**SPECIAL FEATURE: ORIGINAL ARTICLE**

Innovative Partnerships and Methods for Knowledge Co-Production to Support
Indigenous Cultural and Environmental Management

# Learning from knowledge co-production research and practice in the twenty-first century: global lessons and what they mean for collaborative research in Nunatsiavut

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## Abstract

An increasing need for novel approaches to knowledge co-production that effectively and equitably address sustainability challenges has arisen in the twenty-first century. Calls for more representative and contextual co-production strategies have come from Indigenous communities, scientific research forums, and global environmental governance networks. Despite calls to action, there are no systematic reviews that derive lessons from knowledge co-production scholarship to interpret their significance through the lens of a specific sociopolitical and cultural context. We conducted a systematic review of peer-reviewed and grey literature on knowledge co-production published from 2000 to 2020. Using a hybrid inductive and deductive thematic analysis, we identified two conceptual themes—guiding principles and approaches—to structure the synthesis and interpretation of 102 studies. We found that knowledge co-production studies often converged on four interrelated principles: recognition of contextual diversity bounding knowledge co-production, preemptive and intentional engagement with Indigenous knowledge holders, formation of shared understanding of the purpose of knowledge co-production, and empowerment of knowledge holders throughout the co-production cycle. These principles manifested in multiple approaches for interpreting, bridging, applying, and distributing power amongst diverse knowledge systems rooted in different epistemologies. We filter these findings through the social–ecological context that frames an ongoing knowledge co-production project with Inuit communities in Nunatsiavut, Canada: the *Sustainable Nunatsiavut Futures Project*. Our review suggests that emerging forms of knowledge co-production principles and approaches yield immense potential in diverse contexts. Yet in many regions, including Nunatsiavut, principles alone may not be enough to account for systemic and contextualized issues (e.g., colonisation and data sovereignty) that can present roadblocks to equitable sustainability science in the twenty-first century if left unaddressed.

**Keywords** Knowledge co-production · Knowledge systems · Nunatsiavut · Social–ecological systems · Sustainability · Systematic review

## Introduction

The sustainability challenges of the twenty-first century, including climate change, biodiversity loss, and adaptive environmental governance, demand new forms and uses of knowledge that mirror their social and ecological complexity and scales. Scholars, practitioners, policymakers, and Indigenous and local communities are increasingly emphasizing the importance of diverse and even competing values systems, academic disciplines, and ways of knowing to address these challenges (Cash et al. 2003; Chapman and Schott 2020; Hegger et al. 2012; Tengö et al. 2014; Wyborn et al. 2019). These calls to action magnify efforts to enshrine the worldviews, rights, and responsibilities of Indigenous and local knowledge (ILK) holders in environmental

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assessments, monitoring, and management decisions, such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) ILK approach (Hill et al. 2020a) and nature's contributions to people (NCP) framework (Matuk et al. 2020a). Knowledge co-production has become a fundamental stepping stone on this path towards actionable and equitable science that bridges academic disciplines and social spheres in this era of rapid social and environmental change.

Interest in knowledge co-production has sharply risen since Elinor Ostrom and collaborators first used the term 'co-production' in their institutional economics research in the 1970s (Bremer and Meisch 2017; Norström et al. 2020). Similarly, collaborative case studies that bridge diverse knowledge systems have surged in the twenty-first century, particularly knowledge co-production projects with and for Indigenous peoples (Alexander et al. 2019; David-Chavez and Gavin 2018; Klenk et al. 2017; Miller and Wyborn 2020). In response, scholars are building an indispensable catalog of interdisciplinary case studies, conceptual treatments, literature reviews, and co-production frameworks to condense decades of findings (Albrechts 2012; Beier et al. 2017; Bremer and Meisch 2017; Cooke et al. 2020; Djenontin and Meadow 2018; Jagannathan et al. 2020; Norström et al. 2020; Voorberg et al. 2014; Wyborn et al. 2019). Reviews and syntheses provide collective guidance for drawing from and deploying knowledge co-production principles in theory and practice. Moreover, they garner evidence to develop and refine frameworks, which often appear as de facto goals of knowledge co-production research. Yet contemporary scholars and project planners must also wade through this scholarly maze to start, sustain, and position their knowledge co-production efforts among a rapidly growing body of scholarship and practice–much of which extends from a proliferation of case studies in increasingly complex contexts.

Social–ecological context is foundational for understanding processes for knowledge co-production. However, 'context' may be the double-edged sword of these processes. On one side, contextual depth/breadth paints a rich picture of the versatility and transformative power of knowledge co-production approaches worldwide. On the other side, contextual constraints risk producing findings that overlook, overgeneralize, or overprescribe certain aspects of knowledge co-production that are more suitable for some contexts than others. Thus social–ecological context is a fundamental mediator of co-production (Cockburn et al. 2020). Yet to our knowledge, only one study (Singh et al. 2021) *systematically* reviewed the burgeoning knowledge co-production scholarship to purposefully interpret its significance through the lens of a specific social–ecological context. Moreover, few academic articles met the parameters of their targeted research context.

Several important reasons underlie the need to conduct a systematic review of knowledge co-production to glean insights for a specific context. First, familiarity with knowledge co-production literature is considered a critical precursor to effective co-production efforts, independent of context (Cooke et al. 2020; Lemos et al. 2018). Second, participation/collaboration does not guarantee co-production (e.g., Alvarado et al. 2020) in that 'collaboration' can represent a spectrum of governance arrangements that varyingly affect power relations, co-productive capacities, and project intentions (Hill et al. 2012; van Kerkhoff and Lebel 2015). Literature reviews can inform co-productive endeavors in collaborative research contexts where the roles of knowledge co-production and decolonising research in those processes are not well documented, such as the Inuit Nunangat region (Alexander et al. 2019; Wilson et al. 2020). Third, recent work emphasizes the importance of diversifying knowledge co-production approaches to move beyond idealized depictions and towards pragmatic benefits *and* transformative social change, such as magnifying their collaborative reach, depth, and duration (Jagannathan et al. 2020; Mach et al. 2020). Our objective is to conduct a systematic review of 2 decades of knowledge co-production literature to: (1) identify key principles and approaches of knowledge co-production for scholars and practitioners; and (2) synthesise and interpret our findings through the contextual lens of Nunatsiavut for the *Sustainable Nunatsiavut Futures* project.

In summer 2019, the Nunatsiavut Government (NG), academics, government and non-government representatives, and practitioners held a 2-day workshop to develop a proposal for a community-engaged research program to co-produce knowledge about changing coastal ecosystems in Nunatsiavut, Labrador, northeastern Canada. The currently active, 4-year Knowledge Co-production and Transdisciplinary Approaches for Sustainable Nunatsiavut Futures project (hereafter referred to as *Sustainable Nunatsiavut Futures*) emerged from these discussions with a transdisciplinary research agenda centered around three goals: (1) understand changing coastal ecosystem dynamics in the face of climate change; (2) prepare for these dynamics through co-produced planning and adaptive resource management; and (3) evaluate the processes and outcomes of knowledge co-production across scientific and Inuit knowledge, science governance, and relationship building. The project presents a unique opportunity to systematically review and contextually reflect on knowledge co-production within and outside of Arctic regions. In this context, we translate lessons learned from previous work to generate new insights for knowledge co-production in the Arctic's rapidly changing research landscape.

