & Poth, 2016). This acknowledgment not only adds transparency to the research process but also enhances the quality and rigour of qualitative research methods used.

Emma Pirie is a non-Indigenous researcher who currently works alongside faculty and postdoctoral researchers at Trent University to identify research and monitoring projects involving Indigenous communities around the Laurentian Great Lakes in an effort to support Indigenous-led research and conservation efforts. Ms. Pirie is a graduate student and research assistant with Trent University's Indigenous Environmental Institute.

Dr. Tom Whillans is a non-Indigenous scholar who has researched and taught about community-based co-management, cogeneration of knowledge and restoration of fisheries, wetlands, biodiversity, watersheds and lakes since 1972. He has had experience applying local, Indigenous and Environmental science Knowledge in the Northwest Territories, Ontario, the Great Lakes and Latin America. Currently Professor Emeritus in the School of the Environment, Trent University, he Co-Chairs the Committee of Advisors of the Great Lakes Fishery Commission, sits on the Ontario Biodiversity Council, and Boards of the Anishinabek/Ontario Fisheries Resource Centre, Watersheds Canada, and Haliburton U-Links.

Dr. Jennie Knopp, a non-Indigenous researcher, has worked on bridging the gap between different knowledge systems and fostering collaboration between Indigenous and Environmental science Knowledge through her work on harvesting, conservation, and monitoring projects. With over 15 years of experience in the Canadian Arctic, Dr. Knopp has actively engaged with communities, local experts, co-management boards, researchers, land claim organisations and federal government departments. Dr. Knopp currently holds the position of Community and Science Director with Oceans North.

Dr. Chris Furgal, a non-Indigenous scholar, has been involved in research activities in partnership with Indigenous communities across the Arctic and elsewhere for over 30 years. Research activities he works on with and for communities focus on environmental health risk monitoring and assessment, food security and climate change, and knowledge mobilisation and communication. Dr. Furgal is currently an Associate Professor at Trent University where he is the Associate Director of the Chanie Wenjack School for Indigenous Studies, and Co-Director of the Indigenous Environmental Studies and Sciences Program and Indigenous Environmental Institute.

In our collective work and engagement at the intersection of Indigenous Knowledge (IK) and Environmental science Knowledge (ESK) within environmental sciences and studies, our team brings together unique perspectives and experiences. We recognise the importance of enhancing understanding of and bringing clarity to the complex nature of knowledge interactions of a variety of forms. As a team, our work on these topics is influenced, informed and enriched by our interactions and learning with our Indigenous colleagues with whom we work in partnership on a daily basis, and in particular for this project, our colleague and senior Onondaga Scholar, Professor David Newhouse. Embracing this perspective, our commitment lies in fostering inclusive dialogue, promoting mutual understanding and advancing collaborative efforts working towards the bringing together of multiple knowledge systems, such as IK and ESK in academic research.

2.2 | Systematic maps

Systematic mapping approaches can be used to synthesise, categorise and classify all available evidence pertaining to a specific research question/objective (CEE, 2018). The systematic mapping protocol presented in this manuscript provides a transparent and replicable method to capture and synthesise evidence in a standardised and systematic manner (Haddaway et al., 2016). This proposed systematic mapping protocol considers guidelines provided by CEE (2018) and follows the standards of ROSES (i.e. adhering to and completion of ROSES form; Supporting Information 1; Haddaway et al., 2018).

2.3 | Searching for articles

Using four online bibliographic databases, this search aimed to capture all relevant studies in the peer-reviewed literature that relate to the primary research question. The scope of this map report was limited to documents written in the English language as translation capacity is limited. Articles included will be limited to the range of database date coverage as well as the date of final capture.

