

**Understanding knowledge exchange in practice: empirically derived insights
for engaging in effective knowledge exchange for environmental management**

by

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Dedication

I dedicate this work to my parents for their unconditional love, endless support, and encouragement. To my sister, Tanya, for all the school essays of mine that you were forced to edit – thank you for always guiding and challenging me to be a better student. To my brother-in-law, Nathan, for reminding me to get outside and put my skis to good use, even after a tough day. To my close friends, near and far, for always supporting my dreams and for all the belly-ache laughter. To everyone in the Social Ecology and Conservation Collaborative Lab who have made this experience unforgettable and worthwhile. To the rocking team that made this thesis possible, Jenna Hutchen, Matthew Falconer, Alana Westwood, and Kimberly Klenk, thank you for your guidance and for making online meetings something enjoyable to look forward to. I would not be writing this without all your kindness and support. To my supervisor, Vivian, for your dedication, enthusiasm, and encouragement. Thank you for always believing in me and for your enormous support over the past two years. To have felt your unending support from a different province and during a global pandemic is a testament to what an incredibly kind, motivating, and uplifting person you are.

Abstract

Knowledge exchange (KE) is a dynamic process that can support evidence-informed decision-making for environmental and natural resource management. To minimize the gap between how engaging in KE is theorized versus how it is practiced, I investigate empirical case studies to determine what is required to practice effective KE. In Chapter 2, I use a scoping literature review to assess empirical case studies from around the globe. I identify and organize the enablers to KE into an existing framework, in addition to identifying the challenges and impacts of practicing KE. In Chapter 3, I use interviews to collect information on how practitioners at the Canadian Forest Service implement and operationalize KE, and how they evaluate the effectiveness of their efforts. This thesis demonstrates what is required in practice to support and facilitate effective KE and argues why long-term evaluations are necessary to improve how we engage in KE work.

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Co-Authorship

Chapter 2: Taking knowledge exchange to practice: Learning from practical case studies. Tyreen Kapoor, Christopher Cvitanovic, Kimberly Klenk, and Vivian M. Nguyen

While this study is my own, the research was undertaken as part of a collaborative effort and each co-author played a valuable role in its completion. The project was conceived by Nguyen, Falconer, and Westwood. Search strings were developed by Kapoor, Christina Bell, Cvitanovic, and Nguyen. All literature search was completed by Kapoor, Bell, and Nguyen. Screening of the literature was completed by Kapoor, Klenk, and Nguyen. All data extraction and analysis were completed by Kapoor. All writing was conducted by Kapoor. Cvitanovic and Nguyen provided comments and feedback on the manuscript. I have opted to use the term “we” in this chapter due to the collaborative nature of this study.

Chapter 3: Implementing and evaluation knowledge exchange: Insight from practitioners at the Canadian Forest Service. Tyreen Kapoor, Matthew Falconer, Jenna Hutchen, Alana R. Westwood, Nathan Young, and Vivian M. Nguyen

While this study is my own, the research was undertaken as part of a collaborative effort and each co-author played a valuable role in its completion. The project was conceived by Nguyen, Falconer, and Westwood. Interviews were completed by Christina Bell, Jenna Hutchen, and Kapoor. All transcriptions were completed by Kapoor and Hutchen. The codebook was developed and tested by Kapoor, Falconer, Hutchen, and Nguyen. Coding, data analysis, and interpretations were completed by Kapoor. All

writing was conducted by Kapoor. All co-authors provided comments and feedback on the manuscript. I have opted to use the term “we” in this chapter due to the collaborative nature of this study.

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Chapter 1: General Introduction

There is an increasing urgency to develop effective ways of exchanging knowledge for environmental and conservation research to achieve real-world impact (Fazey et al., 2013; Marshall et al., 2017; Cook et al., 2017). This is especially evident as the world faces complex and irreversible challenges such as those associated with climate change, population growth, and biodiversity loss (Felton et al., 2009; Cvitanovic et al., 2016). However, simply the accumulation of scientific knowledge and information is not enough to enhance environmental management and sustainability practices (Reed et al., 2014). Rather, the effectiveness of environmental management may be influenced by how knowledge is exchanged, with whom it is exchanged, and how it is used to influence decision-making and/or practice (Cash et al., 2003; Fazey et al., 2013).

Effective environmental management requires collaborations across various disciplines and sectors such as scientific, economic, and policy sectors (Fazey et al., 2014). The diverse values and objectives of these disciplines and sectors can make it challenging to identify and exchange the best available scientific knowledge for evidence-informed decision-making and practice (Sarkki et al., 2014; Young et al., 2014; Watt et al., 2019). Difficulties exchanging scientific knowledge for evidence-informed decisions and practices have been attributed to communication differences between disciplines and sectors, and challenges for scientific communities to generate useable information (Young et al., 2014; Wurtzebach et al., 2019). As a result, practitioners have turned to knowledge exchange to support evidence-informed decision-making and practices (Van Eerd & Saunders, 2017, Buxton et al., 2021; Singh et al., 2021).

Knowledge exchange (KE) is a dynamic and iterative process of generating, exchanging, and using knowledge through various methods that are relevant to the context and purpose of the project, and are accessible to project actors (Fazey et al., 2013). Generally, there are three main actors involved in KE work. These are: (1) *knowledge producers* who are responsible for generating research or information (Ward et al., 2012), (2) *knowledge users* who adapt and apply the knowledge generated by knowledge producers (Graham et al., 2008), and (3) *knowledge brokers* who facilitate knowledge movement between knowledge producers and users (Naylor et al., 2012). Scholars have outlined that KE is most effective when it facilitates collaborative communication between knowledge producers and users, while also engaging knowledge users in all aspects of the research process (Cook et al., 2013; Bautista et al., 2017; Cvitanovic et al., 2021). A range of approaches have been identified that enable interactive and collaborative KE, some of which include the use of cross-disciplinary intermediaries such as knowledge brokers (Bednarek et al., 2018), building relationships and trust between knowledge producers and users to improve communication and produce usable science (Fazey et al., 2014; Cook et al., 2020; Cvitanovic et al., 2021), and acquiring sufficient resources such as funding, time, and staff (Meadow et al., 2015). In addition, barriers to engaging in effective KE have been explored in detail (e.g., Walsh et al., 2018, Rose et al., 2018). Some barriers to effective KE can include limited capacity, such as resources and staff, to perform KE (Lemieux et al., 2018), limited or short-term funding (Cvitanovic et al., 2018), mismatched project timelines and objectives between knowledge producers and users (Dunn & Brown, 2018), and difficulty for knowledge producers to communicate complex knowledge with knowledge users (Guido

et al., 2016). Although the enablers and barriers to effective KE have been identified, little to no research has synthesized empirical studies to determine how KE is operationalized in practice (Meadow et al., 2015; Rose et al., 2018). Further, it can take three to nine years to observe the impact of interdisciplinary science, policy, and environmental management work (Cvitanovic et al., 2021). As a result, many studies do not empirically assess the impacts of KE work (Westwood et al., 2021). It is therefore important to identify how to evaluate the effectiveness of KE work using empirical evidence to determine how to strengthen KE practices and overcome barriers. Aside from theoretical and suggestion-based guidance for engaging in KE, relatively few studies provide robust empirical evidence about KE strategies and implementation, how KE work is evaluated, and the enablers for effective KE (Rubenstein et al., 2001; Hickey et al., 2013; Reed et al., 2014; LSE, 2019; Westwood et al., in review). Investigating KE strategies and performance through empirical case studies would provide valuable insights on KE practice in environmental management to strengthen and improve evidence-informed decision-making and practices.

Research Objectives

The overall objective of my thesis is to examine how KE is put to practice using empirical case studies. In chapter two, I use a scoping literature review to investigate the enabling conditions, challenges, and impacts of KE through empirical case studies. I first frame and categorize the enabling conditions to KE using a *core capacity* framework first developed by Cvitanovic et al. (2016, 2018) that outlines what is required to support and facilitate KE. In this review I assess a broad range of primary literature and discern how

enablers can be implemented for practicing effective KE within environmental and natural resource sectors and identify the major challenges and impacts to doing so. In chapter three, I use an in-depth case study investigating the Canadian Forest Service (CFS) KE practitioners to offer empirical evidence and insights into effective implementation of KE. This is done by studying the role of CFS KE practitioners, the strategies they use to implement KE, what enables effective KE, and the various metrics practitioners use to analyze the effectiveness of their efforts. Both chapters two and three help to bridge the theory-practice gap by assessing how KE is operationalized and evaluated using empirical evidence. Finally, in chapter four I integrate the findings of the previous two chapters and present key insights and lessons-learned, recommendations for KE practitioners in environmental management, and future research directions.

Chapter 2: Taking knowledge exchange to practice: Learning from practical case studies

Abstract

To gain a better understanding of what is required to effectively operationalize KE in environmental and natural resource sectors, we use a scoping literature review to assess empirical case studies from around the globe ($n = 56$). I identified and categorized the enabling conditions from the empirical case studies into a *core capacity* framework (a framework first developed by Cvitanovic et al., 2018). This has organized the details of what is required to engage in effective KE from an organizational, individual, financial, material, practical, political, and social capacity. The major enablers to effective KE were related to practitioners' *individual* and *organization capacity* and included the ability for practitioners (often boundary spanners) to establish trust with knowledge producers and users through their interpersonal relationships, and possess sufficient background knowledge and communication skills to facilitate collaborations across disciplines and sectors. In addition, I identify the main challenges to engaging in KE (insufficient long-term funding for projects, lack of interpersonal skills for KE practitioners to build relationships and network, and inadequate background knowledge for practitioners to exchange knowledge in an accessible manner) and the outcomes and impacts of KE work. This review reveals a theory-practice gap such that KE practitioners often perform quantitative evaluations that provide instantaneous and measurable impacts for the effectiveness of KE, but do not capture the impact of interpersonal relationships and trust. I recommend that additional research is required to understand how effective KE is

evaluated through both quantitative and qualitative indicators. This would help us discern whether the challenges identified in this review are a result of true barriers to engaging in KE, or a result of limited evaluations assessing interpersonal relationships and the social aspects of KE.