## What is knowledge co-production and why co-produce knowledge?

Knowledge co-production means different things to different actors in different contexts; it encompasses science and governance philosophies, discursive frames, normative stances, relationships between science and society, organizational and institutional structures, theoretical and methodological frameworks, and research processes and outcomes (Wyborn et al. 2019). Definitions of knowledge co-production have expanded for decades to reflect its complexity and conceptual roots in multiple disciplines, philosophies of science, and methodological approaches (Miller and Wyborn 2020; Norström et al. 2020). However, the multifaceted nature of knowledge co-production also stems from an array of definitions and interpretations of its concepts, processes, and components across multiple fields of study and practice (Mach et al. 2020; Wyborn et al. 2019). In short, the multidisciplinary meanings and motivations for knowledge co-production continue to feed into and expand on one another as its scholarship continues to evolve, which may confuse scholars and practitioners who strive to understand how to do it and why (Apetrei et al. 2021; Miller and Wyborn 2020). We ground our review in Wyborn et al.'s (2019) definition of knowledge co-production as "processes that iteratively unite ways of knowing and acting—including ideas, norms, practices and discourses—leading to mutual reinforcement and reciprocal transformation of societal outcomes" (p. 320), which they built on foundational work in sustainability science, public administration, and science and technology studies. We choose this definition because it aligns with who we are as a group (see Researcher positionality below) in full recognition that it is one of many Indigenous and non-Indigenous interpretations of "knowledge", "sharing", and "knowledge co-production" that should be considered to make the most room for a diversity of perspectives in research and practice (Latulippe and Klenk 2020).

Definitions of knowledge co-production and other knowledge- and equity-related concepts help cut through the conceptual fog of these terms by supporting systematic research (Apetrei et al. 2021; Davis and Ruddle 2010; Friedman et al. 2018; Petriello et al. 2021). Yet as noted by Davis and Ruddle (2010), "the definitional approach treats complex processes and phenomenon as self-evident and socioculturally simple" (885). Therefore, it is critical for scholars to outline the importance of knowledge co-production and its components to move beyond the limitations of its definitions. First, knowledge co-production has been linked to cultivating trust, capacity, and knowledge flows, which can assist learning within the participating stakeholder groups, build networks, foster social capital, strengthen funding for collaborative research, inform policy formation, rally public acceptance, and develop actions that contribute to sustainability (Arnott et al. 2020; Norström et al. 2020; Reyers et al. 2015). Second, knowledge co-production is an innovative, flexible, and reflexive concept, allowing co-producers to (re)discover, (re)evaluate, and (re)negotiate principles and approaches to match the context and intent of their initiatives and partnership coalitions (Mach et al. 2020; van Kerkhoff and Lebel 2015). Third, the inclusion of diverse actors increases the potential to produce actionable science and knowledge that will translate to policies and decision-making (Armitage et al. 2011; Beier et al. 2017; Hill et al. 2020a), generating more reliable, representative, and feasible routes to addressing complex challenges, from fisheries management to climate change (Aminpour et al. 2021; Beier et al. 2017; Bremer and Meisch 2017; Cooke et al. 2020). Fourth, its inclusion of diverse knowledge systems allows for epistemologies, or ways of knowing, to be (re)asserted or challenged through attempts to grasp how others view the world, yielding the potential to shift power relations and overcome conflicts between different value positions and worldviews (van der Hel 2016). Fifth, the processes of bridging cultural/epistemological differences force partners to openly confront histories of colonisation, reflect on their positions as researchers, and develop decolonising methods to redress those histories in pursuit of Indigenous data sovereignty, ownership, and intellectual property rights (CTKW 2014; Hill et al. 2020b; Maclean et al. 2021; Zurba et al. 2019). Mutually beneficial knowledge co-production, therefore, hinges on participants recognizing and accounting for perceived divides, complementarities, and power asymmetries between different types of knowledge.

Power asymmetries in knowledge co-production often arise around the reductive but instructive binary of Western Scientific Knowledge (WSK) and ILK systems (Agrawal 1995). WSK is heavily influenced by positivism and often conceptualizes knowledge as products that are packaged in categories, abstract generalizations, ordered observations, and testable hypotheses rather than in processes that incorporate actions, experiences, and relationships (Levac et al. 2018). Conversely, ILK embodies "a cumulative body of knowledge, practices, and beliefs, evolving and governed by adaptive processes and handed down through generations by cultural transmissions, about the relationship of living beings (including humans) with one another and with their environment" (Díaz et al. 2015:13). Yet both knowledge systems possess complementary aspects that together cultivate holistic pictures of research contexts, problems, and solutions (Ban et al. 2018). Both generate observations, develop methods to test those observations, and deploy their knowledge to solve problems that enhance knowledge holders' understanding of the natural world (Berkes 2012). Moreover, their differences also draw attention to power dynamics associated with current western science research structures and norms (Montana 2019). For example, practices dominated

by WSK such as policymaking have led to ILK holders being viewed as mere sources of knowledge to be incorporated into these practices leading to their inequitable inclusion throughout the knowledge co-production process (Montana 2019; Sidorova 2020; Vincent et al. 2020; Zurba 2009). Therefore, even the most well-intentioned efforts to engage with complementary knowledge systems must be aware that they may unintentionally magnify power imbalances. Acknowledgement of the context of knowledge is one step towards balanced power relations for equitable knowledge co-production.

## The context of Nunatsiavut and the Sustainable Nunatsiavut Futures project

Nunatsiavut (Inuttitut for 'Our Beautiful Land') is a subarctic coastal region in the eastern-most part of northern continental Canada (Newfoundland and Labrador province). It is one of four regions that comprise the Inuit homeland known as Inuit Nunangat, including the Inuvialuit Settlement Region, Nunavut, and Nunavik. Nunatsiavut has an estimated population of 2560 (Statistics Canada 2018) spread throughout the communities of Nain, Hopedale, Postville, Makkovik, and Rigolet. These five communities are only accessible by boat and airplane during the summer months, and by planes or snowmobile in the winter months. Many beneficiaries of the Labrador Inuit Land Claims Agreement (LILCA 2005) also live outside of Nunatsiavut in communities around the Upper Lake Melville region including North West River, Mud Lake, and Happy Valley-Goose Bay and across Canada. Pursuant to the LILCA, a beneficiary is a permanent resident of the Labrador Inuit Settlement Area who is either an Inuk (singular of Inuit) or Kablunângajuk (see LILCA 2005, chapter 3). The landscapes are post-glacial, characterised by peatlands, plains, numerous lakes in the interior, and over 20,000 km of rocky coastline cut by deep rivers and fjords.

The history and governance characteristics of Nunatsiavut make it an instructive context for exploring the development and application of knowledge co-production. The Labrador Inuit self-governance initiatives have included the formation of the Labrador Inuit Association in the 1970s and land claim submission in 1977. The settlement of the LILCA in 2005 created the current Nunatsiavut Government (NG). The NG maintains authority over health, education, culture and language, justice, and community matters and works cooperatively with other provincial and federal jurisdictions on other matters, including various environmental governance issues. The NG established the Nunatsiavut Government Research Advisory Committee (NGRAC), which reviews all research that takes place in Nunatsiavut, concerns Nunatsiavut, or involves beneficiaries of the LILCA. In particular, the NGRAC ensures research projects are equitable across communities, provides recommendations on the meaningful engagement of Traditional Knowledge in research, offers recommendations on research communication to help ensure Labrador Inuit are informed about research occurring in their communities prior to, during, and after research activities, and grants approval for research. The NGRAC provides a key regional research structure in the wider effort to improve Inuit self-determination in research identified in the National Inuit Strategy on Research (Inuit Tapiriit Kanatami 2018). More broadly, institutional research review structures (e.g., university Research Ethics Boards) are recognizing the rights of Indigenous governments and communities to approve or deny research taking place in their regions and territories. Across Inuit Nunangat specifically, each Inuit region is working to develop its own research review and approval process that operates based on the specific legal and institutional context of the region. The NGRAC and its roles and procedures ensure that all prospective research is reviewed by the NG based on Labrador Inuit values and the needs of the region, ensuring NG's leadership and the advancement of Inuit self-determination in research. The NGRAC also ensures that proposed research is consistent with the principles of the LILCA and respects Inuit jurisdiction in Nunatsiavut.

