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REGISTERED REPORT STAGE 2

Weaving Indigenous knowledge systems and Western sciences in terrestrial research, monitoring and management in Canada: A systematic map

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Abstract

1. Over the last decades, a growing body of work within environmental science disciplines has sought to co-produce projects led by, or conducted in partnership with, Indigenous communities to ensure more equitable and effective outcomes for biodiversity conservation. Inherent to knowledge co-production is the weaving of Indigenous knowledge systems and Western sciences, a process that emphasizes respect and dialogue, mutual learning, collaboration, holistic understanding, as well as practical outcomes and adaptability.
2. This systematic map aims to compile and summarize studies that have woven Indigenous knowledge systems and Western sciences in research, monitoring and management conducted across terrestrial ecosystems in Canada.
3. We identified a total of 177 case studies dating from 1988 to 2021. Approximately 82% of all the articles were published between 2005 and 2020, with a significant expansion of Indigenous authorship observed since around 2005.

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4. Across the case studies, we found reports on 14 species (including birds, mammals and plants) and 19 ecosystems with a high number of cases coming from northern Canada.
5. First Nations and Inuit knowledge holders were most represented across the case studies. While many studies did not report on the gender or age of Indigenous knowledge holders, Elder contributions were reported in most cases and youth involvement appeared limited.
6. We found 14 distinct methods used to gather Indigenous knowledge and the same number of Western scientific methods to collect biotic or abiotic data. Community-based participatory research was the most common weaving methodology employed.
7. There were a wide range of research outputs and outcomes reported for Indigenous communities across the systematic map including: (i) informing biodiversity management; (ii) having Indigenous knowledge used in decision-making; and (iii) increasing interest in Indigenous knowledge from scientists.
8. *Practical implication*. This systematic map can be drawn upon by environmental research and management practitioners to help ensure that new initiatives are synergistic and that professionals entering the space of knowledge weaving have a comprehensive understanding of the recent landscape in Canada, including the importance of place-based and contextual practices.

KEYWORDS
biodiversity conservation, evidence map, Indigenous knowledge, knowledge co-production, literature review, terrestrial ecosystems

1 | POSITIONALITY STATEMENT

We are researchers of Indigenous (Métis and First Nations) and non-Indigenous ancestry who study a variety of topics through community-based participatory research, including animal behaviour, conservation practices, environmental justice and wildlife health. We come from a diversity of departments within the Government of Canada and academia, with backgrounds in natural sciences and environmental social sciences working on Treaty One territory and the homeland of the Red River Métis, Anishinaabe and Haudenosaunee territory, Kanien'kehá:ka territory, Quw'utsun territory, Syilx Okanagan territory, Treaty Five territory homeland of the Swampy Cree, Sayisi Dene, Métis and Inuit. We approach this work as a group of community-engaged researchers dedicated to exploring practices around co-produced research that supports collaborative work with Indigenous communities. Our goal is to provide insights and recommendations to improve research partnerships in weaving knowledge systems to ensure they are grounded in reciprocity, accountability and alignment of the values and priorities of Indigenous partners.

2 | INTRODUCTION

Globally, over the last decades there has been a groundswell of work within environmental disciplines aiming to co-produce projects led by, or conducted in partnership with, Indigenous communities to ensure more equitable and effective research outcomes for biodiversity conservation (Yua et al., 2022; Norström et al., 2020). Inherent to the knowledge co-production process is the bringing together of key values and practices associated with multiple knowledge systems (related to knowledge co-evolution; Chapman & Schott, 2020). Knowledge systems broadly refer to formal and informal systems that are used to generate and manage information and knowledge; they encompass the methodologies, social mechanisms, technologies and practices that support and sustain knowledge within institutions, communities or society at large (Cornell et al., 2013; Orlove et al., 2023). Indigenous and Western sciences may be conceptualized as particular ways of knowing rooted in empirical methods and embedded within knowledge systems (Johnson et al., 2016).

Knowledge generated within different systems can be brought together through ‘knowledge weaving’, a process which emphasizes respect and dialogue, mutual learning, collaboration, holistic understanding, practical outcomes and adaptability, among other grounding principles, while respectfully maintaining the integrity of each system (Henri et al., 2021; Johnson et al., 2016; Menzies et al., 2024). We employ the term ‘knowledge weaving’ in this paper while acknowledging that this expression is not the only way to describe how knowledge systems (and the knowledge generated within them) interface with one another (see also knowledge ‘bridging’ or ‘braiding’;

Alexander, Provencher, Henri, Taylor, & Cooke, 2019; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019; Kimmerer, 2015; Wilcox et al., 2023).

The joining of knowledge gained through multiple knowledge systems is not a new practice. However, the study and elucidation of the concept and process itself in the context of Western environmental sciences (see also 'Eurocentric sciences' from Aikenhead & Ogawa, 2007: 543) and Indigenous knowledge systems began at the end of the 20th century (Agrawal, 1995; Berkes, 2018). Since then, numerous studies from Africa, Asia, Oceania, South America, Europe and North America have documented how Indigenous ways of knowing need to be mobilized alongside Western environmental science approaches to support epistemic equity and inclusive decision-making (Ban et al., 2018; Jessen et al., 2022). These studies have helped highlight a rich set of practices that can be used to further the field of knowledge weaving. In Canada, the application of Indigenous knowledge systems in Western-based approaches to environmental research dates approximately back to the 1970s in the context of environmental assessments for natural resource projects (Berger, 1977; James Bay and Northern Quebec Agreement, 1975).

Indigenous Peoples is a broad term used to describe the original inhabitants (and their descendants) of the lands that are now within present-day Canada, and include First Nations, Métis, and Inuit, each with their own defining cultures, histories, languages and heritage (Younging, 2018). Indigenous Peoples have deep and longstanding relationships with and knowledge of the lands, waters and wildlife they have stewarded for generations (Indigenous Circle of Experts, 2018; McGregor, 2004). It is critical, however, to acknowledge the disruptive and harmful impacts that settler colonialism has had on Indigenous Peoples living across Canada. For example, large scale land dispossession, residential schools, criminalization of subsistence (e.g. Kulchyski & Tester, 2007) and spiritual practices and systemic discrimination have led to the dual loss of intergenerational knowledge and languages (TRC, 2015). In addition, extractive research operating without free, prior and informed consent has fuelled mistrust and led to concentration of power in the hands of researchers and research institutions (Reid et al., 2024; Wong et al., 2020). These historical and ongoing colonial harms play a foundational role in the research and decision-making systems in which this systematic map is conducted and are key to understanding why more ethical and equitable research practices are urgently required. In its final reporting, the Truth and Reconciliation Commission of Canada was clear that '[w]ithout truth … there can be no genuine reconciliation' (TRC 2015, cited in Reid et al., 2024: 595). As such, grounding research in 'truth' about the deep historical roots of the ongoing issues and effects that stem from settler colonialism supports reconciliation with Indigenous Peoples.

In recent years, the development of equitable knowledge-bridging frameworks explicitly requiring shared decision-making among Indigenous and non-Indigenous research partners has shaped knowledge weaving practices in environmental research in Canada (McMillan & Prosper, 2016; Pedersen et al., 2020; Reid et al., 2021; Tengö et al., 2014). For example, Two-Eyed Seeing (*Etuaptmumk* in Mi'kmaw, conceptualized by Elder Albert Marshall from the teachings of Chief Charles Labrador of Acadia First Nation; see Bartlett et al., 2012) refers to seeing from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to use both of these eyes together. The values underpinning the powerful act of Two-Eyed Seeing when approaching environmental challenges compel participants not to focus on just filling in information gaps, but to be critical of their own paradigms, collectively uphold the strengths of those paradigms and transform new knowledge into ongoing action in responsibility to all beings (Reid et al., 2021).

Over the past few decades, Indigenous-led initiatives and advocacy, reconciliation efforts and an increased understanding of the value of multiple knowledge systems have resulted in growing acknowledgement of the importance of Indigenous perspectives not only in environmental research, but in the policies that influence research in Canada. This recognition has been reflected in collaborative and interdisciplinary research initiatives, policy frameworks, as well as in research funding guidelines within Canada. Each of these factors and their roles in further shaping the landscape of knowledge weaving in environmental research, including terrestrial research and monitoring, are discussed below.

A growing respect for both the process and the outcomes that result from embracing epistemic pluralism in biodiversity research and conservation is a likely contributor to an increasing interest in knowledge weaving in terrestrial research, monitoring and management. Epistemic pluralism refers to the respect for and promotion of different ways of knowing, and the recognition that 'there are many fundamentally different, genuinely alternative epistemic systems' of equal standing, where none is more correct than another (Carter, 2017: 4). Knowledge gathered within different knowledge systems can provide complementary, deep, and holistic understandings of the natural world (Tengö et al., 2014). For example, in British Columbia, longstanding Indigenous knowledge held by Indigenous Peoples about fish body size and abundance greatly extended Western scientific baselines for yelloweye rockfish, as well as for other data-poor species (Eckert et al., 2018, as cited in Kadykalo et al., 2021). In Nunavut, Inuit and scientific knowledge gathered at complementary spatial and temporal scales yielded a better understanding of the local ecology of the Arctic fox and the Greater Snow Goose (Gagnon & Berteaux, 2009).

Within Canada, the legal and policy landscape has been characterized by a growing recognition of the importance and value of Indigenous knowledge systems in environmental research and decision-making. For example, the assent of the United Nations Declaration on the Rights of Indigenous Peoples Act in 2021 serves to align Canadian federal law and policy with the United Nations Declaration on the Rights of Indigenous Peoples (United Nations, 2007) and will continue to have a profound and far-reaching impact on how environmental sciences are practiced in Canada. Many federal acts also explicitly require the engagement and consultation of Indigenous Peoples and the inclusion of Indigenous knowledge systems in environmental decision-making (e.g. Canadian Environmental Protection Act, 1999, c. 33; Impact Assessment Act, 2019, c. 28, s. 1; Migratory Birds Convention Act, 1994, c. 22, and Parksville Protocol; Oceans Act, 1996, c.31; Species at Risk Act, 2002, c. 29). The Government of Canada has provided guidance to support the consistent application of provisions related to Indigenous knowledge in these acts through the Indigenous Knowledge Policy Framework (Government of Canada, 2022). However, it must be noted that acts and policies vary in how directive and specific they are on the extent to which Indigenous knowledge systems should be considered in research and decision-making which may limit how meaningful they are and the likelihood that they are applied to environmental governance (Claxton, 2019). Furthermore, many Canadian policy frameworks continue to embed settler colonial power dynamics, where mandates for 'consultation' or 'knowledge inclusion' often fail to shift actual decision-making authority away from the state or settler institutions (e.g. Eckert et al., 2020).