Introduction

A disconnect exists between knowledge exchange (KE) theory and practice such that scholars propose theoretical ways to improve KE practice with fewer empirical examples of how this can be done successfully (Rubenstein et al., 2001; Reed et al., 2014; Westwood et al., in review). Scholars propose that practicing KE will be most effective when there is multi-directional communication between knowledge producers and users to build capacity and the exchange of expertise from multiple sources (Fazey et al., 2013; Stewart et al., 2014; Hickey et al., 2013). Although the literature presents ways to engage in effective KE, there are fewer empirical examples of how this can be done and what factors enable KE for impactful environmental and natural resource management (Reed et al., 2014; Reed et al., 2018; Walsh et al., 2019). As such, practitioners often perform KE based on what has worked in the past, emphasizing the need to identify the enabling conditions for practicing effective KE (Reed et al., 2014; Matzek et al., 2014; LSE 2019),

A recurrent theme for improving KE at the interface of environmental science and policy is transitioning away from linear modes of communication and engagement i.e., generating and exchanging knowledge that does not specifically address a target audience and is not generally available or accessible to all knowledge users (Cash et al., 2006; Beier et al., 2017; Rogga, 2021) towards more interactive multi-directional modes of KE

i.e., one that facilitates collaborative communication between knowledge producers and users and engages knowledge users in all aspects of the research process (Cook et al., 2013; Stewart et al., 2014; Bautista et al., 2016; Cvitanovic et al., 2021). A range of approaches have been identified that enable more interactive and collaborative KE and includes the use of science-policy intermediaries such as boundary spanners and boundary organizations (Bednarek et al., 2018), building relationships and trust between knowledge producers and users to maintain ongoing communication to produce useable science (Fazey et al., 2014; Cook et al., 2020; Cvitanovic et al., 2021), improving organizational structures such as embedding knowledge producers within research organizations to conduct long-term research (Roux et al., 2019; Walsh et al., 2019), acquiring sufficient resources (such as funding, time, and staff) to complete projects (Meadow et al., 2015), and improving organizational culture to support the use of scientific evidence (Walsh et al., 2019). Although enablers to effective KE have been identified, little to no research has synthesized empirical studies examining the enabling conditions required for practitioners to effectively operationalize KE (Meadow et al., 2015; Rose et al., 2018)

In their paper related to enabling conditions for KE, Cvitanovic et al. (2016), first identified seven core capacities required to support and facilitate KE, through a study evaluating the Ningaloo Research Program designed to generate new knowledge informing decision-making and management of the Ningaloo Marine Park in northwestern Australia. The seven core capacities were first broadly identified in response to this study (Cvitanovic et al., 2016) and further developed by Cvitanovic et al. (2018). They include (1) *organizational capacity* – organizations should be diverse with effective leaders and clear goals; (2) *individual capacity* – individuals need strong social

networks and should be collaborative with strong communication skills; (3) *financial capacity* – funding should be sufficient, flexible, and long term; (4) *material capacity* – organizations should make information publicly available with an engaging internet or social media presence; (5) *practical capacity* – organizations should provide employees with flexible time and space to learn and grow; (6) *political capacity* – high political interest will strengthen the science-policy interface; and (7) *social capacity* – informal face-to-face engagement with stakeholders is important (see *Table 1* for full list of core capacities adapted from Cvitanovic et al., 2018.). The seven core capacities provide an organized overview and framework of the factors that enable KE, which were derived from the case studies (Cvitanovic et al., 2016 & 2018), and align with those identified in the literature (e.g., Bednarek et al., 2018; Walsh et al., 2019). This is one of the few frameworks that organizes the enablers of KE based on empirical research. In this paper, we are interested in understanding conditions that enable effective KE by synthesizing various empirical case studies using a scoping literature review. We will be using the seven core capacities introduced by Cvitanovic et al. (2016, 2018) to inform, frame, and organize the findings from our scoping literature review. We further identify commonalities among the implementation process, challenges, and outcomes of practical KE case studies to assess how enablers can be implemented for practicing effective KE within environmental and natural resource sectors. A scoping literature review will allow us to assess a broad range of primary literature with various study designs and sources of evidence.

Methodology

Using a scoping review, we examined the current literature on practical examples of KE using case studies. To ensure we broadly captured the enabling conditions of KE, we included search terms describing enabling features that were informed by the core capacities. The core capacities of KE proposed by Cvitanovic et al (2018) include: organizational, individual, financial, material, practical, political, and social dimensions (Appendix A, Table 2-1). The review followed a general framework applied to scoping literature reviews as outlined by Arksey and O'Malley (2005): *stage 1*: identify the research questions; *stage 2*: identify relevant studies; *stage 3*: study selection, and *stage 4*: collate, summarize, and report results.

Stage 1: Identify the research question

The research question, *what are practical examples of enabling conditions that support effective and efficient KE in environmental and natural resource management*, helped guide the development of search strings that will be used to identify papers from online literature search engines (Web of Science and Scopus). The research question was broad to provide extensive coverage when developing search strings while allowing the seven core capacities outlined by Cvitanovic et al. (2018) (i.e., the enabling conditions) to be included into the search strings.

Three team members (CB, VN, TK) developed search strings using a search strategy worksheet (Appendix A, Table 2-6) to organize search terms into four main concepts derived from the research question. The four main concepts included terms related to (1) knowledge exchange, (2) environmental or natural resource management, (3) the field of science, and (4) Cvitanovic et al.'s (2018) seven core capacities. A search

string was developed for each concept using the terms from the search strategy worksheet, where concept four included seven separate search strings including possible keywords describing each of the core capacities. A total of seven search strings were developed where concept one, concept two, concept three, and each of the seven concept four search strings were used alongside the ‘and’ Boolean operator (Appendix A, Table 2-7). An iterative eligibility test was conducted to assess the seven core capacity search strings from concept 4 for high specificity and low sensitivity (i.e., changes were made to the search strings after each test to ensure relevant papers were being identified). Papers were eligible for inclusion if they broadly described a core capacity in their title or abstract in relation to environmental or natural resource management.

Stage 2: Identify relevant studies

We applied the finalized search strings to two literature search engines, Web of Science and Scopus, which resulted in a total of 1848 papers (706 from Web of Science and 1142 from Scopus). We removed 717 duplicate papers, resulting in 1131 papers to be screened, which were uploaded to Covidence (2.0), a web-based tool used to organize the papers when performing full-text screenings and when extracting study characteristics.

Stage 3: Study Selection

Inclusion and exclusion criteria were developed (Appendix A, Table 2-8) to assist in the screening process as the review’s main goal is to include papers that provide *practical* or *empirical* examples for implementing KE. This criterion was first used for a title and abstract screening, where all three questions (Appendix A, Table 2-8) must be

answered ‘yes’ to pass. A total of 123 papers passed the title and abstract screening.

Lastly, a total of 56 papers were included in this study after a full-text screening using the same inclusion and exclusion criteria.

Stage 4: Collate, Summarize, and Report

We extracted data from the 56 papers that passed the full-text screening, where the data from each paper was sorted according to themes, key issues, and processes (Arksey & O’Malley, 2005) such as study objective, KE implementation process, KE enabling conditions, challenges, outcomes, and successes of the case study etc. (see *Table S1, Appendix B* for full list of data extraction items and definitions). The data extracted provided an overview of conditions that enable effective KE through practical case studies, and included analyzing implementation strategies, challenges, and outcomes of case studies to bridge the gap between KE theory and practice. The data collected will provide valuable insight into functional and practical elements of KE for environmental and natural resource management.

Qualitative Text Analysis

For each of the 56 papers, we extracted text relating to KE implementation process, enabling conditions, challenges, outcomes, and successes. We compiled excerpts of relevant texts from the papers into a document to qualitatively code and determine: (1) what conditions enabled practitioners to implement KE, (2) what challenges impeded the implementation of KE, and (3) what were the outcomes of implementing KE.

An inductive coding approach was employed whereby each code served as a label for a theme present in the papers (Saldana, 2016). The codes were not determined in

advance as this could misrepresent the data (Van den Hoonard, 2019). One coder (TK) inductively coded all the relevant text from the papers available for KE implementation process, KE enabling conditions, challenges, outcomes, and successes. To verify the inductively derived codes, two coders (VN and CC) also individually followed an inductive coding approach by coding three random case studies (27% of the papers). Specifically, the two coders (VN and CC) inductively coded excerpts of texts from the three case studies related to KE implementation process, KE enabling conditions, challenges, outcomes, and successes. This was an important practice in ensuring that all possible themes were identified given the varied background knowledge and experience of the coders (Van den Hoonard, 2019). The additional codes identified in the verification process were applied to all the relevant text and the codes were compiled into a codebook consisting of 89 codes (Appendix C) where we provide samples of coded case studies for further transparency (Table S2, Appendix D). To develop a comprehensive inventory of the enablers of KE and to contextualize them, we used the seven core capacities identified by Cvitanovic et al. (2018) to inform and frame the inductively derived codes from the case studies (Table 5).

For this review, we considered the main themes related to enablers of KE that were identified during the inductive coding process and used concepts from existing KE research to classify the enabling conditions within a single core capacity. We acknowledge that many of the enabling condition codes can be conceptualized and operate differently in various disciplines, sectors, and settings (Bornbaun et al., 2015). For example, the enabling condition code *boundary spanner: KE broker* can fit into the *Individual* core capacity in addition to the *Political* core capacity (see Table 2-2 for example). This is because boundary spanners must possess excellent interpersonal skills

and possess knowledge and interest of multiple disciplines and sectors to communicate knowledge across boundaries effectively (Michaels, 2009; Saarela & Soderman, 2015). However, given how boundary spanners were interpreted during the inductive coding process, they best fit into the political core capacity for this review. We acknowledge that this work is not free from subjective interpretations and biases but nonetheless, the results of this review help illustrate the breadth of enablers to KE that will be useful in promoting how to engage in KE effectively.

Results

General Characteristics

The 56 case studies extracted for this study were published between 2008 – 2020, where 57% of the papers were published between 2016 – 2020 ($n = 32$) (Figure 2-2). The case studies belonged to a variety of knowledge sectors within environmental management and natural resource conservation, including marine conservation, forestry, fisheries management, climate science, etc. (Figure 2-3, see *Appendix 2* for full list of data extraction items). The case studies varied in duration, ranging from two months to three years with the number of participants for a case study ranging from four individuals to approximately 500. The participants for the case studies included individuals and groups belonging to academic institutions, government, private industry, NGO's, and local communities. The knowledge producers and users identified for the case studies included a combination of individuals belonging to these groups who often collaborated to engage in KE together. The frequency of mentions for knowledge producers and users were not mutually exclusive. Knowledge producers belonged to academic institutions ($n = 20$), federal or regional government organizations ($n = 26$), private industry ($n = 10$),

NGO's ($n = 27$), and local communities ($n = 10$). Knowledge users belonged to academic institutions ($N = 2$), federal or regional government organizations ($n = 46$), private industry ($n = 11$), NGO's ($n = 22$), and local communities ($n = 17$).