*Sustainable Nunatsiavut Futures* is a new multi-year, transdisciplinary, and cross-sectoral research project dedicated to equitable and representative knowledge co-production in planning for and advancing understanding of changing coastal ecosystem dynamics in Nunatsiavut. It currently comprises >50 collaborators that represent 18 governmental, nongovernmental, and academic partners (OFI 2021). The project began through a collaborative planning process with NG representatives and researchers from academic institutions and the Canadian federal government. The NG expressed an interest in pursuing scientific research focused on the marine environment through a transdisciplinary lens that was informed by various community engagement and knowledge gathering activities (e.g., Imappivut, Nunatsiavut Government 2020a). Per the LILCA (2005), the Labrador Inuit Constitution (Nunatsiavut Government 2020b), and the National Inuit Strategy on Research (Inuit Tapiriit Kanatami 2018), the NG administers a research review body and process that currently retains responsibility over research governance through a commitment to approaches that support Inuit self-determination in research and knowledge co-production in Nunatsiavut. Our project is thus guided by these legal and cultural mandates, with the goal of decolonising research and fostering interactions among Inuit and WSK systems to reify, respect, and engage with Inuit rights holders and their self-determination in research. In this context, we strive to be reflective and prospective, rather than prescriptive, as we use the review as a descriptive template to reflect on Nunatsiavut as a research context

and glean potential lessons for current and future knowledge co-production research.

## Methods

### Researcher positionality and a Sustainable Nunatsiavut Futures positionality statement

Positionality statements, whether or not authors and project partners refer to them as such (e.g., Carter et al. 2019), are increasingly becoming a cornerstone of knowledge co-production work in all its forms (Buzinde et al. 2020; Maclean et al. 2021; McCarney 2018; Wilson et al. 2020). According to Maclean et al. (2021), "With regards to research, Positionality traditionally refers to the powerful and privileged position that researchers often have vis a vis those whom they 'research'. Effectively, researcher positionality influences the collection, representation, and production of knowledge, and may reproduce inequalities and further disadvantage to project partners and their own communities (see Muhammad et al. 2015)" (3). We present the following positionality statement to respectfully portray the place-based origins of our work, transparently represent our individual and collective roles and identities in these processes, and purposefully acknowledge and work towards redressing the history of colonial approaches to research in Inuit Nunangat (Inuit Tapiriit Kanatami 2018)–an acknowledgement that Wilson et al. (2020) recently found to be surprisingly uncommon in the Arctic environmental science literature.

The *Sustainable Nunatsiavut Futures* project is structured around an adaptive transdisciplinary model that encompasses four interrelated levels of knowledge co-production: empirical (What exists?), pragmatic (What are we capable of?), normative (What is it we want to do?), and value (How should we do what we want to do?) levels. The empirical level houses our organizational structure, which is distributed across four work packages (WP). WP1 is tasked with developing and evaluating knowledge co-production processes and outcomes, including the contributions of our approach to benefits for all partners. Although the systematic review originated from WP1's preliminary efforts to identify best practices to facilitate knowledge co-production, our team of authors (all current project partners) embodies the organizational (i.e., authors from different WPs), institutional (e.g., current students, postdoctoral fellows, faculty members, and one Nunatsiavut government representative), disciplinary (e.g., marine policy, oceanography, conservation social science), and cultural diversity (e.g., Inuit and non-Inuit authors) of the broader project. In this research context, we strive to appropriately acknowledge and account for the contributions of multiple ways of knowing to our shared goal: to explore pathways for inclusive

and sustainable solutions to the impacts of shifting marine resources on livelihoods along the Nunatsiavut coast. As such, our review is an extension of the processes and products of knowledge co-production efforts guiding the overall project, grounded in an acknowledgement that there is a placed-based need to change how science is done as identified by the NG and rights holders in Nunatsiavut. Our team mutually agreed on the following study design and methods for the review.

### Approach to the literature review

We conducted a systematic review of knowledge co-production literature emerging from different epistemologies and ontologies from 2000 to 2020. We selected the systematic review method to reduce bias and enhance the reliability of our results and conclusions (Clark 2011). We restricted our search to literature published in the twenty-first century (2000–2020) due to the concentrated emergence of knowledge co-production literature in sustainability science near the turn of the twentieth century (Miller and Wyborn 2020). We also used ISI Web of Science (WoS), the Scopus database, and Google Scholar to obtain the widest representation of peer-reviewed knowledge co-production studies available. This approach aligns with advice that systematic reviewers draw from multiple databases in the review process (Bramer et al. 2017), including for environmental science reviews (Haddaway et al. 2015).

We conducted our literature search in six phases to optimize our access to a broad collection of peer-reviewed and grey literature on knowledge co-production and situate the findings in the context of Nunatsiavut (Fig. 1). Zurba, Madge, and Petriello carried out phases 1–4 and Petriello carried out phase 5. Phase 1 centered on broadly identifying studies that used or produced knowledge co-production frameworks. Phase 2 included a combination of terms focused on Indigenous and Inuit knowledge, ontologies, and epistemologies to identify literature that aligned with the socio-cultural context of Inuit Nunangat. Phase 3 adopted slight modifications to the combinations to conduct searches in WoS and Scopus. Phase 4 comprised scoping searches in Google Scholar (Haddaway et al. 2015; Martín-Martín et al. 2018) with three broad phrases about successful and principle-driven knowledge co-production to increase our access to grey literature (Fig. 1). Phase 5 deployed citation tracing and Google Scholar alerts to accrue additional articles that were either published after the first 4 phases (August 2020) or were not found in previous phases (Fig. 1).

We screened abstracts in phases 1–5 using 3 criteria. First, we reviewed abstracts that engaged with the concept of knowledge co-production in some form, such as references to knowledge production, co-creation, and integration. Second, we reviewed abstracts that conceptualized knowledge
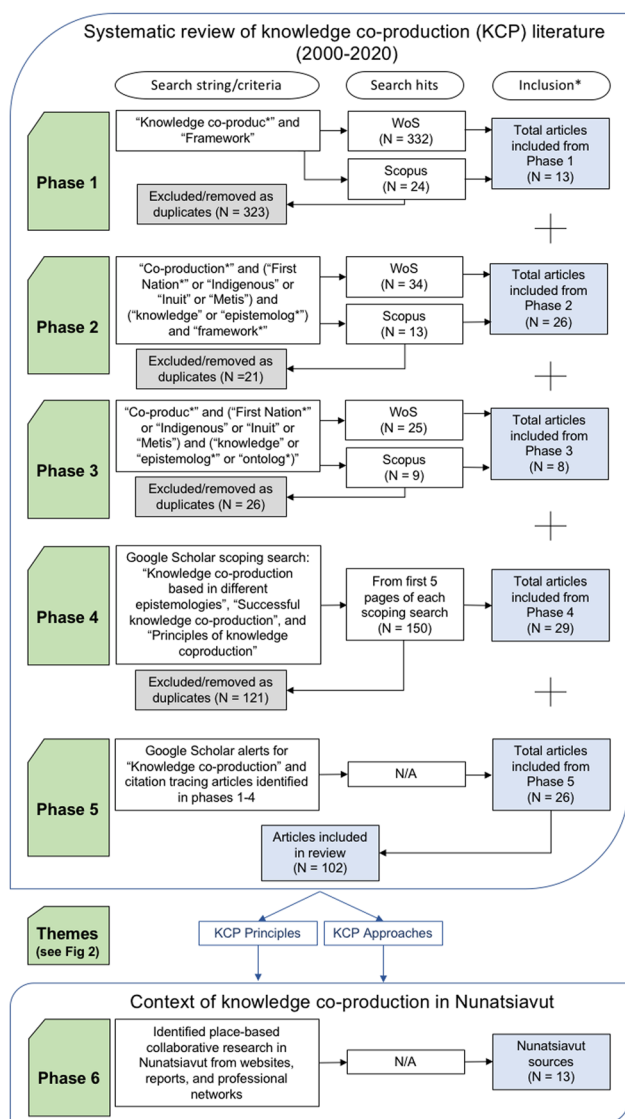
**Fig. 1** Schematic diagram of the literature review structure. *Inclusion criteria are described in the approaches to the literature review section

co-production as *interactions* among knowledge systems linked to different ontologies or epistemologies rather than those strictly focused on distinct, nested components of knowledge co-production (e.g., knowledge sharing). Third, we only reviewed English publications due to the reviewers' linguistic constraints. If exclusion could not be determined solely based on the abstract, it was included for full text review. In total, 102 knowledge co-production articles met our inclusion criteria (Fig. 1; supplementary material S1).