Changing norms in research and monitoring funding structures have also been reshaping the research landscape towards practices that support epistemic equity across Indigenous and Western knowledge systems. For example, the Canadian federal government is the main source of funding for many academics through the Tri-Council (the umbrella term for Canada's three main federal research agencies: the Canadian Institutes of Health Research [CIHR], the Natural Sciences and Engineering Research Council of Canada [NSERC] and the Social Sciences and Humanities Research Council of Canada [SSHRC]). In recent decades, the Tri-Council has established policies and guidance that emphasize respectful and ethical engagement with Indigenous communities and provide funding for research that is led by Indigenous scholars, as well as work that includes Indigenous knowledge with other ways of knowing (CIHR, NSERC and SSHRC, 2022).

As non-Indigenous researchers seek meaningful collaboration with Indigenous partners and respond to changing norms by actively weaving multiple knowledge systems in research, there is a need to learn from past and ongoing efforts. There is currently a need to map the landscape of methods and practices applied to weaving knowledge systems in a region, within a community or applied to species or ecosystems to ensure that new work can be undertaken in a way that considers synergy, co-learning and growth. In doing so, knowledge weaving can contribute to future research in an informed way that is beneficial for all partners.

Systematic mapping is a way to rigorously, objectively and transparently 'collate, describe and catalogue available evidence' within a research space (James et al., 2016). Previous work on knowledge weaving using systematic mapping has focused on case studies of coastal and freshwater habitats in Canada (see Alexander et al., 2021a, 2021b; Alexander, Provencher, Henri, Taylor, & Cooke, 2019; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019). To date, understanding patterns on how knowledge systems are brought together in the Canadian terrestrial landscape has not been examined systematically and comprehensively. Given that Canada is the second largest country in the world by landmass and encompasses 26 ecoregions that span from the Carolinian forests to the Arctic tundra, from deserts to rainforest, and is the ancestral lands and current home of approximately two million First Nations, Métis and Inuit, there is a rich diversity of experiences rooted in knowledge weaving studies that can help academic, Indigenous and community researchers in their work. The objective of this project was to compile, collate and summarize studies that have woven Indigenous knowledge systems and Western sciences in terrestrial research, monitoring and management in Canada to elucidate any patterns and identify gaps in research approaches. By providing a comprehensive summary and baseline analysis of work, we reduce duplication of efforts by researchers. We use the systematic mapping technique as a tool to explore patterns and insights in knowledge weaving studies, including where case studies prioritize Indigenous Peoples and knowledge in the work. In doing so, we aim to elevate research grounded in epistemic pluralism and reciprocity and support practices through which Indigenous knowledge systems can be equitably woven with, not assimilated to or subsumed by, Western sciences.

3 | MATERIALS AND METHODS

This systematic map followed methods outlined in the a priori systematic map protocol (Stage 1 report; Henri et al., 2021). Our methods involved the application of standardized search terms and inclusion criteria, a two-stage screening process, systematically coding the published studies using a standardized questionnaire, followed by a narrative synthesis to summarize findings and insights (sensu Popay et al., 2006). This systematic map followed the guidelines provided by the Collaboration for Environmental Evidence (2018) and ROSES reporting standards (Haddaway et al., 2018; Supporting Information S1).

3.1 | Searching for articles

We applied standardized English search terms across four publication databases focused on peer-reviewed publications, carefully selected specialist websites and one web-based search engine. Database-specific search strategies, date ranges and number of returns can be found in Supporting Information S2. Two supplemental searches were performed including one comprehensive Google Scholar search (the top 500 results were exported) as well as calls for evidence that were circulated among professional networks, social media, co-management boards and Aboriginal Aquatic Resource and Oceans Management organizations.

3.2 | Screening process and eligibility criteria

Articles were screened with a priori eligibility criteria (Table 1). At title and abstract, 577 articles were screened by a subset of reviewers, and inter-reviewer agreement was assessed (Table 2, row 1). All discrepancies were discussed, and a separate subset of reviewers helped reconcile differences and modify inclusion criteria as required. Following consistency checks, 110 articles were again screened at title and abstract by five reviewers to ensure strong inter-reviewer agreement prior to moving to full-text screening (Table 2, row 2).

Following this first stage of screening, the remaining articles were screened at full-text. Prior to commencing on this second stage of screening, two rounds of full-text consistency checks were carried out by a subset of reviewers (Table 2, rows 3 and 4). Given the number of reviewers and time constraints, the decision was made to move forward with individual screening when the full review team was confident in their understanding of the eligibility criteria.

During full-text screening, reviewers identified any articles they were unsure of as 'second opinion'. These articles were discussed with the full review team at weekly meetings to obtain consensus on eligibility before moving forward. A full list of articles excluded at full-text and their reason for exclusion can be found in Supporting Information S3. Note that empirical studies focused on environmental/ecological research and monitoring needed to weave biological or ecological data (collected through Western natural science methods) and Indigenous knowledge (mostly gathered through Western social science methods) in order to be included; therefore, research and monitoring studies applying Western social science approaches to document Indigenous ecological knowledge only (i.e. with no biological or ecological data) were excluded (see 'Study design' criteria in Table 1 and Supporting Information S3).

TABLE 1 Description of eligibility criteria guiding article screening.

Population
Articles that concern all terrestrial ecosystems (e.g. grasslands, prairies, forests, woods, mountains, taiga, tundra, terrestrial components of watersheds, marshlands), habitat or species (including birds, mammals, herpetofauna, insects, plants and fungi). Articles involving resource management (i.e. silviculture, soil, agriculture) were only included if outcomes were directly related to biodiversity or ecosystem health. Studies reporting process optimization (e.g. timber production, harvest techniques) were excluded.
Study design
Articles that report empirical results (either qualitatively or quantitatively) where knowledge combining or weaving practices and/or methods are discussed or inferred. Empirical studies included fell into one of three broad categories: (1) studies focused on environmental/ecological research and monitoring (i.e. those reporting on direct or indirect observation or experience from Indigenous knowledge systems and Western natural sciences; to be included studies needed to include biological or ecological data and Indigenous knowledge); (2) studies focused on the processes and practices of bringing knowledge systems together in the context of environmental decision-making; and (3) studies concerned with perceptions of ecological or environmental phenomenon that weave Indigenous knowledge systems and Western sciences (e.g. perceptions of ecosystem services).
Geographical scope
Articles including case studies conducted within Canada's jurisdictional boundaries, as well as cases where traditional Indigenous territories transcend contemporary nation-state boundaries (i.e. the Canada-United States border).
Language
English.

3.3 | Study validity assessment

As described in the Stage 1 report (Henri et al., 2021), the study validity of articles was not appraised.

3.4 | Data coding strategy

Coding and data collection was completed at the case study level rather than the article level because an article could contribute more than one case study when the purpose of the article is comparing multiple cases (e.g. Gilchrist et al., 2005). A standardized coding questionnaire was used to collate responses and ensure cross-coder consistency. The review team extracted data from a subset of five articles (3% of those included at full-text). Coding decisions were reviewed by the review team (EB, JRS, LRJ, CC, DAH, JFP, AAEW). Any discrepancies were reconciled, and clarifications were made to the coding form before moving forward. Any uncertainties during coding were collectively discussed by the review team during weekly meetings to obtain consensus on codes.

TABLE 2 Consistency checks for article screening. Consistency checks were performed twice at each the title and abstract screening text to improve consistency scores.

Screening stage	Subset of articles	Inter-reviewer agreement	Reviewers
Title and abstract 1	577 (5% of the articles included)	90%–95%	CC, JFP, JRS, EB
Title and abstract 2	110 (1% of the articles included)	91%–96%	CC, JFP, JRS, EB, DAH
Full-text 1	18 (4% of articles retrieved at full-text)	Substantial variance[a]	EB, JRS, OHD, CC, DAH, JFP
Full-text 2	10 (2% of articles retrieved at full-text)	70%–100%	EB, JRS, OHD, CC, DAH, JFP, AAEW

[a]A total of 77 questions were coded by reviewers. There was too much variation in agreement in our initial full-text coding of all questions to quantify agreement.

3.5 | Data mapping and presentation method

The terrestrial systematic map included two central outputs: (1) composite geographical maps showing the distribution of case studies; and (2) a coded database that informed our narrative synthesis of the data.

To produce the composite geographical maps to look for trends related to case study locations, we used an ArcGIS Web Application to create polygons that approximated the studies' spatial extent. For 127 of the 177 articles, the polygons were based on a figure of the case study area published in the article. For the other 50 articles that did not provide a figure, other sources of information were used to approximate the study area. For example, the article by Robinson (2010) looks at the Likely/Xat'sull Community Forest as a case study for local resource management. They did not provide a study area figure in the article, but a figure was found online that delineated the boundaries of the Likely/Xat'sull Community Forest. Some articles had more than one study location for which we created separate study area polygons. This resulted in a total of 248 study area polygons.

The geodatabase file with the study area polygons was converted to a raster heatmap in R 4.2.2 using the 'rasterize' function from the raster package (v3.6–20; Hijmans et al., 2023). We used ArcGIS Desktop 10.8.1 to convert the polygons into centroids and to perform geospatial analyses. We used the Jenks Natural Breaks classification method to identify logical polygon size thresholds and omitted polygons larger than 120 million hectares (Mha). Excluding these large polygons, which represented pan-Arctic or national-scale studies, ensured that the centroids provided the geo specificity needed for accurate spatial analyses, such as identifying the number of studies that took place within each ecoregion. After removing the large polygons, we created 226 centroids to represent the approximate location of the study areas.