A variety of study approaches were applied to assess KE, including interviews (open-ended ($n = 14$) and semi-structured ($n = 31$)), surveys ($n = 7$), questionnaires ($n = 3$), ethnographies ($n = 4$), discourse analysis ($n = 2$), network analysis ($n = 2$), focus groups ($n = 9$), and workshops ($n = 6$). The frequency of mentions for study approaches are not mutually exclusive as multiple approaches were often used for a single case study. Eighty-six percent of the authors were from Australia ($n = 11$), Canada ($n = 12$), USA ($n = 11$), UK ($n = 8$), and the Netherlands ($n = 6$). Over half (55%) of the case studies took place in Australia ($n = 8$), Canada ($n = 10$), USA ($n = 7$), and the UK ($n = 6$). Nearly half of the case studies involved implementing and examining KE at a regional scale ($n = 27$), followed by case studies at a national scale ($n = 23$), and a single case study at the global scale ($n = 1$). A few case studies involved examining KE at both a regional and national scale ($n = 5$).

Most of the texts were written by an academic organization ($n = 44$), followed by government organizations ($n = 6$), private industries ($n = 4$), and non-governmental organizations (NGO's) ($n = 2$). Groups responsible for knowledge production within the case studies were identified to belong to academic organizations ($n = 8$), government organizations ($n = 7$), private industries ($n = 1$), NGO's ($n = 9$), and local communities and/or Indigenous communities ($n = 1$). Most often, knowledge production was identified to be a collaborative effort involving more than one of the knowledge producers listed above ($n = 30$). Similarly, KE work was often intended for more than a single knowledge user group with the majority of knowledge users belonging to a combination of academic

organizations, government organizations, private industries, NGO's, and local and/or Indigenous communities ($n = 29$). When KE work was intended for a single knowledge user group, it was most often for government organizations ($n = 20$), followed by local and/or Indigenous communities ($n = 5$), private industries ($n = 1$), and NGO's ($n = 1$).

Knowledge exchange enabling conditions

We qualitatively examined the enabling conditions and implementation strategies of the 56 case studies to identify a total of 31 codes describing enabling conditions for KE (Table 2-2). The most frequently identified conditions enabling KE work included: collaboration ($n = 29$) with multidisciplinary organization; relationship building ($n = 29$), networking ($n = 28$); employing a boundary spanner ($n = 27$) to facilitate the exchange of knowledge between knowledge producers and users; building and establishing trust ($n = 24$) with project stakeholders; aligning project objectives ($n = 22$) with all stakeholders involved, and; tailoring communication ($n = 22$) to make information relevant and accessible to the knowledge user. We noted that boundary spanners often took the role of a knowledge broker i.e., and individual acting as an intermediary between knowledge producers and users (Naylor et al., 2012). Informal communication ($n = 17$) with project stakeholders, evaluations ($n = 12$), and funding ($n = 11$) were also conditions that were frequently cited to help enable KE work. The 31 enabling condition codes were subsequently organized into one of the seven core capacities (organizational, individual, financial, material, practical, political, and social) which were defined by Cvitanovic et al. (2016, 2018) to contextualize them within this framework and the literature. We identified 20 codes that describe the challenges to performing KE from the case studies reviewed (Table 2-3). Of these, limited organizational capacity to execute KE work ($n =$

13), mismatched project objectives and timelines between science and policy sectors ($n = 12$), lack of interpersonal skills for KE practitioners ($n = 10$), acquiring sufficient long-term funding ($n = 10$), few interpersonal relationships between project stakeholders ($n = 9$), and inadequate background knowledge for KE practitioners ($n = 9$) were mentioned most frequently. Additional challenges frequently cited include difficulty for KE practitioners to communicate complex ideas, information, and knowledge with knowledge users ($n = 8$), a lack of trust between project stakeholders ($n = 8$), and mismatched values between knowledge producers, users, and KE practitioners ($n = 8$).

Outcomes and Impact of KE work

It is important to note that the case studies used in this review focused on the implementation of KE, not the assessment of KE outcomes or impacts. To distinguish between the outcome and impact codes, we define the *outcomes of KE* as the measurable change due to information and advice (LSE, 2019), while we define the *impact of KE* as the longer-term effect of an outcome i.e., the effect information and advice can have on the ability to make an informed decision or empower broad life experiences (LSE, 2019). While outcomes tend to be determined in advance, can be measured objectively, and are often evaluated by quantitative means, assessing impact can be more complex as it involves personal experiences and relationships which are often evaluated by qualitative means (LSE, 2019). As such, distinguishing between outcome and impact codes (i.e., the quantitative and qualitative effects of KE) were based on the perceived length of time required to achieve a single ‘outcome’ or ‘impact’.

We identified nine codes that address the outcomes of the KE case studies (Table 2-4). The most frequently cited outcomes of KE work were the development and adoption of a new technology, boundary object, or policy ($n = 28$), increased understanding of a topic by knowledge users ($n = 17$), increased collaboration amongst all project stakeholders and across disciplines ($n = 13$), and alignment of interests i.e., alignment between science and policy objectives or with knowledge user concerns ($n = 11$).

We identified 12 codes that describe the impact of KE work from the case studies (Table 2-5) and of these, change in knowledge user behaviour or being more receptive to change due to an increased understanding of a topic ($n = 16$) and encouraging similar research to take place elsewhere ($n = 4$) were the most frequently cited impacts of KE work.

Discussion

The 56 empirical case studies assessed in this scoping literature review allowed us to first provide detailed enablers to KE, supplementing Cvitanovic et al.'s (2018) broad core capacities to support practitioners in identifying how to improve KE work. Secondly, we identify challenges to effectively implement and engage in KE at an individual and organizational level. Lastly, we attempt to distinguish indicators for evaluating the outcomes and impacts of KE work which are needed to assess how effective KE is through short- and long-term evaluations. This review attempts to bridge the theory-practice gap by providing a comprehensive analysis and list of the enablers, challenges, outcomes, and impacts of KE based on practical case studies – contributing to

a wider understanding for practitioners of what is needed to put KE to practice in environmental management.

Enablers to effective KE for practitioners

The identified enabling conditions for KE were most often related to the organizational, individual, and social capacity for KE, such as those related to trust, collaboration, interpersonal relationships, and communication practices to facilitate collaboration across disciplines and sectors. These are consistent with participatory KE approaches (such as co-production) that recognize KE as an iterative process reliant on multi-directional communication and relationships to improve mutual understanding (Kirchhoff et al., 2013; Young et al., 2014, Nguyen et al. 2017). Participatory forms of KE involve trust and relationship building to increase knowledge sharing and requires honest participation by all actors. In addition, participatory forms of KE encourage knowledge uptake into policy and practice by establishing practices (i.e., boundary spanners) that facilitate collaborations and KE between knowledge producers and users for evidence-informed decisions and practices (Cash et al., 2006; Kirchhoff et al., 2013; Levesque et al., 2017; Cook et al., 2020). For example, in the case study produced by Coleman and Stern (2018), they investigated the roles of individuals working for the US Forest Service (USFS) and discovered that collaborating with all project actors enhances forest management by encouraging the sharing of diverse information and ideas, diminishing conflict, and enhancing productive deliberation. Specifically, this study identified that such collaborations increased the development of trust and relationships between environmental groups and the USFS, and that boundary spanners played an important role in facilitating collaborative networks. The role of boundary spanners in

this case study assisted the USFS in increasing the knowledge and tolerance of new knowledge for stakeholder groups to inform discussions and policies related to forest management by engaging in informal conversations with all project actors to build trust and align values and objectives. In addition, boundary spanners in this case advocated for all project actors to share their knowledge and expertise to ensure discussions were well-rounded and fair.

Maintaining interpersonal relationships between knowledge producers and users, such as researchers and decision-makers, has been cited as an integral component to KE to bridge multiple sectors (Bradshaw & Borchers, 2000; Girling & Gibbs, 2019). Informal communication, such as face-to-face interactions, are of particular importance to KE practitioners who seek to expand networking opportunities and build and maintain trusting relationships with knowledge users from various sectors and disciplines (Schwarz et al., 2020; Nguyen et al., 2021). Opportunities to engage in informal communication are important because oral and experiential forms of knowledge are often developed and communicated by engaging in hands-on practices or through in-person observations and interactions (Nguyen et al., 2021). In a case study produced by Ryan and Cervený (2010), the ability for knowledge producers to communicate research findings to managers (knowledge users) at the US Forest Service through face-to-face interactions and hands-on technical demonstrations was critical for managers to interpret the highly complex knowledge accurately.

Boundary spanners were regularly cited among the case studies to enable KE work (e.g., Cohen et al., 2012; Berglund et al., 2015; Coleman & Stern, 2018; Holzer et al., 2019; Cadman et al., 2020), which is consistent with the broad literature suggesting that they play a key role in collaborating, facilitating, and exchanging context-specific

knowledge with diverse knowledge users (Armitage et al., 2011; Bednarek et al., 2018; Karcher et al., 2021). It is necessary for boundary spanners to possess sufficient background knowledge and expertise of the knowledge they are exchanging (Michaels, 2009; Saarela & Soderman, 2015). With comprehensive knowledge and experiences in multiple disciplines, boundary spanners can identify and communicate the emerging scientific needs of decision-makers to mobilize evidence-informed decision-making (Cvitanovic et al., 2018; Rose et al., 2020). Our findings also highlight important individual attributes of KE practitioners consistent with Cvitanovic et al. (2018). Individuals working in the KE space should develop clear goals and objectives related to their KE work, possess strong leadership qualities, and be adaptable and capable of modifying work to meet the needs of various actors. For example, in a case study produced by Stange et al. (2016), when researchers (knowledge producers) developed clear project goals and objectives, they were able to explicitly share how they would like project collaborators to engage in the research process. This enhanced project actors' understanding of how they can contribute with their knowledge and concerns.