Lastly, phase 6 included a supplementary scoping search of collaborative projects in Nunatsiavut to form the contextual contours of the review. McCarney, Denniston, Bishop, and McBeth carried out this phase. Given the lack of peer-reviewed knowledge co-production research in this region, the prevalence of ongoing collaborative research, and authors professional and personal experience in Nunatsiavut, we used project and government websites, previously identified peer-reviewed sources, and professional networks to locate place-based literature in the region. In total, we identified 13 sources that described collaborative research projects in Nunatsiavut.

## Analysis

We adopted a hybrid form of exploratory inductive and deductive thematic analysis to analyze the original 102 articles (Fig. 2). First, we used NVivo (QSR International 2019) to identify 9 emergent themes from the 76 articles identified in phases 1–4, such as factors contributing to successful knowledge co-production, best practices for knowledge co-production, and types of knowledge holders. Second, we reanalyzed all 102 articles after phase 5 of the literature review, resulting in 6 additional themes. We then condensed all 15 themes into 2 themes—guiding principles and approaches—which fall along the concise yet multilayered descriptive/normative divide that tends to frame the knowledge co-production literature (Bremer and Meisch 2017). We draw from Bremer and Meisch's (2017) description of normative co-production to define knowledge co-production principles as fundamental philosophies, values, beliefs, and normative frameworks that guide how different groups *should* define and approach knowledge co-production across all levels of society. Adapting Bremer and Meisch's (2017) descriptive lenses of co-production, we define approaches to knowledge co-production as the processes, strategies, methods, and tools used to *interpret* and *diagnose* the shifting relationships at the science-society interface. This framing helped interpret and juxtapose two decades of findings with the Nunatsiavut context. We describe and synthesize these components and their documented roles in collaborative research in Nunatsiavut below.

## Bibliometrics from the systematic review on knowledge co-production

Bibliometric information from the knowledge co-production literature enabled us to glean temporal and geographic (i.e., the study sites) insights about the knowledge co-production process relating to each article. We also assessed if authors invoked positionality statements (broadly considered references to researcher's identities in relation to the study context and/or goals), references to colonisation, decolonising methods, and Indigenous data sovereignty. Indigenous authorship was also assessed from in-text references to authors' identities and Google searches for authors using their names and affiliations in the literature. Indigenous membership refers to author's self-reported identities either

**Fig. 2** Structure of the inductive and deductive thematic analysis applied to 102 knowledge co-production studies published from 2000 to 2020
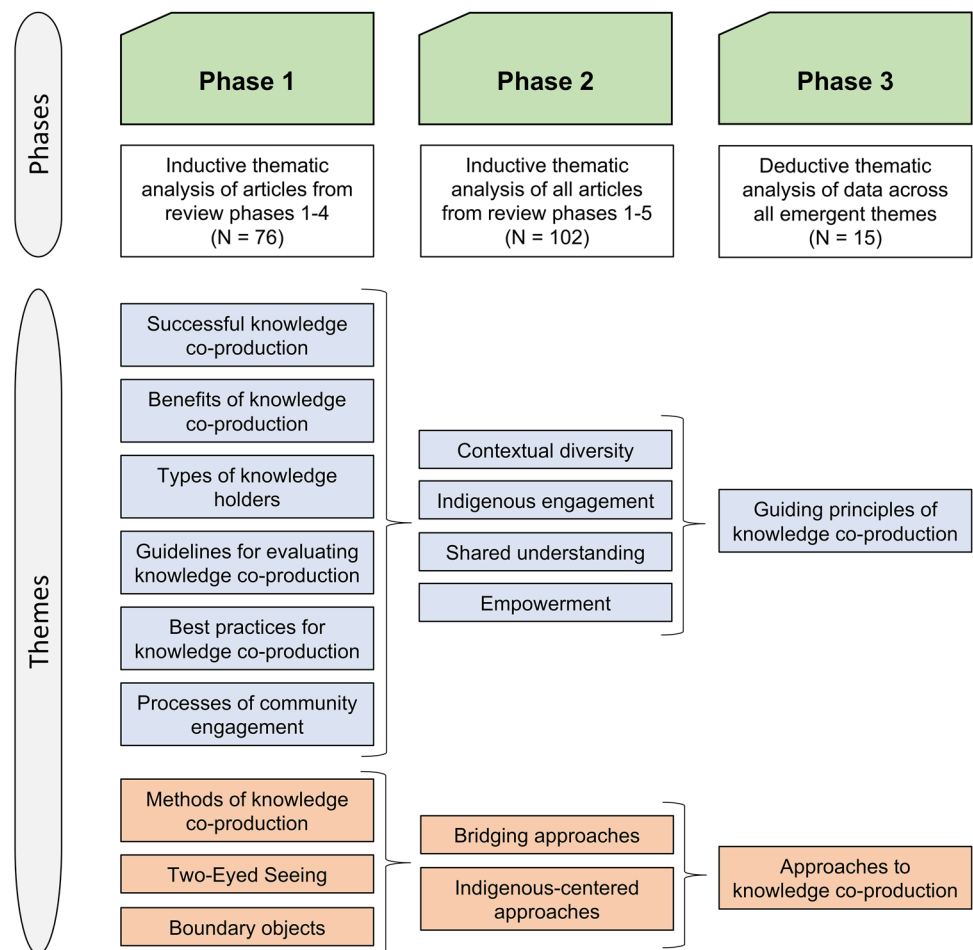


in the article text or online professional biographies. Due to time constraints, we limited our search to the first two pages of Google results.

Most of the 102 knowledge co-production articles (92%) were peer-reviewed. All remaining articles (8%) were grey literature (i.e., theses, dissertations, and technical reports). Conversely, most Nunatsiavut sources (77%) were grey literature (i.e., technical reports, websites, and regional presentations) rather than peer-reviewed publications (23%). Knowledge co-production articles (77%) were mostly published after 2014 (Fig. 3) as single- or multi-site case studies in 28 countries (Fig. 4). Yet articles largely focused on knowledge co-production work in Canada (26%), the United States (16%), and Australia (10%), with global reviews or conceptual articles comprising 27% of all articles. We also found 19 articles (19%) with information to indicate that their publication was co-produced, such as authorship background statements, descriptions of efforts to account for author's academic and cultural diversity, and reflections on the iterative, interactive, and contextualized processes underlying their written work (e.g., Carter et al. 2019; Reid et al. 2020). Fourteen of the 19 articles with positionality statements (74%) and 30 of the 83 articles without positionality

statements (38%; or 43% of all articles) situated their contextual reflexivity or research as efforts towards decolonisation, Indigenous methodologies or Indigenous data sovereignty to counteract regional colonial legacies (e.g., Davidson-Hunt et al. 2013). Thirty-nine studies took place in Canada (59%), the United States (28%), or both countries (13%). Although only 22% of all articles included Indigenous authors from over 16 groups (see supplementary material S1), Indigenous authors contributed to 69% of co-produced articles and 45% of articles that referenced (de)colonisation, Indigenous data sovereignty and methods, and related terms, including 88% of co-produced papers in North America and 100% in Canada. Ninety percent of Indigenous authored articles had positionality statements.