Consistent with the Stage 1 report (Henri et al., 2021), we generated a database (i.e. list of articles, associated meta-data and the coded categorical values; see Henri et al., 2026) to inform a narrative synthesis (Popay et al., 2006) in which we explored evidence gaps and trends in the data. We relied on descriptive statistics, figures and tables (generated in base R) on the metrics of article publication year and type, Indigenous authorship (as disclosed by the authors), Elder participation, the age group and gender of knowledge holders and the ecological level of focus (ecosystem, community and/or species). We used data from our coded database to generate a Sankey data visualization using the publicly available package *networkD3* in R (Allaire et al., 2017) to analyse the Indigenous and Western science methods used in the articles and how they were brought together across studies. Using framework-based synthesis as a guide, we generated a structured matrix using *ggplot2* (Dixon-Woods, 2011; Wickham, 2016) to explore the number of links between Indigenous and Western science methods used in the articles. When analysing weaving methods, we employed the term 'Indigenous sciences' intentionally as a way to highlight equity across knowledge systems, recognizing that Indigenous sciences are embedded in Indigenous knowledge systems (Johnson et al., 2016; Liboiron, 2021). The input for the Sankey visualization and structured matrix were case studies focused on 'research and monitoring' only ($n=91$); we omitted publications focused on the processes and practices of weaving knowledge systems in the context of environmental management and decision-making for that component of the analysis because both the structure (e.g. the type of data that is reported) and intent of 'management and decision-making' articles were different from 'research and monitoring' papers. The structure of the management articles precluded coding all of the same elements that can be coded in research and monitoring papers; structure was also not consistent among management articles.

4 | RESULTS

4.1 | Article search

The article searching, screening and synthesizing process is depicted in the ROSES flow diagram in Figure 1. Searches of four bibliographic databases and Google Scholar resulted in 12,088 records upon removal of duplicates. About 423 records of the 12,088 were retained after being screened for relevance at the title and abstract level. About 408 full-text articles were retrievable for screening through open access, Carleton University institutional subscriptions, or interlibrary loan services. After a full-text screening, 122 articles remained within the scope of this systematic map (Figure 1). The most common reasons for exclusion at full text included failing to meet the 'population' criterion (i.e. articles did not report findings on research, monitoring or management related to terrestrial ecosystems, habitat or species) or the 'outcome' criterion (i.e. articles did not include Indigenous knowledge and Western natural sciences data [biological or ecological data]). Excluded articles and the rationale for their exclusion can be found in Supporting Information S3. We included an additional 52 pre-screened articles/studies that originated from specialist and supplemental sources (e.g. grey literature, organizational websites, reference lists of relevant reviews and supplementary articles). In total, the systematic map database and narrative synthesis represents 174 articles or 177 case studies (Figure 1; Henri et al., 2026).

4.2 | Geographic distribution of case studies

The composite map shows the distribution of the case studies across Canada at the national and sub-national level (Figure 2a,b). Case studies are also found in the United States of America in Alaska, Washington, New York, Maine and Montana,

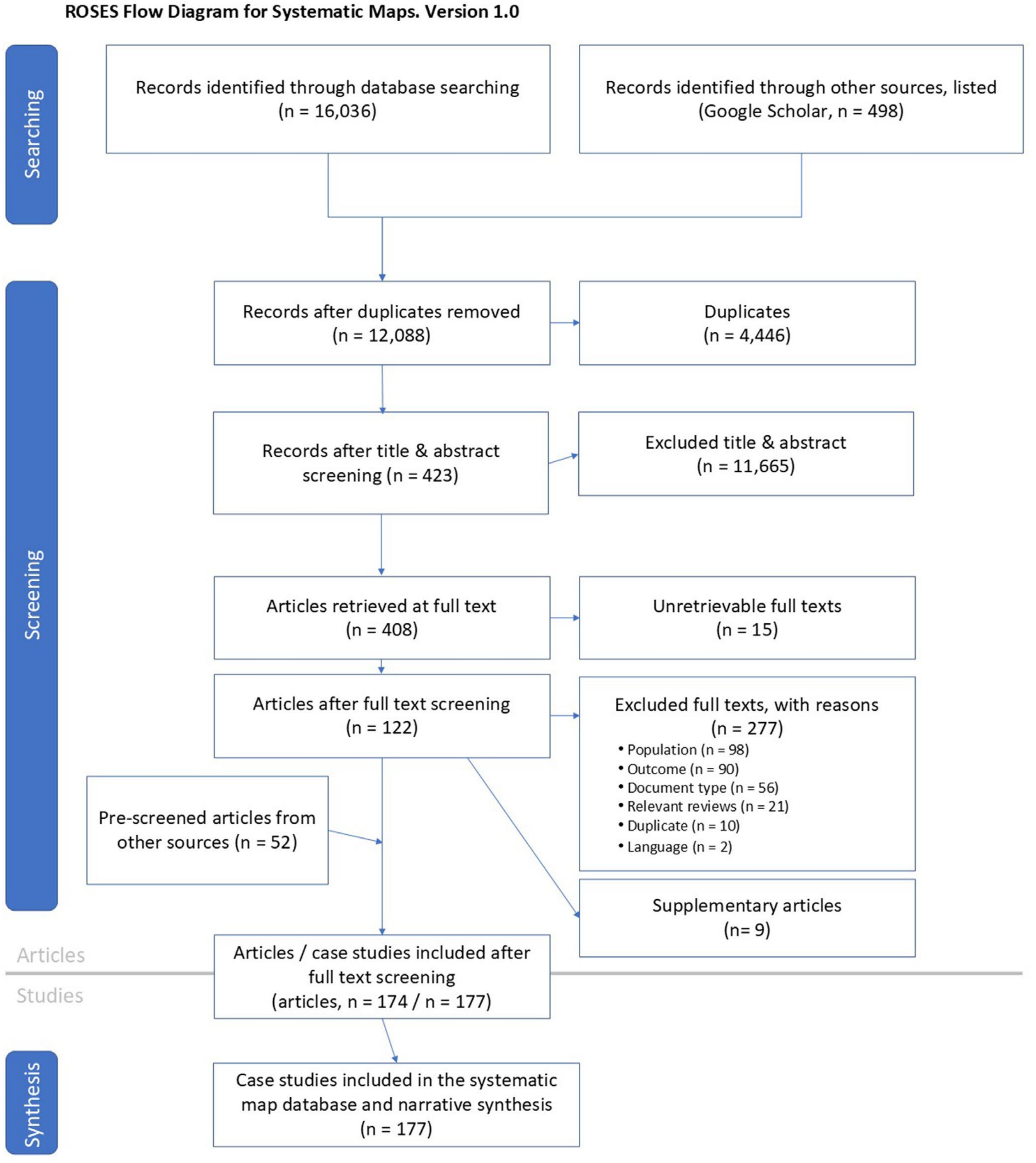

FIGURE 1 ROSES flow diagram depicting article search and screening process.

close to the Canadian national border, as well as a single case study in Greenland (Figure 2a,b). There is a clear concentration of study areas in Nunavut with the highest study activity in the Kivalliq region on the western coast of Hudson Bay (Figure 2a) and inland in the Southern Arctic ecoregion (Figure 2b). Studies are also concentrated in the Arctic Cordillera and Northern Arctic Region on the coastal areas of Baffin Bay, Cumberland Sound, Frobisher Bay and Hudson Strait. In terms of Canadian provinces, the fewest number of case studies are found in Saskatchewan and Nova Scotia.

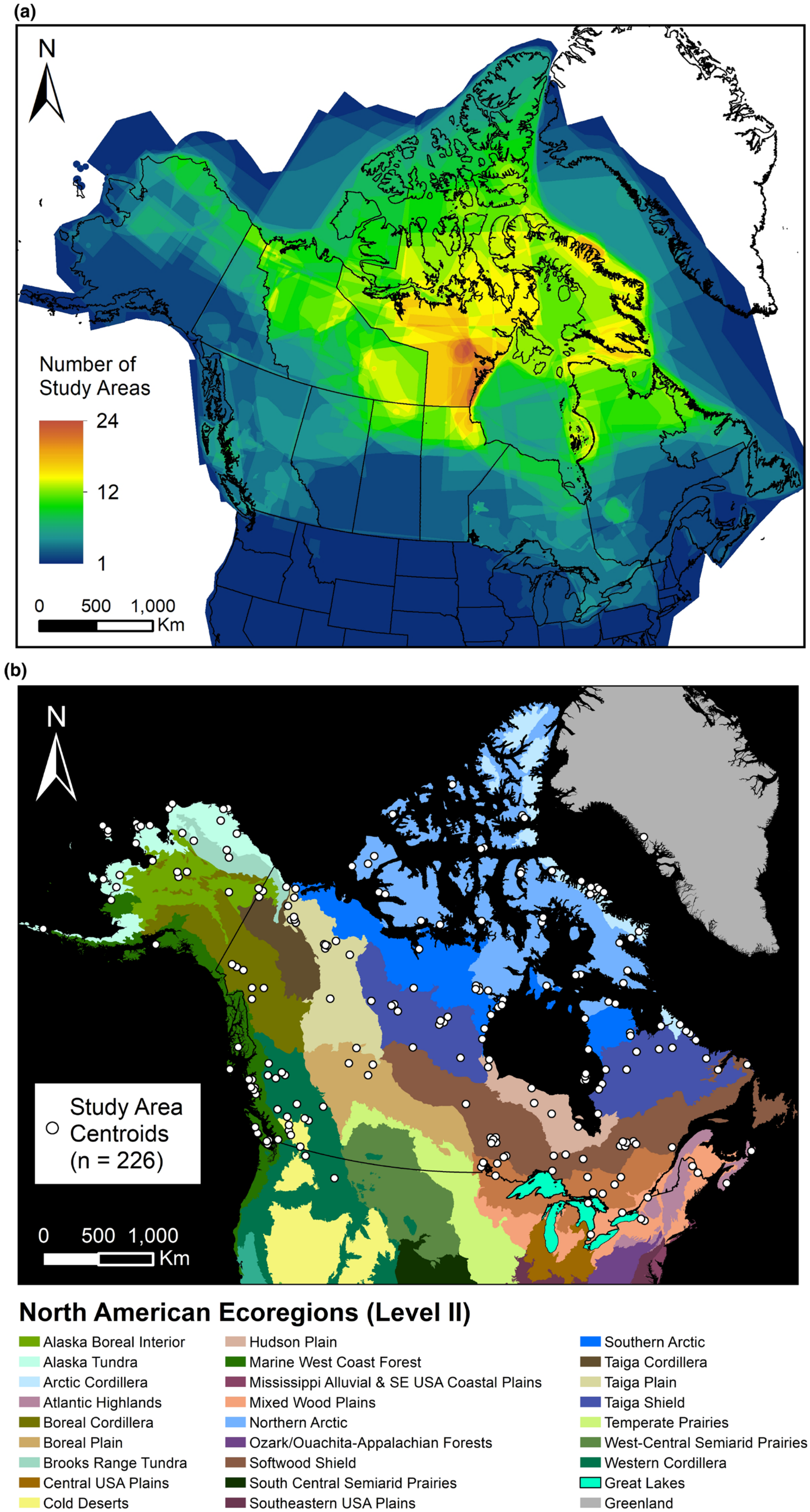

FIGURE 2 (a) Raster heat map representing study area locations ($n = 248$) from a total of 177 case studies. Some case studies included more than one study area polygon. (b) Approximate case study locations <120 mha ($n = 226$) overlaid with North American Ecoregions (Level II) from a total of 177 case studies. Some case studies included more than one study area centroid.