Challenges: how implementing more enablers can help overcome barriers

We identified a limited capacity (i.e., resources or staff) for organizations to perform KE work as the most common barrier (e.g., Carneiro and da-silva-rosa 2011; Knight et al., 2015; Medema et al., 2016; Lemieux et al., 2018; Kaiser et al., 2019), which may result in challenges for organizations to obtain secure, long-term funding (Cvitanovic et al., 2018). We noted mismatched timelines and objectives between knowledge producers and users (e.g., Ryan & Cerveny, 2010; Hastings 2011; Dunn &

Brown 2018), and a difficulty for knowledge producers to communicate complex knowledge with various end-users (e.g., Sheikheldin et al., 2010; Guido et al., 2016; Grygorik & Rannow 2017). This is consistent with the difficulties cited by researchers and decision-makers to translate or align their differing objectives across disciplines and sectors (Pennington, 2008).

Many of the challenges to implementing KE were related to the expertise and interpersonal skills of KE practitioners. For example, practitioners had difficulty maintaining trusting relationships with all project actors and sustaining regular communication to identify the evolving needs of knowledge users (e.g., Berglund et al., 2015; Laatsch & Ma, 2016). In the case study produced by Berglund et al. (2015), they explored how officers at the Soil Conservation Service of Iceland (SCSI) can improve soil conservation decisions and practices through their interactions with project actors, specifically farmers and locals. One of the main challenges for SCSI officers was the ability to establish and maintain contact with farmers and other locals, which is needed to support and influence their soil conservation practices. Through semi-structured interviews with SCSI officers, this study identified that SCSI officers did not possess adequate interpersonal skills to remain impartial when communicating with farmers and locals. This study concludes that if SCSI officers possessed the skills to maintain regular contact with farmers and locals, they could maintain trusting relationships and better support and influence soil restoration work.

Our findings also highlight the challenges associated with power imbalances, language barriers, and cultural barriers (e.g., Crona & Parker, 2012; Hickey et al., 2013; Stewart et al., 2014). For example, in the case study produced by Crona and Parker

(2012), power imbalances between science and policy sectors led to misalignment of project objectives, decreased interactions between project actors, and fewer networking opportunities which can impact the exchange of knowledge across boundaries. Existing research has identified a range of factors that can empower actors to collaborate equally, such as equal access to information and the ability for all project actors to shape discussions (Tuler & Webler, 2010; Levesque et al., 2017). Our findings suggest that boundary spanners play a critical role in overcoming these challenges because they act as intermediaries capable of facilitating KE across sectors and disciplines, and they possess excellent interpersonal skills that enable them to overcome communication differences (Naylor et al., 2012). Specifically, this review suggests that boundary spanners successfully facilitate multidisciplinary collaborations when they set clear goals and objectives for all project actors, possess strong leadership qualities to organize KE work, are adaptable to new working conditions, and can modify their work for various audiences. These boundary spanner characteristics align with those identified by Cvitanovic et al. (2018), such that these individual attributes are important features of a flexible and adaptive organization engaging in effective KE work.

Additionally, organizations that possess extensive *practical* core capacity i.e., engage in social learning, peer-to-peer learning, and sharing expertise, may be better equipped to overcome communication and interpersonal barriers to KE. This is because organizations that promote social learning and share their expertise are more likely to be inclusive in their stakeholder engagement and develop collaborative solutions, which is consistent with our findings of the practical capacity enabling conditions (Reed et al., 2010; Koontz, 2014).

Outcomes and impacts of KE work

The results highlight a number of outcomes and impacts of KE, where outcomes of KE are easily measurable often by quantitative indicators, and impacts require more time and resources to evaluate often by qualitative indicators. Oftentimes, the case studies described overall outcomes and impacts of KE that were not identified as a main goal of the KE work at the beginning of the case study. The most frequently cited impacts of KE work were change in behaviour, increased resiliency, increased sense of trust, improved relationships, and lowered cultural barriers (e.g., Feeney et al., 2010; Crona & Parker, 2012; Kaiser et al., 2019). The most frequently cited outcomes of KE work were the development and adoption of new technologies, boundary objects, or policies, increased collaboration, and alignment of objectives or interests of multiple actors and stakeholder groups (e.g., Bautista et al., 2017; Chapmen et al., 2017; Dunn & Brown, 2018; Holzer et al., 2019). We noticed higher frequencies associated with outcome codes (*see frequencies associated with outcomes: Table 2-4 and impacts: Table 2-5*). This may be due to the easily quantifiable nature of outcomes, making them easier to identify as direct successes of KE work. As such, our results may not accurately depict the impacts of KE work due to how difficult social (or qualitative) forms of effective KE can be to evaluate (Bowen & Martens, 2006; Fazey et al., 2014).

One of the most widely used frameworks for analyzing research impacts describes three types of approaches: conceptual, instrumental, and symbolic (Amara et al., 2004). Research that has conceptual impact involves changing perceptions, raising awareness, or changing beliefs (Rudd, 2011). Instrumental impact occurs when research results in direct changes to policy and practice, often through the use of boundary objects (Rudd, 2011). Finally, symbolic impact refers to using research results to legitimize and sustain existing

policies and practices (Amara et al., 2004). In this review, *impacts of KE*, which often resulted in changes in behaviour or perceptions, can be considered to have conceptual impact. *Outcomes of KE* can be considered to have instrumental impact, as these outcomes often resulted in direct changes to policy and practice through the development and adoption of technologies or boundary objects. It is possible for both *impacts* and *outcomes* of KE in this review to have symbolic impact to justify existing policies or practices.

Further, it often takes three to nine years to notice any observable impacts in interdisciplinary science, policy, and environmental management work (Cvitanovic et al., 2021). As a result, many studies do not empirically assess the effectiveness of KE work (Westwood et al., 2021), highlighting the importance for practitioners to derive methods for evaluating the long-term impacts (i.e., qualitative indicators) of KE. To evaluate the full scope of how effective KE is, it is necessary to assess KE work through both quantitative and qualitative lenses. This review highlights an important KE theory-practice gap, such that KE is often performed via collaborations, relationships, and trust, but is often evaluated by quantitative means that cannot capture the impacts of interpersonal relationships.

The impacts to KE with the lowest mentions, such as increased sense of trust and improved relationships, coincide with challenges to KE that had the highest frequencies of mentions among the case studies, such as lack of interpersonal skills, few/poor interpersonal relationships, and lack of trust. Although it is difficult to determine with certainty, it is possible that these challenges may be associated with difficulties in evaluating the social impacts of KE through qualitative indicators. This emphasizes the need for evaluations of KE work (a *practical capacity* enabler) to assess the effectiveness

of KE through both quantitative and qualitative lenses to discern the full scope and impact of KE work. Without a combination of quantitative and qualitative evaluations, KE practitioners may miss opportunities to strengthen and improve their interpersonal skill and relationships – skills that heavily influence the effectiveness of KE.

This review further demonstrated that many of the enablers required to engage in effective KE are also the main challenges for practitioners. For example, possessing excellent interpersonal skills, acquiring long-term funding, aligning project objectives, maintaining regular communication with project actors, and the ability to communicate complex knowledge are simultaneously enablers to KE and what practitioners struggle to achieve. With additional research assessing both the quantitative and qualitative impacts of KE work, we may be able to better understand specific actions that can transform challenges into an enabler. This will require researchers to perform impact research over long time periods using empirical case studies.

Strengths and limitations of the framework

We expanded upon Cvitanovic et al.'s (2018) core capacity framework to detail specific enabling conditions for effective KE through an organizational, individual, financial, material, practical, political, and social lens. Although enablers, barriers, and impacts of KE have previously been identified by researchers, little to no research has synthesized empirical case studies to bridge the theory-practice gap and determine what is required for practitioners to operationalize KE effectively. We were able to logically organize and categorize the findings from case studies into the core capacity framework

used in this review – helping to bridge the theory-practice gap by confirming the enablers experienced by practitioners with those identified in the literature.

This review provided useful information as to how enablers to KE can be conceptualized and organized based on empirical evidence but highlights the highly context-dependent nature of KE. As such, there can be limitations to the applicability of this framework such that specific enabling conditions may fit into different core capacities based on the interpretations of the researchers. Further, much of this review considered the perspectives of KE practitioners at an individual and organizational level. This limits our understanding of what enables KE from a knowledge user's perspective or as a stakeholder organization collaborating on a project. The synthesis of enablers, challenges, outcomes, and impacts that this empirical review provides can be used a broad resource for practitioners to identify what enablers may be missing from their KE work and in what capacity their work can be strengthened.

Future research

Additional research is required to understand how effective KE is evaluated through both quantitative and qualitative indicators. This would help us discern whether the challenges identified in this review are a result of true barriers to engaging in KE, or a result of limited evaluations assessing interpersonal relationships and the social aspects of KE. Future research in this area could help minimize the theory-practice gap identified in this review, that KE is often performed via collaborations, relationships, and trust, but is often evaluated by quantitative means that cannot capture the impacts of interpersonal relationships.

Future research could benefit by evaluating empirical case studies that attempt to achieve a common outcome or impact. By assessing empirical case studies that have determined a specific impact they wish to achieve in advance and that is common across all cases studies, we can determine in greater detail the enablers or challenges associated with achieving the stated impacts. For example, future research may investigate empirical case studies in environmental and natural resource sectors and the enabling conditions required to operationalize KE specifically within the science-policy interface – where the pre-determined outcome is to implement or supplement regional or federal policies. In addition, by assessing the relationship between KE enablers and challenges with respect to a singular pre-determined impact, we may gain unique insight into what actions are required to transform a challenge into an enabler. This is especially relevant as this review identified that many of the enablers to KE were simultaneously identified as challenges to engaging in KE effectively.

Future research should also be broadened to include more empirical case studies that originate from outside western countries, such as those from the global south. This is an important area of research to potentially strengthen KE practices in the west and gain a deeper understanding of how KE practices differ across the globe.

Limitations of analysis

We acknowledge several limitations in our analysis. This study focused on capturing items published in academic databases which tends to be biased towards government and academic sources. As such, we were likely unable to capture the full scope of empirical case studies by NGO's, Indigenous organizations, or private industries (Westwood et al., in review). Our use of English as the study language may account for

the majority of case studies taking place in Australia, Canada, USA, and the UK. We observed that most publications for this review were recent (after 2012) and related to Western countries. This may be due to a bias in search terms and language or could be a result of discussions and evaluations of KE recently occurring predominantly in Western countries (Ferreira et al., 2021; Westwood et al., in review). Reporting of frequency of mentions for enablers, challenges, outcomes, and impacts may not be a true measure of importance, but rather a description of the factors that are easily observed and described. Absence or low frequency of mentions for an enabler, challenge, outcome, or impact does not imply they are not important, as practitioners may not have mentioned factors that they assume are obvious or irrelevant to the case study. Despite these limitations, this review provides a solid framework for practitioners to develop and expand upon the enablers, challenges, outcomes, and impacts to engaging in effective KE in environmental management.