# Results: knowledge co-production principles and approaches

## Guiding principles of knowledge co-production

As a first principle, we found that *context dependency* is the most salient knowledge co-production principle in the

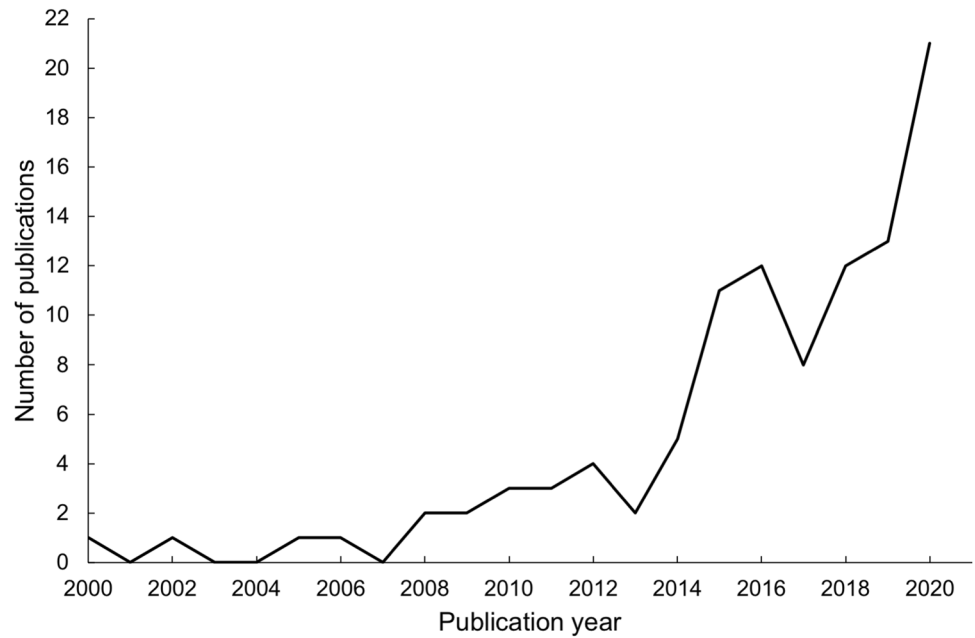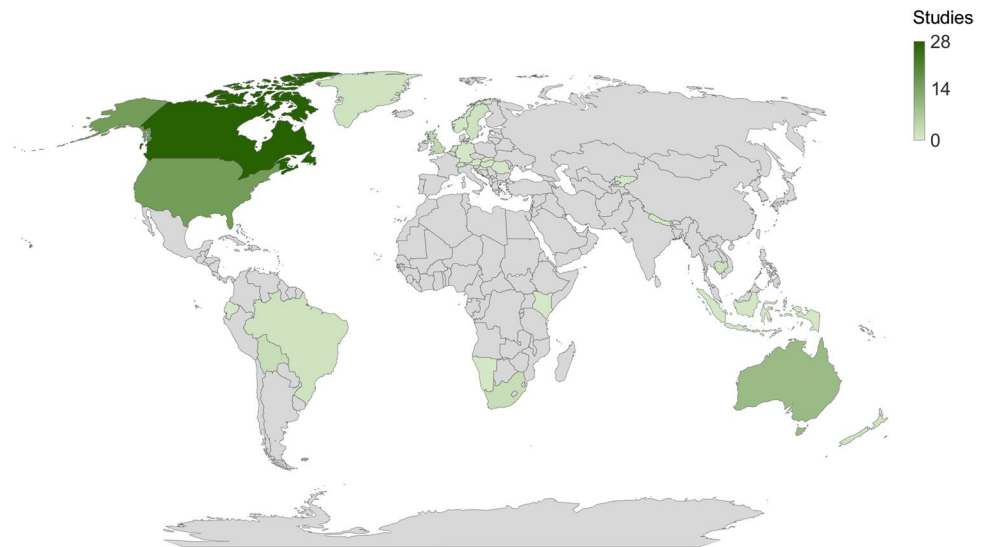**Fig. 3** Publication years of 102 knowledge co-production studies from 2000 to 2020



**Fig. 4** Geographic distribution of 74 knowledge co-production studies published from 2000 to 2020, omitting 28 articles that were conceptual, theoretical, or global reviews



reviewed literature (Brattland and Mustonen 2018; Norström et al. 2020; Rathwell et al. 2015). Norström et al. (2020) succinctly capture this principle in the following terms: "A co-production process can be place-based, but 'context' is not synonymous with 'local'; it could be national, regional, global or even scale-agnostic, but restricted to a defined set of issues. Context-based co-production also means taking into account the different needs, interests and beliefs of the different social groups…". In other words, knowledge co-production processes should recognize and respond to the many contexts—whether ecological, economic, cultural, social, disciplinary, or institutional—that bound their success (Davidson-Hunt et al. 2013; Kettle 2019; Polk 2015; Rathwell et al. 2015; Schuttenberg and Guth 2015). Such

contextual diversity and dependence ensures that no one knowledge co-production process will conform to all projects and 'context' will mean and achieve different things for different actors and endeavors. For example, Schuttenberg and Guth (2015) found that social–ecological context represented a component of co-productive capacities that increased the salience of knowledge for a climate change action plan in Hawaii. Knowledge co-production in northern Canada often centered on fostering contextual benefits for Indigenous communities and ILK, such as reversing colonial research legacies and lack of agency in Arctic communities, promoting ecosystem health, and institutional adaptations to climate change (Carter et al. 2019; Falardeau et al. 2019; Kourantidou et al. 2020; Mantyka-Pringle et al. 2017; Schott

et al. 2020; Vogel and Bullock 2020). Indeed, equitable recognition and interactions with contextual ILK emerged as a common theme in this review, contrasting with findings that climate adaptation scholars tended to study ILK in co-production as fixed data rather than contextual relationships (Klenk et al. 2017). This suggests that context not only shapes interactions with knowledge, but also its perceived research value.

The second principle we identified was *frequent, sustained, and early engagement* with ILK holders (Huntington 2000; Huntington et al. 2002). The literature highlights that engagement with ILK holders should begin even before the start of any knowledge co-production processes (Chapman and Schott 2020; Matuk et al. 2020b). Early collaboration allows for knowledge co-production efforts to develop in ways that comply with local priorities and expectations (Falardeau et al. 2019), identify culturally appropriate methods and communication channels (Huntington et al. 2002; Jones et al. 2008; Maclean and Cullen 2009), anticipate power sharing scenarios and conflicting worldviews (Pohl et al. 2005; Zurba 2009), and foster trust, respect, and reciprocity among all project partners. Furthermore, ILK holders are also experts in what they do not know (e.g., Idrobo and Berkes 2012), meaning they are best equipped to decide where and how to use their knowledge for co-production. To optimize the potential for successful knowledge co-production, scholars recommend reflexive and iterative engagement with ILK holders throughout all stages of knowledge co-production cycles (Armitage et al. 2011; Dale and Armitage 2011; Raymond et al. 2010). Others also suggest that non-Indigenous co-producers should create space for Indigenous peoples to lead and move beyond just being stakeholders and knowledge sources (Latulippe and Klenk 2020). Otherwise, knowledge co-production can turn into an exercise that leverages the rhetorical strength of ILK as a "political crowbar for Indigenous empowerment and engagement" (Sidorova 2020:10) without conferring any substantive decision-making power to ILK holders, such as a role in shaping project goals.

The third principle we identified was shared understanding and commitment to knowledge co-production and project goals. Common awareness of knowledge co-production and what it entails can be approached by familiarizing co-producers with academic and grey literature (Reed and Abernethy 2018). For example, Cooke et al. (2020) present reading key articles as part of the best practices for knowledge co-production. Familiarity with knowledge co-production literature facilitates the creation and application of place-based and actionable knowledge and science (Beier et al. 2017; Reed and Abernethy 2018). Moreover, this principle can act as a normative compass, or context, for co-producers. This normative compass orients project partners towards a conceptual and practical 'true north', which may help project

partners identify the different assumptions, values, and worldviews they and others are using to define the problem. It can also push co-producers to expand on existing science, discover questions leading to new scientific frontiers, and reevaluate inadequately conceptualized problems to align with their shared vision (Hegger et al. 2012; Jagannathan et al. 2020). In turn, maintaining shared understanding, commitment, and objectives may also allow knowledge co-producers to intuitively assume roles that best fit their skill sets within their projects (Pohl et al. 2010). However, the lack of shared understanding may impede actor's abilities to recognize other's perspectives and knowledge (McCarney 2018), reinforcing the challenge of achieving a common goal with multiple partners in a transdisciplinary context (Harris and Lyon 2014). Shared understanding, therefore, sets a baseline for iterative and interactive reflection on the purpose and progress of knowledge co-production as a whole, including whether it empowers those who are disproportionately affected by power imbalances (e.g., Hill et al. 2020b; Vincent et al. 2020).