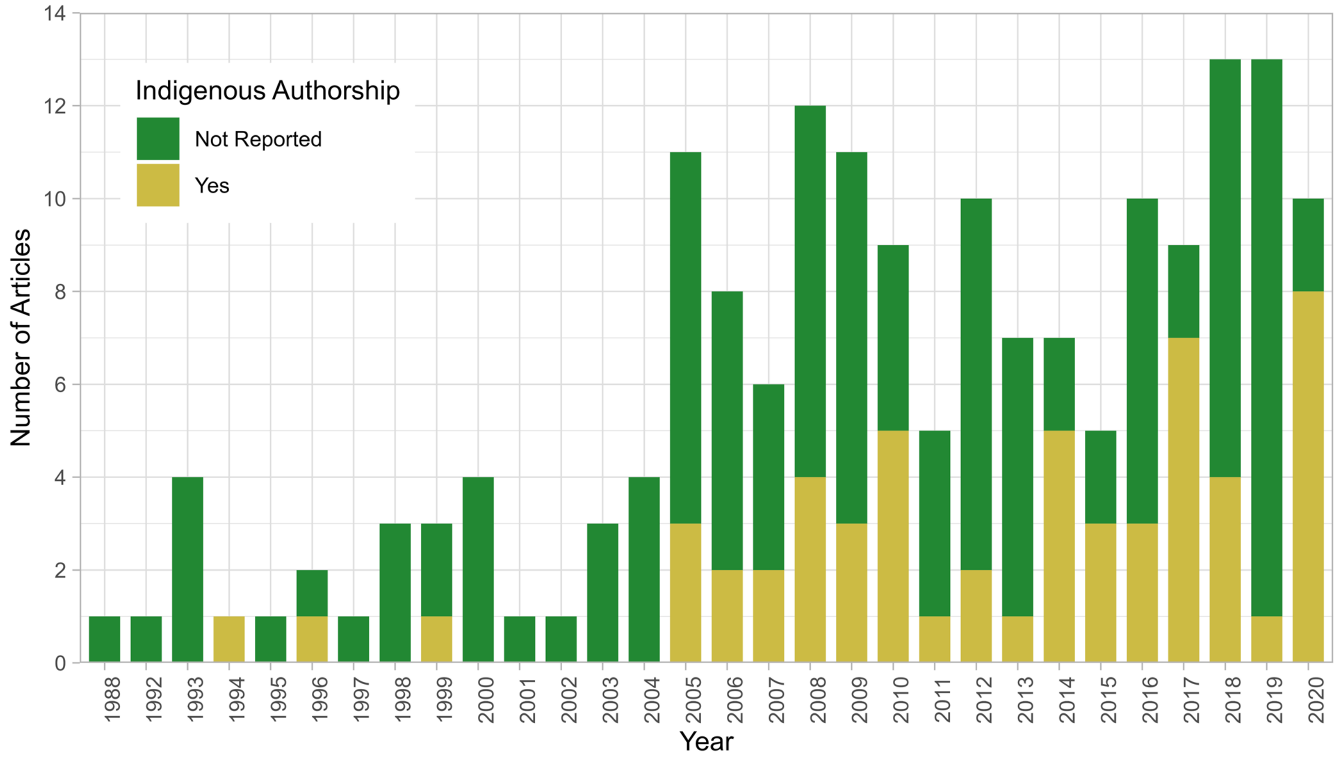

FIGURE 3 Frequency of articles (n = 173) included by publication year from 1988 to 2020 (which only includes years for which we have complete search parameters). Since the search did not span the entirety of 2021, the one article in the database from 2021 is not representative of the whole year and thus not represented in the figure.

4.3 | Article type, frequency and author affiliation

Metrics derived from the coded database component of the systematic map such as the frequency of publications, article type, authorship affiliations and Indigenous representation varied across the dataset. We found a difference in the average number of articles produced annually prior to 2004 compared with after (Figure 3). An average of two studies a year between 1988 (the oldest record in the dataset) and 2004 jumped to an average of just under 10 articles per year in the years between 2005 and 2020. Approximately 82% of all the articles included in the systematic map were published between 2005 and 2020 (Figure 3). Between 2004 and 2005 was a turning point not only for article frequency but for explicitly referenced Indigenous authorship, generally (i.e. Indigenous authors or authors who represent Indigenous communities, organizations and/or governments). In 2005, three (of the 11) articles were reported to feature Indigenous authorship whereas there were none in the 5 years immediately prior. Only 10% of all articles were reported to feature Indigenous authorship between 1988 and 2004. From 2005 to 2020, Indigenous authorship was reported on 37% (54/146) of the articles. From year to year, proportion of reported Indigenous authorship varies representative to the whole but in 2010, 2014, 2015, 2017 and 2020, articles with reported Indigenous authorship contributed more than half of the total publications for that year (Figure 3). In terms of article type and author affiliation, the majority of articles were peer-reviewed (76%; 132/174), and approximately 77% of the 168 articles that reported authorship featured first authors with academic affiliation and 12% featured government first authorship (Figure 4).

4.4 | Ecological level of focus

There are some clear trends in the case study ecological scale of study (Figure 5). Most case studies focused on ecosystem scale (n = 89) followed by species (n = 82). A small minority of the cases included a focus at the scale of ecological communities (n = 6). Across the case studies, we found reports on 14 specific species within five taxonomic/species groupings (e.g. small mammals, seabirds, species at risk). Most case studies were focused on birds or mammals and a smaller number focused on plants or berries. Caribou was the most represented single species (n = 25) followed by moose (n = 11) and polar bear (n = 11). The most popular ecosystems represented in the case studies included boreal forest (n = 24), tundra (n = 26), taiga (n = 21) and Arctic sea ice (n = 22). Tundra, taiga and Arctic sea ice were either mentioned as the sole ecosystem of focus or were found in various permutations under the category of Arctic ecosystems. The least represented ecosystems were oak savanna, wetlands, meadows, Hudson plains, Arctic coastal plains, coastal ecosystem, prairies, boreal cordillera, Acadian forest, boreal plains and Eastern deciduous forest which were each represented three or less times across the dataset (Figure 5).

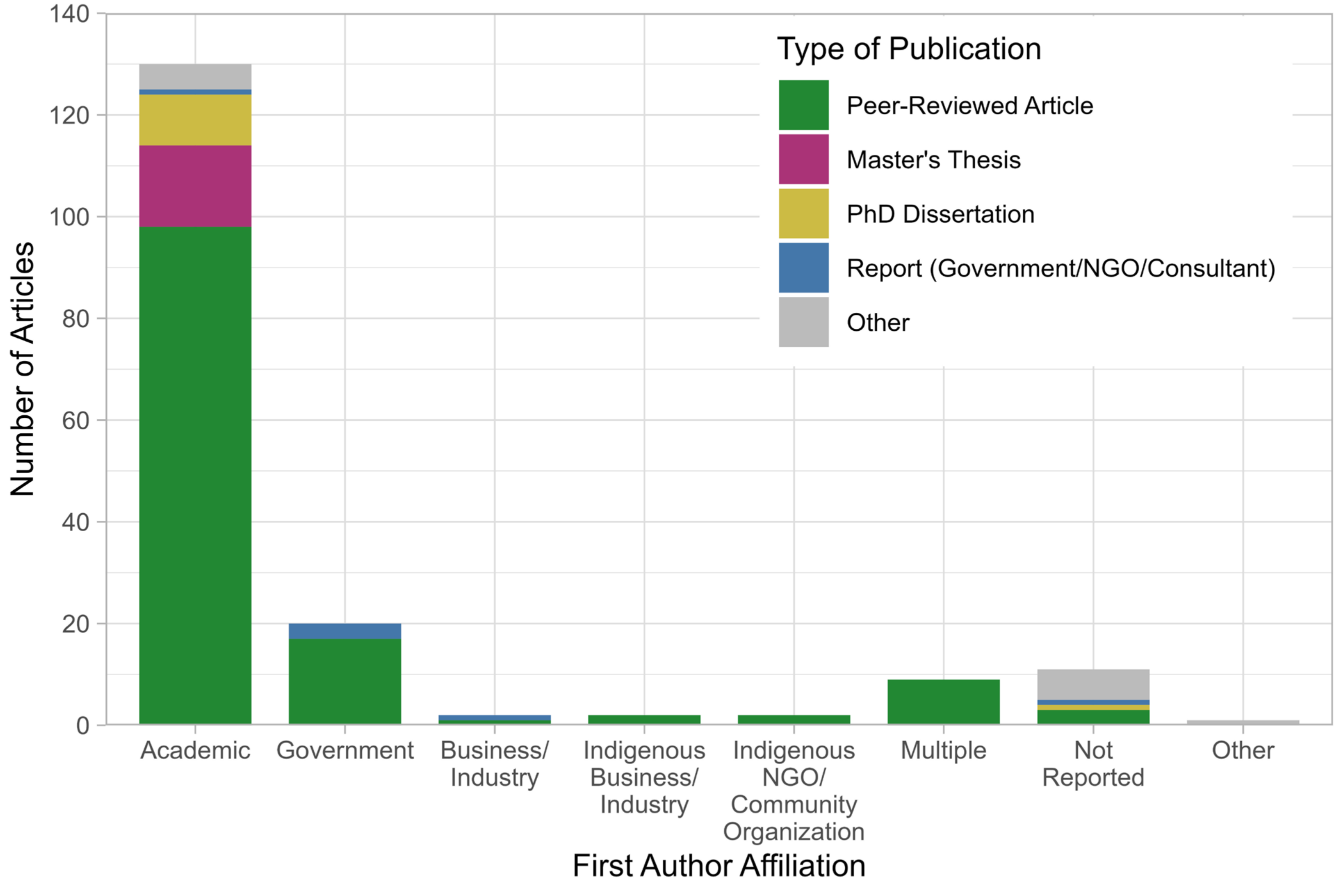

FIGURE 4 Articles included in the systematic map by publication type and first author affiliation ($n=174$).