2.3.1 | Search string development

A list of keywords and synonyms informed by the primary research components were compiled in order to begin the development of a search string. The web-based search engine Google Scholar was used as an aid to scope out keywords and related synonyms. Various keywords and synonyms were compiled and combined using Boolean Operators (AND, OR, NOT) and wildcard characters in order to assess the sensitivity of possible search terms and combinations within the online bibliographic database, Web of Science. Search terms were separated into three groups, guided by the primary research components, and combined using Boolean Operators "AND" and/or "OR" and the proximity indicator "NEAR/#" (Supporting Information 2). Keywords were included if they resulted in the addition of any number of relevant sources relating to the primary research question. A list of benchmark articles ($n = 15$; Supporting Information 3), identified through hand searching, was used to ensure relevance and comprehensiveness of the search string. These benchmark articles are representative of the diversity of parameters (i.e. linking Indigenous Knowledge and Environmental science Knowledge within the fields of environmental studies and sciences) included in the search string protocol. It is expected that the search protocol will capture the benchmark articles. If the benchmark articles are not captured with

the search protocol, the search protocol will be revised or picked up by hand searching as necessary.

2.3.2 | Bibliographic database searches

A total of four databases were searched for peer-reviewed articles in the English language. The final search string was developed in Web of Science and was standardised and adapted to each database. Search abilities and capacities for each database were considered when determining whether to include or exclude a database; for example the batch export function and capacity, the coverage and extent of research topics included in each database (e.g. disciplinary focus), and the range of publication dates included in the database. The search was conducted until no further relevant articles were found. The following databases will be searched using subscriptions from Trent University:

1. EBSCO*host* Academic Search Elite: a multidisciplinary database that offers full text for scholarly journals covering several areas of academic study including social sciences, sciences and humanities.
2. EBSCO*host* Bibliography of Indigenous Peoples in North America (BIPNA): a bibliographic database covering all aspects of Indigenous Peoples in North American culture, history, and life and including topics such as archaeology, multicultural relations, gaming, governance, legend and literacy.
3. ISI Web of Science (Core Collection): multidisciplinary database consisting of various subject areas including science, social sciences, and arts and humanities.
4. ProQuest International Bibliography of Social Sciences (IBSS): a bibliographic database for social science and interdisciplinary research.

2.4 | Screening articles and eligibility criteria

2.4.1 | Screening process

Results from the online bibliographic databases will be exported into Endnote 20 and duplicates removed before stage 1 of the screening process. Remaining sources will then be screened in two stages: (1) at the level of title and abstract and (2) full-text analysis.

Stage 1: Title and abstract screening

The title and abstract for each study will be screened for relevance during stage 1. Any studies that fully or partially align with the inclusion criteria (see eligibility criteria below) will proceed to stage 2 of the screening process. Articles which do not align with the primary research question will be excluded at this level. To test the consistency of the screening process, the two reviewers, EP and CF, will independently screen the same subset of titles and abstracts (5%) and compare results. The selection of a subset of articles will be made by choosing articles from varying disciplines and publication years to ensure diverse representation. A training phase will be undertaken prior to the independent screening where the two reviewers will meet to practice, discuss and adapt the eligibility criteria on 100 test titles and abstracts.

Stage 2: Full-text analysis

This stage will involve a manual search and review of entire articles. In order to ensure eligibility criteria are consistent across and applicable to captured articles, a subset of articles (10%) will be selected and screened independently by EP and CF. The selection of a subset of articles will take place by choosing articles from varying disciplines and publication years to ensure diverse representation. The two reviewers will meet to compare their results, discuss and adapt the eligibility criteria as necessary. Similar to stage 1, a training phase will be undertaken prior to the independent screening where the two reviewers will meet to practice, discuss and adapt the eligibility criteria on 50 test full texts. The goal of these meetings will be to ensure both reviewers have a clear understanding of the eligibility criteria and their application.

A list of excluded articles and reasons for exclusion at the level of full-text review will accompany the resulting systematic map report.

2.4.2 | Eligibility criteria

A set of pre-established inclusion/exclusion criteria will be used to guide the screening process (Table 2). All inclusion criteria will need to be met in order for an article to be included in the final dataset.

2.5 | Study validity assessment

It is not the intention of this systematic map to assess the validity of identified articles.