Lastly, we found that the fourth principle of *empowerment* encompassed all other principles that manifested from our review. Empowerment emerged as an implicit and explicit principle of knowledge co-production, which some have described as an "intangible benefit" (Djenontin and Meadow 2018:894). It is implicit in that many scholars have proposed or identified empowerment as a central philosophy, ethical orientation, conceptual lens, or an extension of the fundamental values of knowledge co-production (Bell and Pahl 2018; Bremer and Meisch 2017; Bremer et al. 2019; Tengö et al. 2014; Turnhout et al. 2019). Others explicitly see it as a necessary precondition, component, or outcome of knowledge co-production and resultant cross-cultural exchanges (Chapman and Schott 2020; CTKW 2014; Enengel et al. 2012). Klenk et al. (2017), for instance, noted that the literature presents knowledge co-production as an empowerment process in itself. Just as it can implicitly and explicitly embody a philosophy, component, or outcome, empowerment through knowledge co-production also means many things to the scholars and practitioners that embrace its potential. Empowerment often centered on balancing the scales of power to create more decision-making capacity and space for marginalized and/or oppressed co-producers, particularly Indigenous peoples (Hill et al. 2020a; Latulippe and Klenk 2020; Schott et al. 2020). Others highlighted that "power should be used to construct and empower institutions to facilitate sustainability" (Miller and Wyborn 2020: 93). These frames shift knowledge holders from simply being sources of information to equal partners who can ensure their rights, worldviews, and lived experiences guide co-productive endeavors (CTKW 2014). Moreover, they may shed light on the (un)equal distribution of power across organizational dimensions of co-production projects

(Montana 2019). Importantly, empowerment places power at the forefront of knowledge co-production decisions and actions, suggesting that it has the potential to produce multiple (in)tangible benefits for actors at the many scales of the science-society interface.

## Approaches to knowledge co-production

Authors frequently presented approaches as domains, stages, and steps (e.g., Muñoz-Erickson 2014), whereas others directly referenced them as methods and tools (e.g., Fratnz-eskaki and Kabisch 2016). However, most authors embedded their approaches in frameworks and principles that reflected the contextual diversity of their knowledge co-production initiatives. This contextual diversity parallels calls for increased methodological diversity and "methodological bricolage" in knowledge co-production to evaluate actionable knowledge in all its forms (Jagannathan et al. 2020; Matuk et al. 2020b). Amidst this diversity, the approaches were united by the conceptually diffuse goals of creating *actionable* science towards catalyzing *transformative* societal change (Beier et al. 2017; Jagannathan et al. 2020; Mach et al. 2020). In this spirit, we present snapshots of multiple methods that represent the rich, interrelated tapestry of approaches directed towards practical and transformative knowledge co-production outcomes.

We found that knowledge co-production approaches largely bridged or rested on either side of the perceived divide between WSK and ILK. One such approach is the concept of Two-Eyed Seeing (*Etuaptmumk* in Mi'kmaw) (Reid et al. 2020). According to Reid et al. (2020), "Mi'kmaw Elder Albert Marshall defines Two-Eyed Seeing as 'learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all' (Bartlett et al. 2012)". Two-Eyed Seeing is centered in action that bridges knowledge systems, especially Indigenous and scientific, while respecting and upholding their different perspectives. From our review, scholars applied this framework to knowledge co-production for environmental health (Mantyka-Pringle et al. 2017) and the theoretical development of an expanded model of knowledge co-production known as knowledge coevolution (Schott et al. 2020). The Two-Eyed Seeing framework similarly aligns with the multiple evidence-based approach in which different knowledge systems are brought together and evaluated in a manner that is appropriate for their particular knowledge system (Tengö et al. 2014). This approach attempts to respectfully 'weave' together diverse knowledge systems, which can be achieved through multiple participatory methods (Johnson et al. 2016) and tasks (Tengö et al. 2017) that empower knowledge holders to address a common problem.

Many of the bridging approaches encapsulated the process of boundary work and the creation of boundary objects. Boundary work represents "engagement at the interface among potential collaborators to address practical, political, and cultural mismatches in their notions of usable knowledge" (Clark et al. 2016:4574). Similarly, Zurba et al. (2019) indicate that "Boundary work includes methodologies to support knowledge sharing and co-creation between research partners as well as work that can translate research outcomes into on-ground action" (1024). In doing so, boundary work breaks down boundaries that may exist between different stakeholders, organizations, and institutions (Buzinde et al. 2020; Leimona et al. 2015; Zurba et al. 2019). Boundary objects can be concepts, ideas, and items that all groups recognize and use as a mutual point of reference for actors with different epistemologies (Rathwell et al. 2015). They are thus conduits for connecting different organizations, actors, and cultures, functioning as a mutually beneficial tool for learning and adaptation. However, their effectiveness likely depends on their connection to contextual details (Zurba et al. 2019) and the presence, value, and capabilities ascribed to boundary workers and organizations (Clark et al. 2016; Reed and Abernethy 2018; Schuttenberg and Guth 2015). Boundary objects, workers, and organizations, therefore, have the ability to bridge multiple knowledge systems, cultures, and institutions across multiple contexts in multiple directions (Reed and Abernethy 2018; Tengö et al. 2014, 2017).

Boundary objects emerge from many tools and methods that are instrumental in knowledge co-production. Examples include sharing, yarning, and talking circles that take group-based conversational approaches to knowledge and data gathering (Levac et al. 2018); scenario planning for complex and uncertain futures (Reyers et al. 2015); workshops to facilitate discussions about project goals and established collaborative baselines for co-production (Huntington et al. 2002; McCarney et al. 2014); and the use of a facilitator (i.e., boundary worker) to cultivate trust, promote common interests, manage conflicts, maintain shared understanding, and empower participants by recognizing their values and advocating on their behalf (Reed and Abernethy 2018). Methods that incorporate art or the creation of art can also nurture ILK, bridge knowledge across cultural gaps, and be the site for knowledge co-production (Zurba and Berkes 2014; Zurba and Friesen 2014; Zurba et al. 2019).

We also found that authors deployed multiple approaches that empowered Indigenous voices, amplified knowledge, and reaffirmed rights to self-determination within knowledge co-production. For example, the literature showed that engagement with Indigenous youth and Elders presented a path towards self-autonomy, cultural revitalization, and intergenerational transfer of ILK. Carter et al. (2019) reported that Inuit youth cultural liaisons honed facilitation

skills from Elders, allowing both groups to learn from one another, rekindle family relationships, and co-develop knowledge co-production tools. Others noted that youth played an important role in project design, which resituated power dynamics in the hands of community members (Bell and Pahl 2018). And Cunsolo Willox et al. (2013) similarly found that digital storytelling sparked agency and a sense of control over one's knowledge among Inuit youth and Elders in Nunatsiavut, which helped storytellers push against the history of colonial research in the region. Working with Elders and storytelling are two of many approaches from Levac et al.'s (2018) comprehensive list of Indigenous methodologies.

## Knowledge co-production in Nunatsiavut

Here we use the results of our systematic review to sift knowledge co-production principles and approaches from ongoing research projects in Nunatsiavut. We do not intend to provide an exhaustive review of Nunatsiavut-based research, nor do we claim to present complete interpretation of the results of the review; rather, we describe select projects as a way to ground the literature review results in contextualized examples of the many ways that researchers in Nunatsiavut deploy knowledge co-production in principle and practice.