4.5 | Indigenous representation and demographics of knowledge holders

To develop a better understanding of the representation of Indigenous knowledge systems and knowledge holders across the case studies, Indigenous participation was summarized as shown in Figure 6a–d by 'Indigenous Group', 'Gender', 'Age Group' and 'Elder Participation'. In terms of Indigenous group representation among knowledge holders, First Nations knowledge holders were the most often represented ($n=100$) followed by Inuit ($n=52$). Métis knowledge holders were considered exclusively in only one case and were most often considered in case studies that included knowledge holders representing multiple groups ($n=9$). Native Alaskan knowledge holders were the sole Indigenous group of knowledge holders in five case studies and were among multiple knowledge holder groups in two cases (Figure 6a).

Most case studies did not report on the gender of the knowledge holders. Of those that did, males and females were represented in 40 of the case studies and eight cases reported the inclusion of male knowledge holders only (Figure 6b). Most of the case studies did not report on the age of knowledge holders who served as research participants or partners. Of the articles that did include details on participant age, middle-aged (30–59 years) and older individuals were the most represented. People 29 years of age or younger were the least represented group and contributed knowledge in only 12% (21/177) of the case studies reviewed here (Figure 6c). About 110 case studies reported Elders as contributing knowledge holders and 67 did not report whether contributions from Elders were specifically considered (Figure 6d).

4.6 | Methods and weaving methodologies

A main purpose of the systematic map was to identify the methods of inquiry and approaches that have been used to bring together Indigenous and Western science-based knowledge systems (referred to as Indigenous sciences [IS] methods and Western sciences [WS] methods below) to answer questions related to the research and monitoring of terrestrial ecosystems. We defined WS methods as natural sciences methods used to collect biotic or abiotic data on terrestrial ecosystems, and IS methods as methods used to collate/gather Indigenous knowledge; IS methods included both Western social sciences methods adapted to inquiry of Indigenous knowledge (e.g. interview, workshop) as well as Indigenous science methods (e.g. sharing circle, ceremony). Figure 7a,b break down the type of methods used, the weaving methodologies applied, and how frequently the methods are coupled in the case studies.

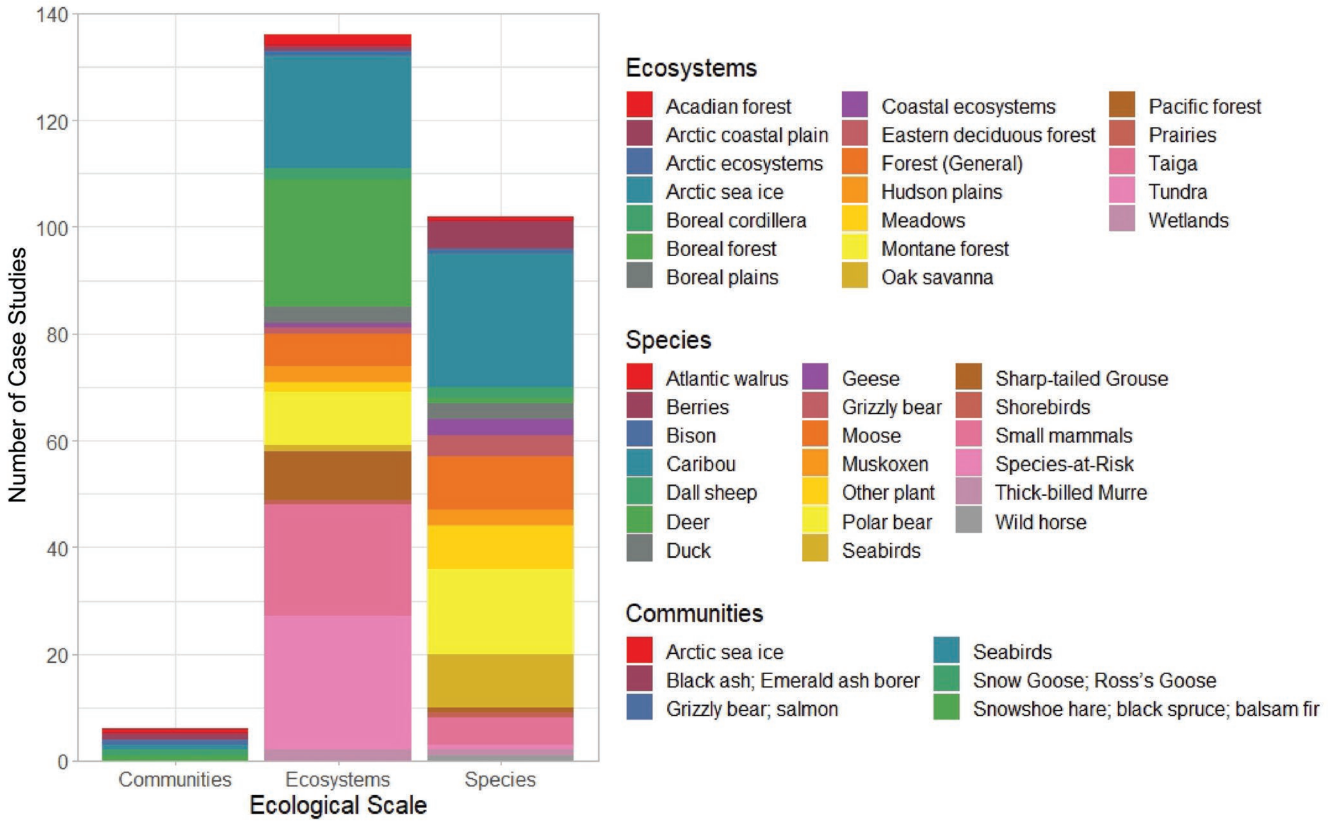

FIGURE 5 Breakdown of study scale and main species (if focus was at the species scale) for each of the case studies ($n=177$). Note that while scale was coded as a mutually exclusive variable, a single case study could be coded for more than one species or ecosystem and thus counted more than once.

We found 14 distinct methods under the umbrella of IS and the same number of methods for WS. Methods were either used alone or in combination with other methods. The IS methods most utilized were interviews ($n=69$), participatory mapping ($n=29$) and workshops ($n=28$) (Figure 6a). Although interviews and workshops were among the most popular methods for gathering Indigenous knowledge, they were much less frequently employed to collect WS data ($n=3$). The top three methods utilized with Western-based sciences were document review ($n=39$), GIS/geographical mapping ($n=24$) and biotic and/or abiotic sampling ($n=18$). Document review was a method commonly used to gather information for both IS and WS, but more commonly used by those practicing WS ($n=20$ and $n=39$, respectively) (Figure 7a).

In terms of weaving methodologies, we classified 12 distinct research designs that were used (sometimes conjointly). The six most used were community-based participatory research, case study, mixed methods, ethnography, Indigenous methodology and participatory modelling (Figure 7a). Community-based participatory research was the most common methodology and was used in 58 case studies either as the predominant weaving methodology or as a complement to other methodologies (Figure 7a).

When approaching terrestrial research and monitoring questions, the IS and WS methods paired most frequently included: interviews (IS) and document review (WS; 54/91 or 59%); interviews (IS) and biotic and/or abiotic sampling (WS; 37/91 or 41%); and participatory mapping (IS) and mapping (WS; 33/91 or 46%) (Figure 7b).

4.7 | Outcomes for Indigenous communities

There was a wide range of research outputs and outcomes reported across the systematic map, some of which were specific to weaving knowledge systems, and others that were generally positive outcomes for biodiversity conservation (Figure 8; Supporting Information S4). Overall, the most common outcomes were that the paper proposes that research or monitoring will have an impact on or can inform management ($n=48$), that the study adds to scientific understanding ($n=43$), that including Indigenous knowledge ensures that not only centralized perceptions are used in decision-making ($n=39$), and increased interest in Indigenous knowledge from scientists ($n=20$). Most combinations of outcomes were only observed once, and the most common outcomes that co-occurred were combinations of the most common outcomes noted above. For example, a total of 15 case studies are shown to report both 'centering Indigenous knowledge and values' and 'improving conservation outcomes and process', which is the highest overlapping set of outcomes reported.