Conclusion

This study provides evidence of empirical case studies confirming the theoretical enablers to implementing and engaging in KE to bridge the KE theory-practice gap. We provide insights into the specific enablers of KE by using the broad core capacities first outlined by Cvitanovic et al. (2018). This contributes to a wider understanding of the enablers to KE and provides practitioners with the ability to first identify areas for improvement by assessing which core capacity may require additional work, then concrete examples of how they can further enable their KE work within each core capacity. This review highlights a theory-practice gap with respect to evaluating the impact of KE work, such that KE is often evaluated by quantitative means that cannot

capture the impacts of interpersonal relationships, collaborations, and trust. In addition, this review outlines the challenges to engaging in effective KE, many of which are the same as the identified enablers to KE and require qualitative indicators to assess their impact. Thus, this review emphasizes the need for researchers to perform more long-term, qualitative evaluations of empirical case studies to discern whether the challenges related to the social aspects of KE are a result of limited impact evaluations or a true barrier to KE work.

We recommend practitioners incorporate long-term assessments to evaluate and report upon the qualitative indicators of KE to help bridge our understanding of KE in practice over long timescales. We encourage researchers and practitioners to build upon the proposed framework for enabling conditions categorized by core capacities using empirical case studies to garner a deeper understanding of how to effectively engage in KE, both within and outside of environmental and natural resource management.

Tables

Table 2 - 1 The seven core capacities that enable KE work developed and defined by Cvitanovic et al. (2018). This figure is an adaptation of Figure 1 featured in Cvitanovic et al., 2018.

| Core Capacity | Definition |
|----------------------|---|
| Organizations | Organizations should have diverse teams, effective leadership, clear goals, a good culture, credibility, and appropriate reward systems. |
| Individual | Individuals require strong and diverse social networks, should be collaborative, open to new ways of doing things, resilient, self-motivated, honest, and strong communicators. |
| Financial | Funding should be sufficient, secure, long-term, autonomous (i.e., managed internally), and flexible. |
| Material | Organizations should produce publicly available policy briefs with recommendations and public summaries. They should also have an engaging website and utilize social media. |

| | |
|-----------|---|
| Practical | Organizations should provide employees with ‘time’ and ‘space’ to try new things, fail and learn; to think; and to pursue own interests |
| Political | The interface between science, policy, and practice will be most effective when there is high political interest in a topic. |
| Social | Organizations need to ensure that employees have opportunities for informal face-to-face engagement with external stakeholders. |

Table 2 - 2 A list of the enabling conditions inductively coded from the 56 case studies. Enabling conditions were organized into one of seven applicable core capacities (Cvitanovic et al., 2018). Frequency of mentions (not mutually exclusive) is the number of times a code was applied, where codes could be applied multiple times to a single case study.

| Core Capacity | Code | Definition of Code | Frequency of Mentions |
|---|--|---|-----------------------|
| Organizational Capacity: organizations should be diverse with effective leaders and clear goals | Align project objectives | The KE practitioner or group collaborates with stakeholders to modify research questions, KE activities, products, or processes to address the goals of the KE project. | 22 |
| | Co-production | An iterative and collaborative process involving diverse types of expertise, knowledge, and actors to co-design context-specific knowledge (Schneider et al., 2021). | 8 |
| | Shared value | All project stakeholders hold KE work and objectives to the same standard, level of importance, and usefulness. | 7 |
| | End-user history | Learning about end-user history and operational capabilities to better understand what knowledge is relevant or accessible. | 6 |
| | Boundary spanner characteristics: clear goals and objectives | A clear set of goals and objectives are established for a KE project by and/or for the boundary spanner. | 3 |
| | Boundary spanner characteristics: leadership qualities | Strong leaders who can lead, direct, and organize KE work. | 2 |
| | Boundary spanner | Able to adjust to new conditions and modify work as a result. | 1 |

| | | | |
|---|--|--|----|
| | characteristics: adaptable | | |
| | Boundary organizations: communities of practice | Facilitate collaboration between disciplines or sectors, such as scientific and non-scientific domains (Guston, 2001) | 1 |
| Individual Capacity: individuals need strong social networks and should be collaborative with strong communication skills | Collaboration | Collaborating with individuals internally or with individuals from other disciplines. | 29 |
| | Relationship building | Establishing and maintaining interpersonal relationships with all project stakeholders such that you can share information across organizations because of the relationships you have built. | 29 |
| | Networking | Importance of networks, partnerships, stakeholder engagements, or other ways of interacting within networks. | 28 |
| | Trust building | Establishing and maintaining trust such that all project stakeholders feel like they are a part of the team, they can communicate honestly and freely, and trust each other to work towards a shared goal or way of working. | 24 |
| | Tailored communication | Modifying data or experiences to make it relevant and accessible to the knowledge user. | 22 |
| | Shared language | Developing and using common words and phrases with project stakeholders to improve understanding and ensure accessibility. | 5 |
| | Transparency | KE practitioners receive the approval or acceptance of a community (Lowey, 2016) by sharing project information with all stakeholders. | 3 |
| | Establish credibility | Establish that KE practitioners and your organization are worth believing in and are trustworthy. | 2 |
| Financial Capacity: funding should be sufficient, flexible, and long term | Funding | Acquiring sufficient, long-term funding to execute KE work. | 11 |

| | | | |
|--|---|--|----|
| | | | |
| Material Capacity: organizations should make information publicly available with an engaging internet or social media presence | Boundary objects | They are adaptable to different knowledge domains and perspectives but maintain their identity across disciplines. They can help to overcome interpretive differences across disciplines (ex. definitions and standards, models that integrate scientific and political viewpoints, indicators that improve communication across knowledge domains). | 8 |
| Practical Capacity: organizations should provide employees with flexible time and space to learn and grow | Evaluations | Conducting evaluations or receiving feedback from past work to improve KE strategies and practices. | 12 |
| | Social learning | Gaining a better understanding of a topic by observing or working with a community. | 8 |
| | Sharing expertise | Sharing personal or organizational expertise across disciplines. | 6 |
| | Peer to peer learning | Where knowledge users teach and train other knowledge users. | 5 |
| | Training | Can include hands-on demonstrations, teaching, and co-learning to improve the collective (i.e., all stakeholders involved) understanding of a topic. | 3 |
| | Research | KE practitioners engage in gathering data or conducting secondary research to aid in KE work. | 3 |
| Political Capacity: high political interest will strengthen the science-policy interface | Boundary spanner: KE broker | Individuals or organizations that actively facilitate the exchange between the production and use of knowledge to support evidence-informed decision-making (Bednarek et al., 2018). | 27 |
| | Boundary spanner characteristics: adequate background knowledge | Possess sufficient background knowledge and expertise on a topic to be able to exchange knowledge effectively and accurately between producers and users. | 1 |

| | | | |
|--|-------------------------------------|--|----|
| Social Capacity: informal face-to-face engagement with stakeholders is important | Informal communication | Based on the informal, social relationships that are formed in a workplace. Includes casual conversations to establish personal contacts, making friendships, influencing, and motivating others, etc. | 17 |
| | Face to face engagement | Importance of face-to-face interactions with stakeholders for developing interpersonal connections. | 9 |
| | Regular and sustained communication | Maintaining communication with end-users throughout a KE project and after it is completed to remain engaged and receive updates. | 6 |

Table 2 - 3 A list of the challenges to performing KE that were inductively identified and coded from the 56 case studies. Frequency of mentions (not mutually exclusive) is the number of times a code was applied where codes could be applied multiple times to a single case study.

| Code | Definition of Code | Frequency of Mentions |
|---|---|------------------------------|
| Limited capacity | Limited number of staff or resources to perform KE work. | 13 |
| Mismatched timelines and project objectives | Differing timelines and project objectives between different disciplines (often between science and policy). | 12 |
| Funding | Insufficient funding to conduct KE work. | 10 |
| Lack interpersonal skills | A lack of social competencies required to interact with other. | 10 |
| Inadequate background knowledge (for KE practitioner) | KE practitioners did not possess sufficient background knowledge on a topic required to exchange complex information. | 9 |
| Few/poor interpersonal relationships | Difficulty establishing and maintaining interpersonal relationships with all project stakeholders. | 9 |
| Mismatched values | Differing perceptions of value placed on a project or KE work. | 8 |
| Lack of trust | Difficulty establishing and maintaining trust such that all project stakeholders feel like they are a part of the team, they can communicate honestly and freely, and trust each other to work towards a shared goal or way of working (Stern & Baird, 2015). | 8 |
| Difficulty communicating complex ideas and data | Difficulty modifying data or experiences to make it relevant and accessible to the knowledge user. | 8 |

| | | |
|--|---|---|
| Maintaining regular communication | Difficulty maintaining regular communication with project stakeholders which can limit opportunities for feedback and to adapt work. | 6 |
| Power imbalances | Power dynamics that influence collaborative KE work such that the more powerful individual or organization influences many decisions. | 6 |
| Language barriers | Difficulties with communication due to languages spoken or language proficiencies. | 5 |
| Time | Time restraints on KE work. | 4 |
| Cultural barriers | Misunderstandings caused by cultural differences. | 4 |
| Institutional structures | An organization's aversion to risk, bureaucratic structure, or lack of communication channels. | 4 |
| Geographical limitations | Any barriers in accessibility associated with geographic location. | 3 |
| Little collaboration | Few opportunities to work with organizations from other disciplines or to share expertise across organizations and disciplines. | 3 |
| Difficulty implementing tools/technology | Difficulty implementing tangible changes once KE work has concluded. | 3 |
| Remaining impartial | Difficulty for KE practitioners to remain impartial, unbiased, and remove their emotions from KE work. | 2 |
| Few networking opportunities | Few opportunities to develop new partnerships or engage stakeholders. | 1 |

Table 2 - 4 A list of the outcomes (i.e., a measurable change due to information and advice from KE) to performing KE that were inductively coded from the 56 case studies. Frequency of mentions (not mutually exclusive) is the number of times a code was applied where codes could be applied multiple times to a single case study.