## SakKijânginnatuk Nunalik

Founded in 2012, SakKijânginnatuk Nunalik (Sustainable Communities) is a transdisciplinary initiative designed to enhance sustainable community development in Nunatsiavut through partnered and integrated methodologies. The project aims to identify best practices to inform a holistic approach to infrastructure development and water, energy, and food security–all in the context of changing climatic, socioeconomic, and environmental conditions. Led by the NG, the initiative is grounded in Indigenous epistemologies and philosophies and follows "principles of transparency, respect, accountability, collaboration, and holisticness" (Riedlesperger et al. 2017:323)–all centering around relationships with Inuit in Nunatsiavut (Goldhar et al. 2012). The initiative follows a phased approach. Phase I focused on understanding current community priorities, opportunities and challenges through workshops. Phase II aims to adopt integrated, comprehensive, and solutions-focused approaches to community priorities and challenges (Goldhar et al. 2012). In response, SakKijânginnatuk Nunalik created several projects to address regional development needs, such as InosiKatigeKagiamik Illumi (Healthy homes in Nunatsiavut) to guarantee dependable and affordable housing, the Digital Information System for Communities (DISC) to identify suitable building sites via databases informed by

geoscientific and Inuit knowledge, and Aullak, sangilivallianginnatuk (Going off, growing strong) to teach at-risk youth Inuit knowledge and skills through mentorships with Elders and hunters (Riedlsperger et al. 2017).

SakKijânginnatuk Nunalik, therefore, responds to local priorities and needs in ways that outwardly reflect knowledge co-production principles of *contextual diversity*, *engagement with Indigenous knowledge holders,* and *empowerment.* However, study participants identified that low community awareness of the project and the lack of a framework to assess interlinkages among different project/sub-projects, suggesting that more emphasis on community-engaged approaches would reify the initiative's commitment to Inuit communities and culture (Riedlsperger et al. 2017). These challenges demonstrate the importance of revisiting principles and approaches at all stages of a project.

## Torngat Mountains Caribou Herd (TMCH) Inuit knowledge, culture and values study

Knowledge co-production principles and approaches are also reflected in the Torngat Wildlife and Plants Co-Management Board's (TWPCB) transdisciplinary, transboundary and multi-partner co-management of the Torngat Mountains Caribou Herd (TMCH) (Snook et al. 2018; Wilson et al. 2014). The TWPCB is composed of three Nunatsiavut representatives, two provincial representatives, one federal representative and one independent chair. The TMCH is a unique and important herd of caribou harvested by Nunasiavut and Nunavik Inuit. Nunatsiavut Inuit requests for research around TMCH survival and stewardship initiated this TWPCB-led work in 2010 (Snook et al. 2018). The research mobilized Inuit knowledge from 33 semi-directed interviews and participatory mapping as *boundary work* in Nain and Kangiqsualujjiaq, Nunavik, Québec (Wilson et al. 2014). A community liaison and Elder helped correct a deficit of Inuttitut place names on the reference map early in the interview process. Community validation of knowledge ensured shared understanding and ownership of that knowledge. As such, research and practice with the TWCPB seem to have been grounded in principles of social–ecological *context* of local caribou, *inclusion and engagement with ILK holders*, and *empowering* Inuit with new knowledge and decision-making capacities (Snook et al. 2018; Wilson et al. 2014). Inuit knowledge holders allowed the Committee on the Status of Endangered Wildlife (COSEWIC 2017) to recommend designating the TMCH as endangered (Snook et al. 2018).

## Community-based Observing of Nunatsiavut coastal Ocean Circulation (CONOC)

Initiated in 2018, Community-based Observing of Nunatsiavut coastal Ocean Circulation (CONOC) aims to improve knowledge of coastal ocean currents to assist local climate change planning in Nunatsiavut. CONOC integrates a number of dimensions and activities ascribed to knowledge co-production processes. In particular, it draws on information derived from traditional oceanographic observation methods and participatory mapping workshops with Elders and other knowledgeable community members (CONOC n.d.). Both of these approaches are grounded in methods of community engagement through various educational and participatory workshops.

For example, researchers and community members collaboratively produced regional maps depicting Inuit knowledge of local oceanographic conditions in two participatory mapping workshops (Bishop 2020). The maps served as effective *boundary objects* that facilitated discussion and translation of knowledge in a cross-cultural setting (Rathwell et al. 2015). Knowledge from these workshops will be used to project future regional changes through a computational model. Moreover, the project is currently producing community-centered travel and education books informed by the project results and pushed forward by community member's suggestions. CONOC demonstrates *workshops* and *boundary objects* as important enablers of meaningful communication and knowledge translation. We cannot speak to the success of the project overall from the perspective of community members as this project is ongoing and community feedback is not publicly available.

## Land-based workshops for climate change research and adaptation in Nunatsiavut

In September 2019, academic partners and the Nunatsiavut Government organized and facilitated two land-based workshops to exchange knowledge on climate change research and adaptation in Nunatsiavut (Flynn et al. 2020). The rationale for the workshops was to create a space where academic and government researchers, Nunatsiavut Government representatives, and Inuit youth, adults, and Elders could exchange interdisciplinary and multifaceted information about climate change in Nunatsiavut. The workshop was formatted to allow participants to have a two-way exchange of ideas and knowledge and communicate about climate change based on their lived experiences rather than within the more narrow confines of university disciplinary or government departmental mandates. In addition, climate change information is often shared in boardrooms and meeting rooms where it is physically and conceptually removed from the landscapes and environmental contexts within which the

impacts are actually observed and felt. The workshops brought participants onto the land to speak about climate change in place.

The use of a land-based setting provided physical spaces for participants to convene and interact. These spaces also helped facilitators to address traditional power dynamics between multiple groups of participants by removing the physical sense of hierarchy often present in indoor settings where a perceived expert speaks to a group of perceived non-experts. To achieve the translating function, the facilitators compiled materials and information in advance during pre-workshop meetings with researchers. These pre-workshop meetings allowed the facilitators to identify linkages between the research areas and fields of work among the diverse disciplines of the researchers. This approach also ensured that workshop materials, including those used in group and breakout discussions, were in language that was accessible to all participants. To achieve meaningful collaboration, interactions took place in group settings and there was time purposefully scheduled for informal interactions, such as during meal times. The facilitators also ensured that all participants had time to speak and created dedicated time for Elders to share their knowledge with researchers. Careful planning among co-facilitators helped achieve the function of mediating by having multiple facilitators able to observe the dynamics between participants and make fine adjustments to the format and tone of the workshops as needed. The mediating function was integrated throughout each of the other three functions to create the physical and discursive space that upheld fairness and equity among participants and ensured that facilitators were cognizant of power dynamics.

## Qanuippitaa? National Inuit Health Survey (QNIHS)

The Qanuippitaa? National Inuit Health Survey (QNIHS) is a national health research initiative running in all four Inuit regions in Canada. The project is managed by regional organizations in the four Inuit regions yet centrally coordinated by Inuit Tapiriit Kanatami. Its goal is "to provide high-quality, Inuit-determined and Inuit-owned data to monitor change, identify gaps and inform decision-making, leading to improved health and wellness among Inuit in Canada" (Inuit Tapiriit Kanatami 2019). Six principles guide the QNIHS: Inuit-determination, focus on Inuit health and social equity, being strengths-based, collaboration, methodological rigor, and innovation. A regional QNIHS committee advises the development of research tools and approaches appropriate to Nunatsiavut. The regional QNIHS committee is composed of a range of actors, including health professionals, medical practitioners, academic researchers, Nunatsiavut Government representatives from multiple departments, and Inuit youth and Elders. In this respect, the committee ensures input from a range of participants who contribute

their specific knowledge to give shape to the project. For instance, QNIHS used a collaborative consensus-based decision-making process wherein the project team determined specific focal health areas for its survey, identified inclusion and exclusion criteria for survey questions, and collaboratively defined the parameters of the health survey data. In these ways, QNIHS echoes the knowledge co-production principle of *shared understanding of problem definitions* among actors and participants.