The Venn diagram presented in Figure 8 highlights co-occurring outputs and outcomes within the case studies. For example, while a total

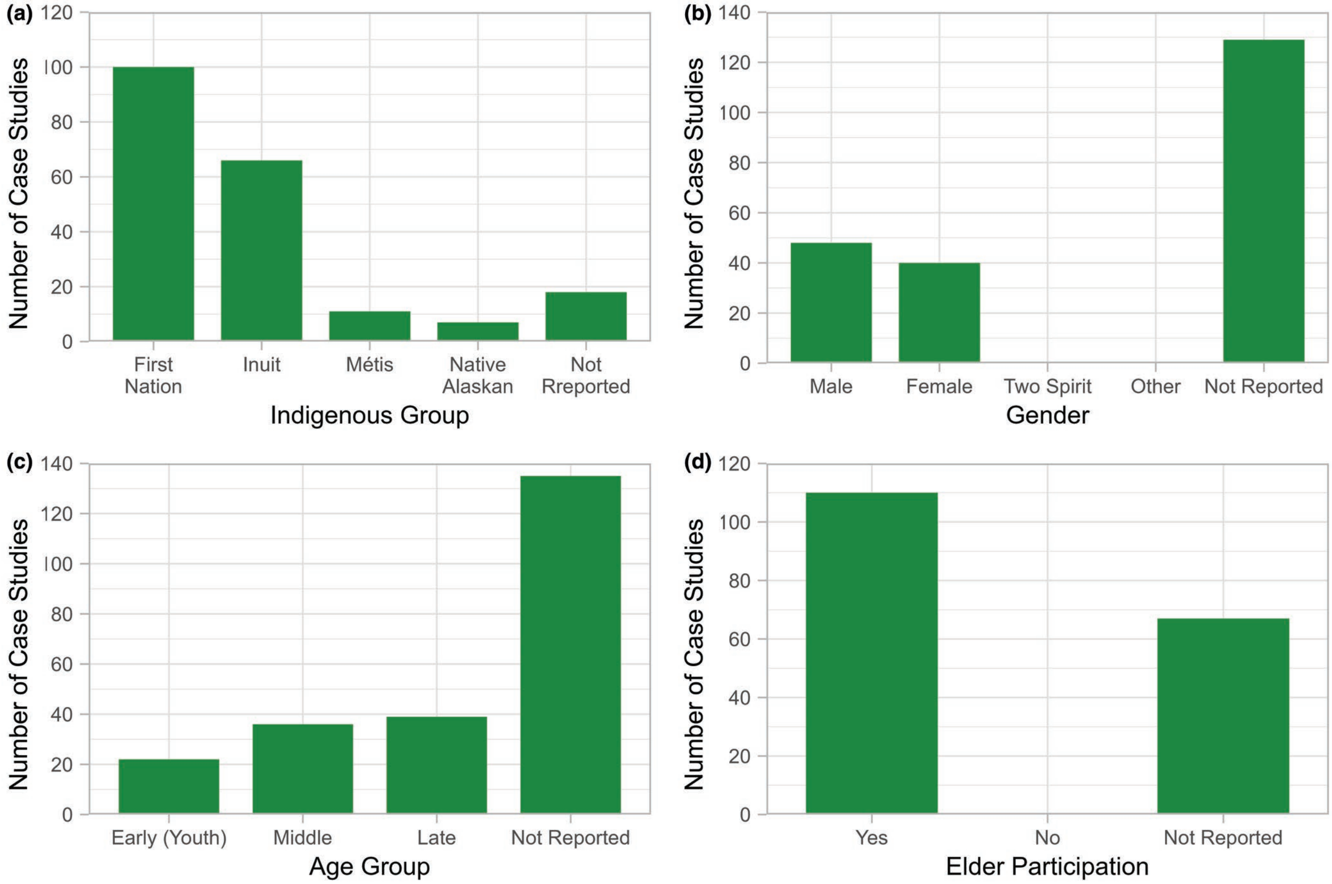

FIGURE 6 Indigenous group representation and demographics of Indigenous knowledge holders across case studies ($n=177$). Four categories were used to describe Indigenous knowledge holders: 'Indigenous Group', 'Gender', 'Age Group' and 'Elder Participation'. Each case study could be coded for multiple categories.

of 64 case studies indicates 'centering Indigenous knowledge and values' as an outcome, nine of these only report this outcome, eight report 'centering Indigenous knowledge and values' alongside 'adds to more holistic scientific knowledge/research', and an additional 12 report these two outputs as well as 'improving conservation outcomes and process'.

5 | DISCUSSION

This systematic map aims to highlight ways in which the existing literature has brought together knowledge generated within Indigenous and Western knowledge systems, specifically through IS and WS methods, in research, monitoring and management conducted across terrestrial ecosystems in Canada. Through our work, some evidence gaps and key insights have come to our attention. These are discussed below along with limitations related to both our methods and the evidence base.

5.1 | Evidence gaps

Regarding authorship, 32% of the articles were authored by Indigenous researchers or those who represent Indigenous communities, organizations and/or governments. This is less than for the articles analysed in the freshwater systematic map (44%; Alexander et al., 2021a, 2021b) but more than found in articles reporting on Canada's marine and coastal ecosystems (21%; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019). The proportion of articles including Indigenous authors also increased over time (with an average of two articles published annually for the 1988–2003 period and about 10 articles per year for 2005–2020). Regular representation of Indigenous authors alongside the rising frequency of articles since 2004 may indicate the prioritization and/or an increased value placed on the inclusion of Indigenous knowledge systems to bear insight on questions related to the terrestrial environment. This pattern in authorship likely reflects the growing definition of what being a co-author can entail (which includes the many aspects of carrying out research with Indigenous partners); it could also relate to an increase in self-disclosing by Indigenous authors. This pattern may be the result of efforts to improve research in the spirit of true reconciliation which necessitates moving away from harmful, extractive approaches to research to ones that involve partnering with Indigenous Peoples and communities. This expansion of authorship has been discussed by others (Barney, 2023; Castleden et al., 2010; Giles & Castleden, 2008; Loseto et al., 2020;

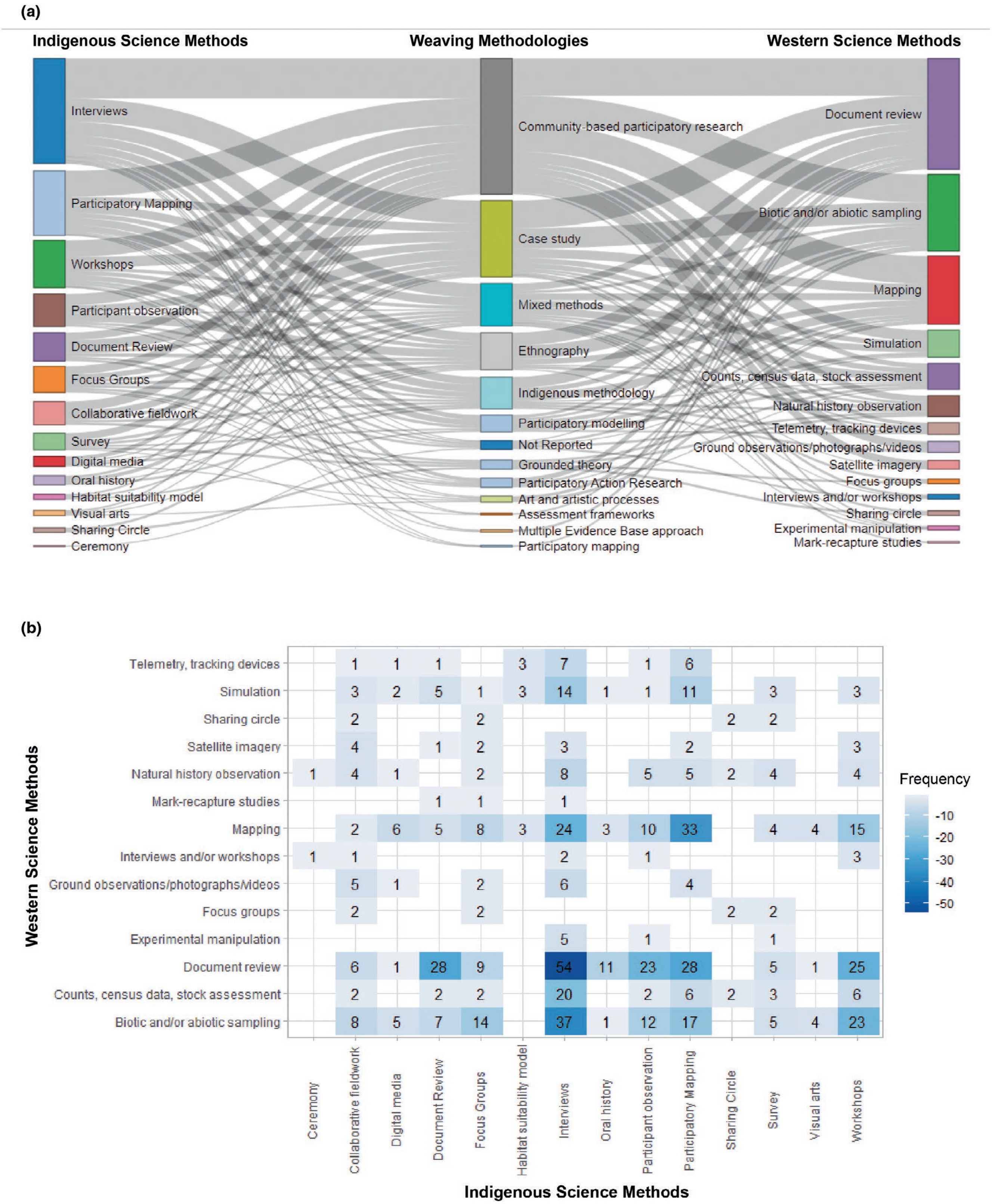

FIGURE 7 (a) Relationships between Indigenous science methods (left column), Western science methods (right column) and the weaving methodologies (centre column). Each case study could be coded for multiple categories for each of these groups. 'Methods' indicate the tools and techniques used to collect and analyse data or information while 'methodologies' refer to the underlying strategies and approaches used in a research study. Based on 91 case studies focused on 'research and monitoring'. (b) Structured matrix showing the frequency where specific Indigenous science methods were paired alongside specific Western science methods for case studies. Each article could be coded for multiple categories for each of these groups. Based on 91 case studies focused on 'research and monitoring'.