| Code | Definition of Code | Frequency of Mentions |
|---|---|------------------------------|
| Development and adoption of new technology, boundary object, policy | A new technology, boundary object, or policy is adopted because of KE work. | 28 |
| Increased understanding | There is an increased level of understanding on a particular topic due to KE work and research. | 17 |
| Increased collaboration | Existing collaborative efforts are improved and/or new collaborations are developed. | 13 |
| Aligning interests | The interests and objectives of multiple disciplines and/or stakeholders are aligned. | 11 |

| | | |
|-----------------------------------|---|---|
| Increased stakeholder engagement | There is an increased level of participation and engagement with all project stakeholders. | 5 |
| New social networks | New social connections are developed as a result of KE work and collaborations. | 5 |
| Increased organizational capacity | Increased number of staff, resources, and abilities to conduct effective KE work. | 4 |
| Expertise transfer | An exchange expertise occurs between or amongst KE practitioners, knowledge producers, and knowledge users. | 2 |
| Incorporate feedback | Feedback is actively incorporated to improve KE practices. | 1 |

Table 2- 8 A list of the impacts to performing KE that were inductively coded from the 56 case studies. Frequency of mentions (not mutually exclusive) is the number of times a code was applied where codes could be applied multiple times to a single case study.

| Code | Definition of Code | Frequency of Mentions |
|--------------------------------------|--|------------------------------|
| Change in behaviour | There is a change in individual behaviour due to an increased understanding of a particular topic, individuals may be more receptive to change. | 16 |
| Encourage similar research elsewhere | Addressing the goals of the KE project allowed researchers to identify emerging issues and inspired additional research elsewhere. | 4 |
| Change in practice | There is a change in how KE is practiced or performed at an organizational and/or individual level. | 3 |
| Improved communication | Communication practices improved or new channels for communication have been developed. | 3 |
| Increased resiliency | The capacity for organizations or individuals to recover from setbacks has improved. | 3 |
| Shared language is developed | Common words and phrases with all project stakeholders are actively used to improve understanding and ensure accessibility. | 3 |
| Improved relationships | Interpersonal relationships with project stakeholders have been established or have improved such that KE practitioners can exchange knowledge across organizations and disciplines. | 3 |

| | | |
|---|---|---|
| Shared value and mutual understanding are developed | All project stakeholders share common project objectives, hold KE work to a similar level of importance and usefulness, and understand each other's contributions and accessibility needs. | 3 |
| Increased sense of trust | An increased sense of trust is developed such that more project stakeholders feel like they are a part of the team, are able to communicate honestly, and trust each other to work towards a shared goal. | 2 |
| Boundary spanner enabled | A boundary spanner position is developed or employed by an organization to facilitate KE between multidisciplinary organizations. | 2 |
| Lowered cultural barriers | Fewer misunderstandings caused by cultural differences. This may be because project stakeholders have developed interpersonal relationships and have learned from multiple project stakeholders. | 1 |
| New economic opportunity | New economic opportunities arise as a result of KE work. | 1 |

Figures

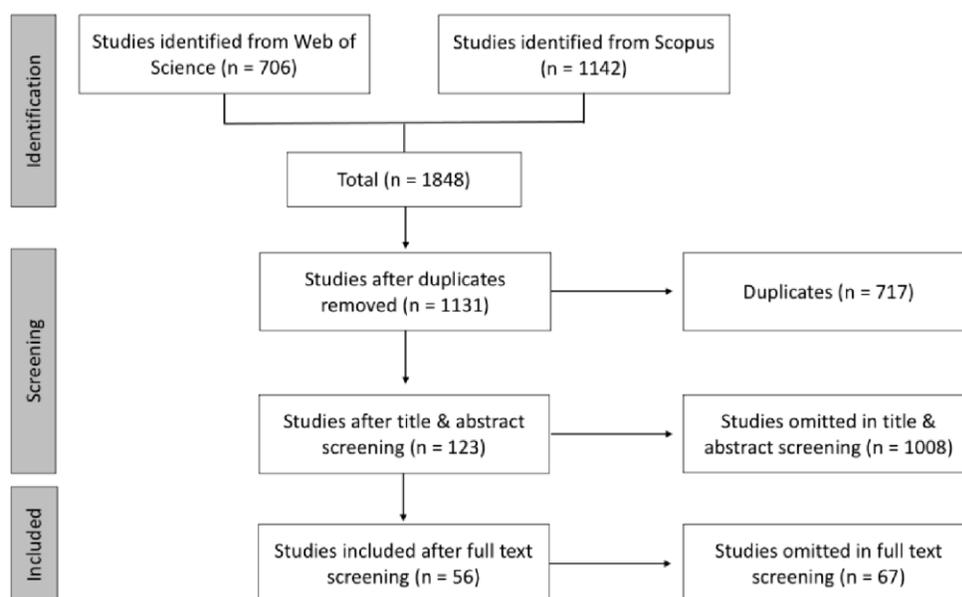


Figure 2 - 1 A visual representation of the number of papers that were included and excluded following title and abstract screening and full-text screening.

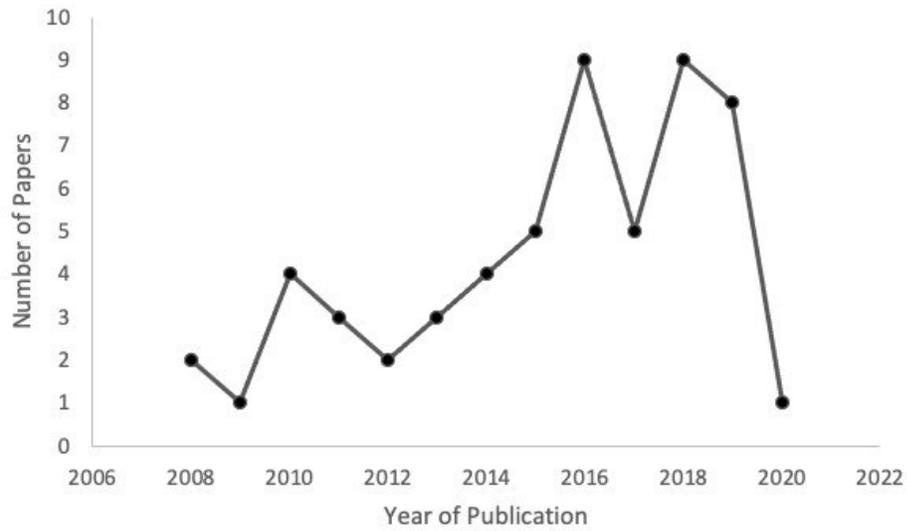


Figure 2 - 2 Year of publication for the 56 case studies on enabling conditions for knowledge exchange. The case studies for this review were collected in April 2020, and therefore represents an incomplete data set that does not accurately depict case studies published in 2020.

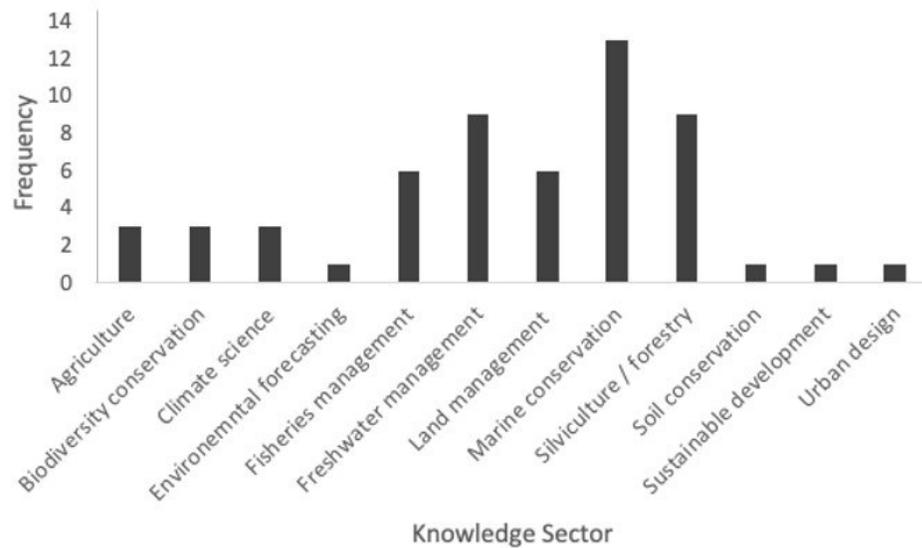


Figure 2 - 3 The knowledge sectors that were identified for the 56 case studies on enabling conditions for knowledge exchange

Appendices

Appendix A Developing search strings and screening criteria

Table 2 - 5 The search-term worksheet used to identify relevant terms for four concepts derived from the research question. The four concepts relate to knowledge exchange, environmental or natural resource conservation, the field of science, and each of the seven core capacities identified by Cvitanovic et al. (2018). There are seven iterations for concept four related to each core capacity. Below is an example of the search terms derived for the ‘organizational’ core capacity.

| Concept 1 Knowledge exchange | Concept 2 Environmental or natural resource conservation | Concept 3 The field of science | Concept 4 ‘Organizational’ core capacity |
|---|--|--|---|
| Knowledge exchang* OR Knowledge translat* OR Knowledge broker* OR Knowledge manag* OR Knowledge mobil* OR Broker* OR Transfer* OR Shar* OR Diffuse* OR Disseminat* OR Uptake OR Util* OR Adopt OR Action OR Technology transfer OR Technology diffusion OR Boundary span | Manag* environment* OR Manag* “natural resource” OR Manag* habitat OR Manag* forest OR Manag* fish OR Manag* agriculture* OR Manag* water OR Manag* marine OR Manag* ocean OR Manag* biodiversity OR Manag* ecosystem OR Manag* ecology* OR Manag*freshwater OR Manag* land OR Conservation | Science transfer* OR Science disseminat* | Organization* OR Institute* OR Agency OR Team OR Leader OR Goal OR Objective OR Culture OR Credibility OR Reward OR incentive |

Table 2 - 6 The finalized search strings using the terms identified through the search-term worksheet (Table 2-2).