## Labrador Inuttitut story database

The Labrador Inuttitut Story Database was a language revitalization project to develop language learning materials at Jens Havens Memorial School in Nain. Although united behind its shared vision, this collaborative project between linguists, a public school teacher and Inuttitut speakers had to reconcile and *bridge* different goals to co-produce knowledge; linguists were interested in the academic study of Inuttitut whereas communities had long-term language teaching goals (Dicker et al. 2009). However, these goals had to be reconciled to reach pluralistic and integrated understandings of how they could be jointly achieved. The project used the approaches of *storytelling* and *youth engagement* to these ends. Youth participation was key, as the attitudes of children and youth are fundamental to the successful creation and application of language revitalization efforts (McCarty and Wyman 2009). The relevance of the project as a language resource was put to the test directly with approximately 400 K-12 students, with seemingly positive results. Storytelling of knowledge increased *engagement* with youth learners and sharing from Inuttitut language experts.

## Discussion and conclusions

Our systematic review of the literature from the first 20 years of the twenty-first century revealed contextually adaptable principles and approaches for knowledge co-production in diverse settings, including Nunatsiavut and the *Sustainable Nunatsiavut Futures* project. We conceptualized both as interdependent components of the same process; principles support *why* different actors *should* pursue knowledge co-production, whereas approaches show *how* different actors can adhere to, enact, and embody those principles in action. This interconnectedness means that they feed into and reaffirm one another, producing multiple benefits at different stages of knowledge co-production (e.g., *contextual* and *sustained engagement* can *empower ILK holders* to *assert their worldviews* through *boundary objects* that generate transformative knowledge). It also means that their benefits and barriers are difficult to disentangle in theory and practice. However, grounding the results of the literature review in

examples of place-based projects in Nunatsiavut enabled us to identify some potential paths for researchers to navigate the challenges and opportunities that emerge when deploying knowledge co-production, in principle and practice, in Nunatsiavut and beyond.

First, the examples from Nunatsiavut highlight the mobilization of principles and approaches that bridge cultural, social and environmental contexts. Given the goals of the *Sustainable Nunatsiavut Futures* project, in particular the co-production of science, planning and adaptive management strategies, it will be essential to pay keen attention to roles (e.g., who is involved in leadership of the knowledge co-production), mechanisms for collaboration (e.g., engagement processes), and where power exists within the knowledge co-production system—i.e., how substantive decision-making regarding knowledge co-production processes take place and how knowledge is eventually synthesised and shared (Zurba 2009). Understanding roles, mechanisms, and loci of power helps co-producers confront contextually varied, potentially unpredictable, or even imperceptible barriers, including epistemological clashes (Díaz-Reviriego et al. 2019), power asymmetries (Schick et al. 2018), competing modes of transmission and communication (König et al. 2013), funder's influence on research (Arnott et al. 2020), uncertainties in knowledge validation (Uliscni et al. 2019), and tokenism (Sidorova 2020). As stated by Mach and colleagues (2020: 32), "the practice of co-production is a means of changing *how* decisions are made by changing *who* is present in the knowledge-production processes." Future knowledge co-production endeavours in Nunatsiavut should mobilize the principles and approaches identified in our review and reflect on what practices have been effective for knowledge co-production (e.g., land-based practice) and what principles require further exploration (e.g., empowerment).

Second, active and meaningful engagement of ILK holders will help to avoid the pitfall of tokenism occurring throughout the co-production process (Norström et al. 2020). Tokenism can be found in an imbalance of roles of knowledge holders, where certain conceptions of who various knowledge producers are influence their credibility. Engagement without resources (financial, human), independence to shape knowledge creation, and representative participants is not credible (Sarkki et al. 2015). Moreover, it may actively *disempower* and reduce ILK holders to one-dimensional symbols of collaboration and cross-cultural exchange (Sidorova 2020). For these reasons, it must be recognized that tapping into the latent potential of powerful, multidimensional concepts such as "knowledge" and "empowerment" demands careful, intentional, and premeditated work with ILK holders. Such work may include efforts to understand the different types of ILK that may be generated and held by specific people, such as common and specialized ILK (Davidson-Hunt et al. 2013; Ulicsni et al. 2019), or open

conversations and assessments of power, including the types of empowerment that are needed or appropriate for the particular project (Petriello et al. 2021; Turnhout et al. 2019). In this way, phased approaches, such as those from the SakKijânginnatuk Nunalik initiative, will be essential for not only maintaining knowledge co-production principles, but also helping partners prepare for the challenges of sustained and meaningful engagement throughout project lifecycles.

Third, phases or stages also act as important building blocks for evaluation, learning and adaptation (Louder et al. 2021; Pohl et al. 2021; Polk 2015). Particular approaches have evolved in the knowledge co-production literature offering practical insights for knowledge co-production phases. Boundary work, in particular, is a practical approach that has been effectively used for knowledge co-production and can help knowledge co-producers to scope projects according to individual and mutual objectives, consider and enhance equity and ethical principles relating to decision-making throughout the project, plan and create knowledge products (boundary objects) that support co-creation objectives, and mobilize co-created knowledge in a way that meets the aspirations of different types of knowledge holders (Zurba et al. 2019). By following a phased approach rooted in contextual empowerment, foundations for greater equity, relationships and trust can be built early on, leading to a greater potential for such qualities to exist in later stages of the co-production process. It is also important that the first phases reconcile with the histories upon which newfound collaboration are grounded, including the impacts of colonisation, the need for truth-telling and any necessary actions that may be taken towards restitution and/or reconciliation (Zurba and Sinclair 2020).

Fourth, context-dependent considerations regarding data sovereignty and decolonising methodologies will also be essential for ethical knowledge co-production processes in Nunatsiavut and elsewhere. While there is not a unified approach to data sovereignty for research in Inuit Nunangat, this fact reflects the diverse political contexts of each of the four Inuit regions in Canada and the tendency of researchers in the region, including those who were proposing novel research agendas (e.g., Westwood et al. 2020), to preemptively reflect on their roles and questions of intellectual property and data sovereignty. The National Inuit Strategy on Research (Inuit Tapiriit Kanatami 2018) acknowledges the need for research to explicitly engage with considerations around data sovereignty and commits Inuit Tapiriit Kanatami and Inuit regions to ensuring "Inuit access, ownership, and control over data and information" (p. 4). Therefore, researchers in Nunatsiavut and elsewhere should consider these principles in developing data sovereignty agreements and approaches in their projects. Researchers may also want to draft individual and group positionality statements to acknowledge histories of colonisation that may not be visible to all project partners. To this end, the nature of individual land claims agreements between each Inuit region can be instructive to researchers in framing their positionality, implementing principles of access, ownership, and control in individual projects, and identifying context-specific outcomes for work in the Arctic, including Nunatsiavut.

Successful or high-quality knowledge co-production processes may result in outcomes that foster new relationships and networks that may help to pave the way for large-scale and long-term changes (Norström et al. 2020). Successful knowledge co-production processes will also result in mutual understanding and a criterion of credibility that has been developed in a respectful way, even in the face of a diverse range of participants (Norström et al. 2020). The findings from this review support the principles described by Norström et al. (2020), yet place greater emphasis on power dynamics. As such, the principles and approaches found here importantly show that markers of success should also include non-conventional outcomes (e.g., youth empowerment) and alternative avenues for mutual understanding (e.g., Two-Eyed Seeing), including assessments of the distribution of power amongst co-producers. Therefore, even if knowledge co-production processes do not result in traditionally tangible outcomes, such as volumes of academic publications or policy changes, they can still be considered successful endeavours that transform science and society.

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