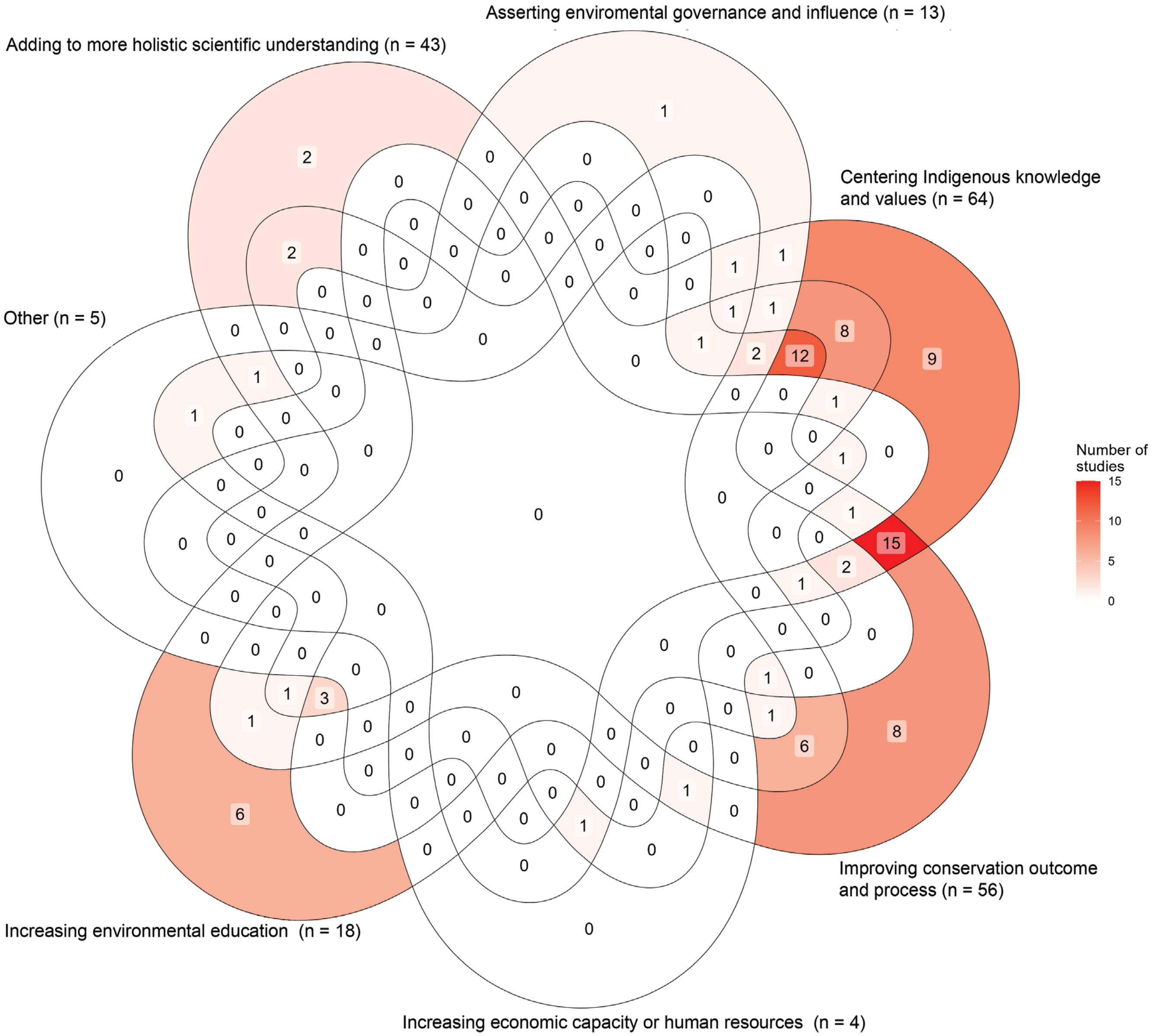

FIGURE 8 Outputs and outcomes of terrestrial research and monitoring case studies ($n=91$). The Venn diagram is read by following each line that is immediately 'above/outside' the number to the associated peak, which describes what category the bubble represents, as well as the lines at each step outward extending to the edge of the figure. For example, the 15 bubble in red on the right shows that a total of 15 case studies report both 'centering Indigenous knowledge and values' and 'improving conservation outcomes and process'.

Sarna-Wojcicki et al., 2017) and we see this pattern represented here.

As found by Alexander et al. (2021b) and again in 2021, Métis knowledge was not well represented. As compared to the coastal/marine systematic map that had no Métis contributors and the freshwater systematic map that considered Métis knowledge in 8% of the articles evaluated, 5% of the articles informing the terrestrial map included Métis input. Métis may be underrepresented in part due to comparatively fewer studies in the Prairie provinces (Figure 2) which contain the largest contiguous area of Métis homeland and the largest populations of Métis people. Due to a variety of factors, the rights of the Métis have also historically lagged those of Inuit and First Nations, which may in turn result in Métis being overlooked by research partners and collaborators (Teillet, 2019). Métis were not recognized as having s.35 rights under the Constitution Act of Canada (Constitution Act, 1982) until 2003 (Powley, 2003). Additionally, there are often provisions and enabling legislation associated with modern treaties or comprehensive land claims agreements that emphasize the importance of Indigenous knowledge in biodiversity work, and in this regard, First Nations and Inuit have the largest number of established agreements in Canada. As a distinct Indigenous culture in Canada, Métis perspectives are clearly needed and should be actively sought in future work. Lack of case studies in the prairies may be linked to many variables that we have not tested, but the presence of enabling legislation in the form of modern treaties and land claims may also be a factor here. This connection was made clear in Nishima-Miller et al. (2025) using a subset of terrestrial case studies focused on co-management.

Another evidence gap relates to gender; of the case studies that did report on the gender of Indigenous knowledge contributors (27%; 48/177), 17% included knowledge from males only (8/48). A larger dataset might better establish this trend, but this result is a marked difference when compared to the lack of a gendered bias in studies informing the freshwater map (; Alexander et al., 2021a). While Indigenous males are consistently more likely to hunt, fish or trap than females, one third to approximately one half of Indigenous females participate in these activities, depending on the group (Anderson et al., 2024; Kumar et al., 2019). Additionally, women are often involved in many aspects of hunts and associated activities such as food processing that can infer important knowledge on the status and health of animals (Halseth, 2015; Ohmagari & Berkes, 1997). Similar to what other scholars have suggested (Hitomi & Loring, 2018; Kermoal & Altamirano-Jiménez, 2016), case studies reviewed through our terrestrial systematic map therefore highlight the need for and importance of elevating the voices and perspectives of female and 2SLGBTQI+ Indigenous knowledge holders in environmental research.

Regarding generational representation of Indigenous knowledge contributors, two points are noteworthy. First, although most case studies did not report information on the age range of contributors, since 110 case studies (62%) reported Elder participation there were likely more people of at least middle age than explicitly reported. Though it must be noted that Elder roles are not necessarily determined by age but rather wisdom or deep cultural knowledge, these attributes are often associated with more life experience. Second, youth representation at 12% is consistent with findings from the coastal/marine systematic map (7%; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019) and the freshwater systematic map (19%; Alexander et al., 2021a, 2021b) which were created using a similar protocol. The low involvement of youth across all three maps likely reflects a tendency in environmental research and management systems to mostly engage Elders and more experienced knowledge holders. However, many authors have identified that youth involvement is critical to Indigenous stewardship practices and stress that efforts to proactively seek distinctive and valuable bodies of knowledge of local environments held by those other than older men should be a priority (Hitomi & Loring, 2018; Menzies et al., 2024; Sadowsky et al., 2022).

As seen in other similar systematic maps, there is a large focus on ecosystems and species, and less on ecological communities. Given that a high number of the case studies in this map come from northern Canada, it is not surprising to see that the taiga and tundra ecosystems are highly represented in results. The dominance of studies located in the North may be in part due to comprehensive land claims agreements and legislation that mandate utilizing Indigenous knowledge in environmental research and decision-making.

5.2 | Key insights

In the context of terrestrial research and monitoring, both WS and IS used 14 different methods to document, gather and mobilize knowledge. This mirrors a similar level of diversity in methods used for monitoring coastal-marine and freshwater environmental issues in IS and WS (13 and 18, respectively; see Alexander et al., 2021a, 2021b; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019). When compared with methods found in the case studies used in the coastal-marine systematic mapping exercise, we found a similar level of diversity among WS (13 distinct methods; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019) but approximately 40% more diversity among IS methods, which included digital media, sharing circles, ceremony and visual arts. This greater diversity found in the terrestrial map could be explained by the fact that coastal-marine and freshwater maps included fewer case studies ($n = 71$ and $n = 74$, respectively, compared to 177 case studies for the terrestrial map), thus highlighting how the growing field of 'knowledge weaving research' can be a catalyst for methodological innovation as a greater number of practitioners enter this interdisciplinary space.

Paired methods in the terrestrial case studies were similar to those of the freshwater map. Frequently paired methods included interviews (IS) with document review (WS) or biotic and/or abiotic sampling (WS). The frequent coupling of participatory mapping (IS) with mapping (WS) was unique to the terrestrial case studies. While the structured matrix (Figure 7b) depicting the pairwise application of methods piqued more questions, we acknowledge that methods are not just utilized in pairs. These observations provide a starting point for deeper inquiry into common method combinations (i.e. bundling) to discover if certain methods are often utilized together to answer specific research questions. For example, is there a bundle most used for caribou monitoring? Are there bundles most used for work in remote locations? Knowing more about common bundles, in turn, paves the way to understanding why methods are used together and if they represent the 'best' approach. Work in this area has already begun. For example, Drake et al. (2023) examined method bundles used in a collection of case studies focused on aquatic research and monitoring in Inuit Nunangat. The authors found that these method bundles varied widely in composition and complexity. While each situation is unique, we echo Drake et al.'s (Drake et al., 2023) emphasis on needing to know more about why particular bundles are chosen and the consequences of those choices in the chance that some aspects of results may be generalized.

Of note are the remarkable benefits of this body of work, both for biodiversity conservation generally and for recognizing the longstanding and integral role of Indigenous Peoples and Indigenous knowledge and in research, monitoring and management (Figure 8; Thompson et al., 2020). Two of the most common outcomes listed were 'increased interest in Indigenous knowledge from scientists' and 'including Indigenous knowledge ensures that not only centralized perspectives are used in decision making';

close to a third of the case studies also cited influencing management and decision-making as an outcome. These outcomes seem to be essential in shifting the paradigm towards inclusive research, monitoring and decision-making practices which respect Indigenous knowledge and rights, leading to better outcomes for Indigenous communities, researchers, practitioners and the environment (Wong et al., 2020).