2.6 | Data coding strategy

Following the full-text screening (stage 2), remaining studies will be exported from Endnote 20 into Microsoft Excel where they will be coded using a pre-established and standardised coding template (see Supporting Information 4). The template was designed to reflect and capture key information about the articles based on multiple parameters, including:

1. Bibliographic information.
2. Geographic location of study.
3. Discipline of study.
4. Methods used to collect IK and ESK.
5. Linking approach segments from the article.
6. Categorical identification of linking approach and method used in data analysis (informed by linking approach segment from the article).

7. Location in the research process where evidence of linking is reported.
8. The study's stated intent or purpose of bringing together IK and ESK.

In order to avoid misrepresentation of articles while coding, missing information regarding any of the parameters will be coded as Unspecified.

For extraction of information identifying the aim or goal of the linking of data from the IK and ESK datasets, as well as the analytical process used to link them (items 5, 6 and 8)—a comprehensive examination of each article will be conducted. This examination will include a thematic content analysis, wherein every section of the article, including captions and other details contained in figures and tables, will be reviewed. The identification and categorisation of content pertaining to items 5 and 6 (above) will be guided by the following questions:

1. How is each individual dataset being analysed?
2. How and where in the research process (and paper) are the results of individual dataset analyses being connected with each other? Is there anything that is being done to each dataset to facilitate interconnection (i.e. transformation of data before merged analysis)?
3. How and where are the linked results presented and interpreted in the paper?

Data from all included articles (i.e. each article remaining after full text screening) will be coded using the standardised coding template. A series of data coding sessions will take place between the primary reviewer, EP, and a secondary senior reviewer, CF. In the first session, coding will be tested on a sample of 15 articles during a face-to-face meeting. This meeting will ensure that each reviewer understands the metadata to be extracted from each article and any adaptations to this list. Following this, EP and CF will each independently code a test sample of 30 articles. They will then compare their interpretations of the extracted data. Discrepancies will be carefully examined and discussed, leading to any necessary adjustments to the coding strategy. In the final phase, EP will proceed to code all articles, with CF verifying any identified as being challenging or questionable to code. This process will be done to ensure the accuracy and consistency of the coded data.

2.7 | Study mapping and presentation

Study characteristics (such as year of publication, geographic distribution, discipline of study) and approaches and methods used to bring together IK and ESK at the stages of data analysis, results and discussion, will be coded, analysed and presented through the application of a narrative synthesis approach, using thematic content analysis and descriptive statistics (Saldaña, 2021). Results of analysis will be presented in tables and figures and knowledge gaps and clusters will be highlighted through the use of a framework-based synthesis using structured matrices (Alexander, Provencher, Henri, Taylor, & Cooke, 2019; Dixon-Woods, 2011; McKinnon et al., 2016). The final output will include a published systematic map.

3 | DISCUSSION

This mapping exercise aims to produce a protocol and systematic map that will identify the approaches and specific methods used to bring together IK and ESK in published scientific articles within environmental research, with particular emphasis on the stages of data analysis, results and interpretation / discussion steps in the research process. The growing methodological complexity that exists in bringing together these diverse knowledge systems, presents a unique opportunity to provide an identification of the types of approaches and methods being used to bring together IK and ESK data through interconnected data analysis, presentation and interpretation of results. If we are to adopt appropriate approaches and methods in future research and decision-making and leverage the opportunities that arise from accessing multiple knowledge systems pertaining to a particular issue, learning from any attempt is critical. By identifying and analysing studies, which have aimed to bring together IK and ESK, the results of this study will yield a unique resource for researchers and policy makers and support ongoing efforts that recognise the opportunities involved in engaging with multiple knowledges in environmental research and management.

AUTHOR CONTRIBUTIONS

The project was conceived by Emma Pirie and Chris Furgal. The manuscript was drafted by Emma Pirie. Chris Furgal, Tom Whillans and Jennie Knopp provided comments and revisions. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.12351.

DATA AVAILABILITY STATEMENT

This article does not contain data.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supporting Information 1. ROSES form for systematic mapping protocols.

Supporting Information 2. Search strings.

Supporting Information 3. Benchmark list.

Supporting Information 4. Coding template.

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