| Concept | Search String |
|--|---|
| <p>Concept 1: Knowledge exchange</p> | <p>TS=((Knowledge NEAR/1 (translat* OR manag* OR exchang* OR mobili* OR broker* OR transfer* OR shar* OR diffus* OR disseminat* OR uptake OR utili* OR adopt* OR action)) OR (Technolog* NEAR/1 (transfer or diffusion)) OR "boundary span*")</p> |
| <p>Concept 2: Environmental or natural resource conservation</p> | <p>TS=((Manag* Near/3 (environment* or "natural resource" or habitat or forest* or fish* or agricultur* or water or marine or ocean or biodiversity Or ecosystem Or ecolog* Or freshwater Or land*)) OR Conservation)</p> |
| <p>Concept 3: The field of science</p> | <p>TS=(Science AND (transfer* or disseminat*))</p> |
| <p>Concept 4: Core capacities</p> | <p><i>Organizational:</i></p> <p>TS=((organization* OR institut* OR agency) NEAR/3 (Team OR leader* OR goal OR objective OR culture OR credibility OR reward OR incentive))</p> <p><i>Individual:</i></p> <p>TS=((Individual* NEAR/10 (independent OR social OR "social network" OR collaborat* OR innovat* OR resilient* OR motivat* OR honest OR strong OR communicat* OR cooperat*))</p> <p><i>Financial:</i></p> <p>TS=((Financ* or fund* OR resource) Near/5 (secure or sufficient OR long-term OR autonomy OR flexib* OR capacity))</p> <p><i>Material:</i></p> <p>TS=((science and (policy or practice) NEAR/10 (communication OR material OR framework OR tool OR print OR plan OR strateg* OR website OR site OR "social media" OR media OR product OR presentation OR publication OR brief* OR website OR webinar OR outreach)))</p> |

| | |
|--|---|
| | <p><i>Practical:</i></p> <p>TS=(employee NEAR/5 (risk OR capacity OR resources or Freedom Or individual* OR culture</p> |
| | <p>OR time OR space OR development OR training OR learning OR creativity OR indepen* OR autonomy OR adapt*)</p> <p>TS=((organization* OR institut*) Near/3 ("risk tolerance" OR creativity OR flexib* OR capacity OR adapt* OR culture))</p> |
| | <p><i>Political:</i></p> <p>TS=((Knowledge NEAR/10 (polarized OR “stakeholder interest” OR “public interest” OR “high profile” OR “media coverage” OR “hot topic” OR (Policy* NEAR/3 agenda OR priority OR interest))))</p> |
| | <p><i>Social:</i></p> <p>TS=(Employee NEAR/10 (social OR "social network" OR team OR collaborat* OR stakeholder OR opportunity OR engag* OR consult* OR communicat* OR cooperat* OR Diversity OR trust OR capacity)</p> |

Table 2 - 7 The inclusion/exclusion criteria consist of three questions used to screen literature in

Covidence.

| | |
|--|---|
| Question 1: Is this study about <i>Knowledge Exchange</i>? | |
| Responses | <ul style="list-style-type: none"> • Yes (Include) • No (Exclude) • Unclear (Include Second Opinion) |
| Notes | <ul style="list-style-type: none"> • Knowledge Exchange definition: • Include if mentioned terms such as: Translate, manage, exchange, mobilization, broker, transfer, sharing, share, diffuse, disseminate, uptake, utilize, adopt, action, boundary spanning |
| Question 2: Is this study about <i>the evaluation of knowledge exchange within environmental sectors</i>? | |
| Responses | <ul style="list-style-type: none"> • Yes (Include) • No (Exclude) • Unclear (Include Second Opinion) |
| Notes | <ul style="list-style-type: none"> • Include if mentioned terms such as: Management, environment, natural resource, habitat, forest, fish, agriculture, water, marine, ocean, biodiversity, ecosystem |
| Question 3: Is this study about <i>the implementation of KE or enabling conditions</i>? | |
| Responses | <ul style="list-style-type: none"> • Yes (Include) • No (Exclude) • Unclear (Include Second Opinion) |
| Notes | Include if paper includes case studies, practical examples, processes of implementation, or barriers. |

Appendix B List of data extraction items

Table S - 1 A list of the data extraction items

| Term | Definition |
|------------------------|---|
| COV number | Covidence number assigned to each paper |
| Shot citation | Short citation |
| Year | Year of publication |
| Full citation | Full citation |
| Auth country | Author's country of origin |
| Format | Format of the paper ex. peer reviewed article, book chapter |
| Core capacity | What organizational arm does the paper belong to based on framework from Cvitanovic et al., 2018 ex. material, financial, etc |
| Desc of case study | Description of the case study |
| Study objective | What is the objective of the study |
| Type of knowledge | What types of knowledge are studied in the case study ex. genomics, fish telemetry, etc |
| Sector | What environmental sector does the case study belong to ex. animal conservation, climate change, etc |
| Country | What country does the case study take place in |
| Spatial scale | What is the spatial scale of the project (i.e. local, regional, national, global) |
| Type of organization | What type of organization is conducting the case study ex. government, NGO, academic, etc |
| Producers | Who are the producers of the knowledge in this case study |
| Users | Who are the users of the knowledge in this case study |
| Length of case study | How long did it take to do this case study |
| # Of participants | How many participants were involved in the case study |
| Study approach | What was the study approach ex. interview, survey |
| Implementation process | Was there an explicit implementation process described for how to do KE? If so, what was it? |
| KE activities | What KE activities were used? KE activities are <i>the act of engaging in (and performing) knowledge exchange, including the process of creating/developing a KE product. The participant needs to be present or be involved in the act.</i> Refer to codebook for examples |

| | |
|---------------------|---|
| KE products | What KE product were produced? KE products are <i>the physical/tangible artefact that is created through a KE activity. A product may also be knowledge uptake by individuals, though this is challenging to measure and does not have a clean metric. This is something that can be accessed after the fact (i.e., after the act of creating it has occurred)</i> . Refer to codebook for examples |
| Enabling conditions | What helped enable KE in this case study |
| Challenges | What were some challenges to doing KE |
| Outcomes of KE | What were the outcomes of their KE work i.e., short-term impacts |
| Success | What were the long-term impacts of KE work |
| Notes | Any additional notes about the case study |

Appendix C Codebook

Below is a list of codes used for the scoping literature review. The coding team consists of Tyreen Kapoor, Vivian Nguyen, and Christopher Cvitanovic. Codes are not mutually exclusive.

Co-production – iterative and collaborative process involving diverse types of expertise, knowledge, and actors to produce context-specific knowledge (Schneider et al., 2021)

- **Align project objectives (co-design)** – the KE practitioner or group collaborates with stakeholders to modify research questions, KE activities, products, or processes to address the goals of the KE project
- **End-user history** – learning about end-user history, operational capabilities, etc. to better understand what knowledge is relevant or accessible to them

Collaboration – Collaborating with individuals internally or with individuals from other disciplines.

- **Networking** – importance of networks, partnerships, stakeholder engagements, or other ways of interacting within networks

Communication

- **Formal** – may include communication through emails, reports, from upper management with few opportunities to develop interpersonal relationships
- **Informal** – based on the informal, social relationships that are formed in a workplace. Includes casual conversations to establish personal contacts, making friendships, influencing, and motivating others, etc.
- **Regular and sustained communication** – maintaining communication with end-users throughout a KE project and after it is completed to remain engaged and receive updates. This is important for evaluating impact of KE work and ensuring long-term implementation of KE work
- **Shared language** – developing and using common words and phrases to improve understanding and ensure accessibility
- **Tailored communication** - modifying data or experiences to make it relevant and accessible to the end-user

Organizational flexibility – organization’s ability to adapt or adjust processes and organizational structures to address projects effectively.

- **Knowledge management** – efficient handling of information and resources within an organization

Evaluations – conducting evaluations or receiving feedback from past work to improve KE strategies

One-way exchange (linear communication)

- **Outreach** – promoting KE work and results to engage wider audience

Trust building – establishing and maintaining trust such that all project stakeholders feel like they are a part of the team, they can communicate honestly and freely, and trust each other to work towards a shared goal or way of working.

- **Establish credibility** – establish that KE practitioners and your organization are worth believing in and are trustworthy
- **Transparency** – the approval or acceptance of a community (Lowey, 2016).
- **Shared value** – regarding KE work and objectives to the same standard, importance, and usefulness

Relationship building – establishing and maintaining interpersonal relationships with all project stakeholders such that you can share information across organizations because of the relationships you have built

- **Face-to-face engagement** – importance of face-to-face interactions with stakeholders for developing interpersonal connections

Boundary objects – they are a product of KE work and are adaptable to different knowledge domains and perspectives but maintain their identity across disciplines. They can help to overcome interpretive differences across disciplines (ex. definitions and standards, models that integrate scientific and political viewpoints, indicators that improve communication across knowledge domains).

Boundary spanners – individuals or organizations that actively facilitate the exchange between the production and use of knowledge to support evidence-informed decision-making (Bednarek et al., 2018).

- **Knowledge broker** – acting as an intermediary between producers and users of knowledge. The person displays characteristics of a knowledge broker such as building relations (personal/professional)
 - **Clear goals & objectives** – having a clear set of goals and objectives for the KE practitioner is important to conducting KE work effectively
 - **Leadership qualities** – KE practitioners that are strong leaders
 - **Adaptable** – practitioners can adjust to new conditions and modify work as a result.
 - **Adequate background knowledge / expertise** – practitioners possess sufficient background knowledge and expertise on a topic to be able to exchange knowledge effectively and accurately between producers and users

Training – can include hands-on demonstrations and co-learning to improve the collective (i.e., all stakeholders involved) understanding of a topic

- **Peer-to-peer learning** – encouraging end-users to teach and train other end-users
- **Social learning** – gaining a better understating of a topic by observing or working with a community

Funding – acquiring long-term funding is necessary for conducting KE work and evaluating its impact in the future

Research – KE practitioners engage in gathering data or conducting secondary research to aid in the KE work

Sharing expertise - sharing personal or organizational expertise across disciplines

Boundary organizations – “providing guidance for both organizational identity and for the organization’s work and activities, whether between science and policy or other counterparts, such as industry. The boundary organization is also seen as an organizational form that not only governs but also facilitates collaborations.” (Gustafsson & Lidskog, 2017)

- **Community of practice** – individuals within an organization who share common training or roles. Communities of practice can be impeded by differences in communication and perceptions or interpretations of information

Challenges – barriers that prevent the uptake of knowledge or the ability of KE practitioners to do their job