5.3 | Limitations in methods used

While we designed the search strategy for this systematic map to be comprehensive, we acknowledge limitations in the approach used. For example, the search was conducted in English only. Documents published in Canada's other official language, French (e.g. theses, provincial reports from the Government of Québec and other studies), as well as any published work in Indigenous languages may have been missed. The wide diversity of terms within an interdisciplinary evidence base may also have precluded the inclusion of some studies; without the advantage of working within a defined field's standard ontology, some terms may have been missed. Search string terms included the relatively contemporary and often externally imposed 'labels' of Indigenous, Aboriginal, First Nation, Inuit and Métis. Indigenous Peoples may not self-identify with these commonplace descriptors or use more precise identifying language. Lastly, to be eligible, the methods/weaving practices needed to be explicitly discussed or inferred in the study design. We acknowledge that while not meeting the criteria for eligibility, it is still possible for study authors to have employed such practices and methods. Indeed, it is also possible that current academic conventions do not capture nor provide space in their formats to allow for descriptions of weaving when it is happening. While some journals are now more explicit about the kinds of details required when it comes to community-engaged research (e.g. Author guidelines: How to report community-engaged research prepared by Canadian Science Publishing), there is an opportunity for journals and publishers to implement changes that would both encourage and allow space for the description of weaving processes. Accordingly, we acknowledge that our choice to use this eligibility criteria also affects the resulting evidence base as discussed in the next section.

There are also limits to this paper in terms of identifying the many themes that relate to environmental research, monitoring and management. We chose to place emphasis on knowledge weaving studies that focused on biodiversity, and therefore, one of the evaluation criteria of a biodiversity metric had to be fulfilled for a study to be included. We recognize that there may be additional bodies of literature that focus on knowledge weaving while exploring other environmental factors such as climate change and fire regimes that may not report on biodiversity metrics. Boundaries on systematic mapping projects such as this are needed to make them achievable, but we recognize that future work building on the base systematic maps (coastal-marine, freshwater and the terrestrial map presented here) will further expand our understanding of knowledge weaving practices.

5.4 | Limitations in evidence base

The condition that case study designs must discuss or infer weaving practices and/or methods means that we have identified a particular group of case studies and may have overlooked those that do not articulate any differentiation between knowledge systems, as well as those for which knowledge weaving is inherent to the process of conducting and interpreting the work. Indeed, while helpful, delineations between knowledge systems are somewhat artificial constructs and fall along a fuzzy spectrum, at best, as Kadykalo et al. (2021) point out in their discussion on the role of Western-based scientific, Indigenous and local knowledge in wildlife management and conservation. A limitation in the evidence base is also imposed by a bias towards peer-reviewed academic literature resulting from the search parameters and engines used. The search strategy employed meant that grey literature (e.g. consultant reports, Indigenous initiative reports) and studies published or distributed outside the Western editorial process or in other formats (e.g. video documentaries, podcasts) were likely underrepresented. Although we made calls for evidence to seek reports from beyond the peer-reviewed literature, there are several reasons why case studies that could have been included may not have been shared.

First, as shown in this systematic map, the field of knowledge weaving is rapidly growing and evolving, so there may be several reports that were in progress but not ready for sharing at the time of this work. Second, the Western peer-review process can be burdensome, and the standards are not only exclusive but reflect culturally specific values of validation that may not align with Indigenous-led reporting. This may result in some researchers not bothering to go through the process or eschewing it altogether (Loseto et al., 2020). In other circumstances, Indigenous-led work may not be intended to be shared with external actors in the first place, for a variety of reasons, including distrust or disinterest in working with researchers due to past harms suffered through extractive science. Finally, there could be cases where projects employed knowledge weaving approaches in biodiversity studies but were sensitive in nature due to ongoing concerns about data sharing or legal proceedings. It is important to recognize that while there is an increasing movement towards Open Data and Open Access, there are equal concerns about Indigenous data sovereignty (i.e. how Indigenous knowledge is used, by whom, and for what purposes). Thus, any work in systematic mapping and synthesizing themes involving Indigenous knowledge must be sensitive towards these ongoing concerns, as well as support Indigenous data sovereignty.

6 | CONCLUSION

In this study, we have completed a systematic map of 177 case studies that have brought together Indigenous and Western knowledge systems for biodiversity work in terrestrial ecosystems and presented high-level trends. Centering Indigenous knowledge and values was one of the most common outcomes herein and is a clear benefit of this work. However, in parallel with recent systematic maps focused on freshwater ecosystems (Alexander et al., 2021a, 2021b) and coastal/marine ecosystems (Alexander, Provencher, Henri, Taylor, & Cooke, 2019; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019), this terrestrial map reflects a need for greater gender and age representation of Indigenous knowledge holders. In addition, although our map indicates a growing trend in Indigenous authorship over time, additional efforts are required to support Indigenous authorship and Indigenous-led research. This study highlights the ongoing responsibility for the Western science community to amplify marginalized voices and knowledge systems in respectful and reciprocal ways, including those of the Métis people.

6.1 | Implications for practice

This map is the third of a series of systematic maps that have used a similar protocol (see Alexander et al., 2021a, 2021b; Alexander, Provencher, Henri, Taylor, & Cooke, 2019; Alexander, Provencher, Henri, Taylor, Lloren, et al., 2019; Henri et al., 2021) to synthesize evidence for bridging knowledge systems in environmental research, monitoring and management. The purpose of this overall project was to bring together publications, ideas and examples of where weaving of Indigenous knowledge systems and Western sciences has taken place in Canada, but the volume of the work in this area necessitated the mapping to be carried out in three parts (coastal/marine, freshwater and this map of case studies from terrestrial ecosystems).

Common criticisms articulated by Indigenous communities to environmental research and management practitioners include a lack of coordination of work already being done with Indigenous Peoples, as well as a lack of understanding regarding how to complete work in a respectful and reciprocal way and avoid common burdens to communities such as inefficient planning and burnout. While our evidence base is not exhaustive, it is our hope that knowledge gathered through the coastal/marine, freshwater, and terrestrial maps can be drawn upon by environmental research and management practitioners to help ensure that new initiatives are synergistic and that professionals entering the space of knowledge weaving have a comprehensive understanding of the recent landscape in Canada.

The importance of place-based and contextual practices is an integral part of using the information in this map, along with the other systematic maps in this series. Accordingly, all three systematic maps have enabled several more focused analyses of thematic and place-based papers. For example, this has included looking at how knowledge is brought together in the oil sands region in Alberta, Canada (Wilcox et al., 2023) and across Inuit Nunangat (Drake et al., 2023) as regional reviews to explore specific patterns in knowledge weaving practices within a specific landscape. A thematic review focused on ecotoxicology and wildlife health studies has also been carried out by Johnson et al. (2023), as this topic was of particular interest to research partners in planning future work. These are all publications that have drawn on a subset of case studies from the systematic maps to explore specific context-based themes that are of particular interest.

Additionally, the maps can also support researchers to engage in respectful and reciprocal work that is beneficial to all partners. The databases created by these maps have been used to explore practices around ethical engagement with Indigenous partners (Rathwell et al., 2025). Other work that weaves Indigenous knowledge from interviews and sharing circles together with the literature from all three systematic maps addresses if/when and how to bring knowledge systems together (Bowles et al., 2026). Readers could also look to Rathwell et al. (2025), Reid et al. (2021, 2024), Menzies et al. (2024), Wong et al. (2020) and Reo et al. (2017), among others, as well as to Indigenous communities and organizations for strong guiding principles on current best practices and respectful ways to weave knowledge.

To further highlight place-based case studies and relevant projects to support learning and awareness, the Bridging Indigenous and Science-based Knowledge Web Portal (https://www.dfo-mpo.gc.ca/science/partnerships-partenariats/indigenous-autochtone/index-eng.html) was developed. This web portal constitutes a publicly accessible version of all three systematic maps and a queryable database. Importantly, while systematic maps like these are critical learning tools, we recognize that there is additional knowledge, expertise and wisdom with Indigenous communities and partners that are best shared through dialogue and learning directly from each other.

AUTHOR CONTRIBUTIONS

Jennifer F. Provencher (JFP), Ella Bowles (EB) and Dominique A. Henri (DAH) contributed equally to this work and are recognized as co-first authors. All authors contributed critically to this manuscript and gave final approval prior to publication. JFP co-created the institutional setting for this research and co-led project conceptualization and methodological design with DAH, SMA and EB; coordinated data collection and analysis; and provided mentorship and training to the review team (JFP, EB, DAH, CC, JRS, AAEW, LRJ, SM, OHD, KMM); contributed to the screening, review and coding of the articles; and drafted and edited the manuscript. EB co-created the institutional setting for this research and co-led project conceptualization and methodological design with DAH, JFP and SMA; coordinated data collection and analysis; provided mentorship and training to the review team; contributed to the screening, review and coding of the articles; and drafted and edited the manuscript. DAH co-created the institutional setting for this research and co-led project conceptualization and methodological design with JFP, SMA and EB; coordinated data collection and analysis; provided mentorship and training to the review team; contributed to the screening, review and coding of the articles; drafted and edited the manuscript; and acted as corresponding author. Rachel Nalepa (RN) drafted and edited the manuscript. Carmen Chelick (CC) contributed to the screening, review and coding of the articles; and drafted Figures 2a–7b. Jade R. Steel (JRS) contributed to the screening, review and coding of the articles. Alana A. E. Wilcox (AAEW) contributed to the screening, review and coding of the articles. Lydia R. Johnson (LRJ) contributed to the screening, review and coding of the articles. Sarah Martone contributed to the screening, review and coding of the articles. Jessica J. Taylor (JJT) supported data management and

quality control; and drafted the Methods section. Oscar Hartman Davies (OHD) contributed to the screening, review and coding of the articles. Katharina M. Miller (KMM) contributed to the screening, review and coding of the articles. Trina Rytwinski (TR) supported data management and quality control; and contributed to drafting the Methods section. Steven J. Cooke (SJC) contributed to project conceptualization and methodological design; and supported data management and quality control. Jesse N. Popp (JNP) contributed to project conceptualization and methodological design. Adam T. Ford (ATF) contributed to project conceptualization and methodological design. Deborah McGregor (DM) contributed to project conceptualization and methodological design. Steven M. Alexander (SMA) co-created the institutional setting for this research and co-led project conceptualization and methodological design with DAH, JFP and EB; provided mentorship and training to the review team; and drafted and edited the manuscript.

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CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The full database supporting the findings of this study is publicly available and archived at the Centre for Open Science data repository (see Henri et al., 2026 for data DOI link). Codes supporting the analyses are available upon request to the corresponding author (DAH).

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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 S1. ROSES Reporting Standards for Systematic Evidence Syntheses.

Supporting Information S2. Literature search strategies.

Supporting Information S3. Excluded articles and reasons for exclusion.

Supporting Information S4. Outputs and outcomes of terrestrial research and monitoring case studies.

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