- Implementing tools / technology
- Regular and sustained communication
- Adequate background knowledge (for KE practitioner)
- Lack of interpersonal skills - Practitioner characteristics: inability for practitioners to listen and communicate with stakeholders; Lack of leadership) • Cultural barriers
- Remaining impartial (interpersonal skills)
- Time (to complete project and to build trust and relationships)
- Funding (long-term)
- Power imbalances
- Mismatched values (can occur between organizations or within one)
- Mismatched timelines & project objectives (often between science and policy communities)
- Language barriers
- Limited capacity
- Geographical limitation
- Customizing data (difficulty communicating complex data or knowledge)
- Institutional structures (Organization’s aversion to risk, bureaucratic structure, lack of communication channels)
- Lack of trust
- Few/poor interpersonal relationships
- Low credibility
- Little collaboration (can include not sharing expertise)
- Few networking opportunities

Outcomes of KE – “the measurable objective changes that are brought about by engagements with information and advice” (LSE; Andrew Harding 2014)

- Development and adoption of new technology, product, policy
- Increased understanding (which can lead to a long-term impact of change in behaviour)
- Incorporate feedback
- Aligning interests (science and policy objectives and with local concerns)
- Increased stakeholder engagement
- Increased collaboration
- Increased organizational capacity
- New social networks

- Expertise transfer – legitimizing and giving voice to non-academic knowledge systems

Success (Impact) of KE – the longer-term effect of an outcome; “the effect information and advice had on ability to make an informed choice, empowerment or wider life experiences” (LSE; Andrew Harding 2014)

- Change in behaviour (due to an increased understanding of a topic individuals may be more receptive to change etc)
- Change in practice (often by informed scientific process)
- Increased sense of trust
- Improved communication
- Increased resiliency (for end-user)
- Shared language is developed
- Lowered cultural barriers
- Encouraging similar research elsewhere
- Boundary spanner enabled
- Improved relationships
- New economic opportunity
- Shared value and mutual understanding are developed

Appendix D Samples of coded text

Table S - 2 Samples of inductively derived coded text used in the scoping literature review.

| Short Citation | Sample Text | Codes |
|---------------------|---|---|
| Feeney et al., 2010 | Co-production processes were repeatedly mentioned as the best method for doing KE and it viewed by the participants as having had the most impact on collaborative fisheries research in the past decade. Participants suggest ways to improve collaborative science: (1) Continuance of collaborative gathering of time series data critically important to monitoring ecosystems. (2) Expansion of the scope of research questions that fishermen are able to answer beyond the species for which they have commercial permits. (3) Expansion of acoustics use in collaborative fisheries science. (4) | Co-production Collaboration Align project objectives Engage stakeholders Outcomes of KE: new tools/technology |

| | | |
|----------------------|---|--|
| | <p>Provision for more venues for diverse stakeholders to communicate. (5) Greater emphasis on communication about project results and technology transfer, particularly engaging industry to conduct outreach. (6) Greater infiltration of collaborative data into mainstream data systems used for management.</p> | <p>Outcomes of KE: new social networks</p> <p>One way exchange: outreach</p> <p>Tailored communication</p> |
| Chapman et al., 2017 | <p>Highlighting the regional interests and concerns raised in the stakeholder interviews, introducing the researchers to new stakeholders, and assisting with the advertising and development of presentations and workshops. Behind the scenes the knowledge broker worked both formally and informally to build trust with local stakeholders. The knowledge broker also assisted the modelling researchers with improving the clarity of their presentations by using common language and easy to understand formats, and by tailoring the focus of modelling results to be relevant to the interests of specific audiences.</p> | <p>Collaboration</p> <p>Align project objectives</p> <p>Build trust</p> <p>Relationship building</p> <p>Informal communication</p> <p>Tailored communication</p> |
| Cadman et al., 2020 | <p>The use of boundary spanners to take scientific information from researchers, and translate it for policy makers, “reflexivity,” that is, the ability of researchers, policy makers, or advocates to adapt their strategies and communication to fit their audience [41]. Organizational flexibility allows for more dialogue between groups, creating better, collaborative results, frequent contact with stakeholders, informal relationships, ability to adapt to changing circumstances</p> | <p>Boundary spanners: KE broker</p> <p>Tailored communication</p> <p>Collaborations</p> <p>Relationship building</p> <p>Organizational flexibility</p> |

| | | |
|-----------------------|--|---|
| Berglund et al., 2015 | Main challenges for individual who work as KE brokers for SCSI: Establishing and maintaining contact, accomplishing objectives of the knowledge user (SCSI), representing SCSI as a government organization (many people confuse their work for private industry), having adequate skills and background knowledge on soils, dealing with own emotions when interacting | Difficulty maintaining regular and sustained communication Difficulty implementing tools/technology |
| | with stakeholders. Moreover, further studies need to be conducted to understand the process of collaboration | Inadequate background knowledge Difficulty remaining impartial Barriers with institutional structures |
| Ingram 2010 | In a number of cases the lack of support acted as a stimulus for a small and discernible community of practitioners to interact and forge communication links to share knowledge and build a supportive environment. The networks established allowed farmers' experiences to be exchanged, compared, and analyzed. A social learning community emerged which enabled many farmers to continuously add to their base of knowledge. It gave farmers a chance to validate, reflect on and reinforce the technical learning that had gone on at the farm level. Through pooling their collective experiences and expanding their knowledge the reduced tillage farmers became 'the experts,' other farmers and even advisors sought information from these practising farmers rather than from traditional sources. | New social networks Increased collaboration Social learning |

Chapter 3: Implementing and Evaluating Knowledge Exchange: Insights from Practitioners at the Canadian Forest Service

Abstract

The relationship between knowledge producers, knowledge users, and how evidence-informed decisions and practices in environmental and natural resource management are implemented is complex. While there is a growing body of work on the barriers to knowledge exchange (KE) and the development of actionable science, what remains more elusive is an understanding of what strategies and conditions lead to effective KE or even how different practitioners define what is a successful exchange of scientific knowledge. This chapter uses semi-structured phone and video interviews with nine KE practitioners at the Canadian Forest Service (CFS) to understand (1) who at CFS is involved in KE and how they perceive their roles, (2) the strategies for KE used in the CFS, (3) how KE practitioners define a "successful" exchange of knowledge, and (4) what conditions enable KE within the CFS. By assessing the role of CFS KE practitioners and how they put KE to practice, we identify areas of strengths and improvement for KE. This chapter identified a general strategy that practitioners at the CFS employ to implement and operationalize KE, which can be applicable and useful to KE practitioners in other disciplines and sectors. We emphasize the importance of identifying and utilizing a KE typology (Westwood et al., 2021) to develop and execute relevant and accessible boundary objects. This study emphasizes the need for organizations to adopt more qualitative evaluations to assess the full scope and impact of KE work, and recognizes the integral role of relationships and trust in all aspects of KE work. Our findings, which

highlight the knowledge of expert practitioners in KE in forestry and natural resource management, may apply equally in other domains.

Background

Achieving successful evidence-informed decision-making has become one of the main goals of science-based government agencies over the past decade (Cook et al., 2017). Evidence-informed decision-making refers to the inclusion of the best available “evidence” in developing policies or management strategies. The use of evidence in this way is an attempt to de-politicize decision-making by using information that can be impartially and objectively evaluated (Haddaway & Pullin 2013; Adams & Sandbrook 2013). However, given the diverse values and objectives of science, policy, and economic actors, there is no universal agreement on what the “best” evidence is, particularly when that evidence is scientific in nature. Translating scientific information into actionable knowledge for policy development and implementation remains a challenge (Sarkki et al., 2014; Young et al., 2014; Watt et al., 2019). To support actionable science (i.e., data, analyses, projections, or tools that can support decisions; Beier et al., 2017) and evidence-informed decision-making, scientists must seek out strategies to make relevant science more accessible to decision-makers from non-scientific disciplines (Van Eerd & Saunders, 2017, Buxton et al., 2021; Singh et al., 2021).

Knowledge exchange (KE) is a dynamic and iterative process that generally involves the interactions of knowledge producers (individuals who produce specific knowledge available to others), knowledge users (individuals who apply knowledge obtained from others), and knowledge brokers (individuals who facilitate knowledge

movement between producers and users) (Wang & Noe, 2009; Naylor et al., 2012; Nguyen et al. 2017). Given that the explicit goal of KE is the translation of discipline-specific knowledge from those who created it to those who can apply this knowledge in different contexts, KE is an emergent tool which could help scientists overcome the knowledge-action gap (Ferreira et al., 2021).

An area of particular concern for understanding the effective exchange of scientific knowledge into practice is natural resource management. Environmental, natural resource, and forestry management require collaborations with various actors, such as those belonging to science, economic, and policy disciplines. The complex and sometimes conflicting values, resources, and management practices of these disciplines can make it difficult for practitioners to effectively exchange knowledge for evidence-informed decision-making (Sarkki et al., 2014; Watt et al., 2019). As such, the disconnect between KE and action is particularly relevant in environmental and natural resource management.

Scholars have outlined a range of barriers to KE and the development of actionable science, such as discipline specific communication differences between knowledge producers and users (Young et al., 2016), a disconnect between science and policy communities (Cvitanovic et al., 2016), and the tendency for scientists to produce information that is not immediately useable in non-scientific settings (Wurtzebach et al., 2019). What remains more elusive is an understanding of what strategies and conditions lead to effective KE or even how different practitioners define what is a successful exchange of scientific knowledge. Most studies that have generated recommendations for conducting successful KE are predominantly theoretical or suggestion based (Westwood et al. in review for a systematic review; but see Reed et al., 2014; LSE 2019), meaning

there remains no universal understanding of how KE can be enacted or evaluated by scientists (Rubenstein et al., 2001; Hickey et al., 2013; Cvitanovic et al., 2016). To overcome this knowledge gap, Westwood et al. (in review) have called for academics and practitioners of KE to design studies which capture robust empirical evidence about KE strategies and their performance so that more specific guidance on KE practices can be developed.

We address the empirical knowledge gaps highlighted by Westwood et al., in this case study of knowledge exchange in Canada's federal forestry agency, the Canadian Forest Service (CFS). The CFS has been a division of Natural Resources Canada – a federal governmental department – since 1899 (Government of Canada, 2021). As a science-based agency, the CFS is both a producer of domain-specific forestry science, as well as a collaboration hub for researchers from different provinces, agencies, and disciplines (Government of Canada, 2021). With six regional centres and three research forests (Figure 3-1) the CFS is in a unique position to act as a knowledge brokering agency, connecting stakeholders from industry, government, academia, and the public. CFS also maintains internal “Knowledge Exchange Specialists” and other individuals whose jobs involve the explicit exchange of scientific knowledge with various knowledge users. In this way, the CFS provides a unique opportunity to study how a national agency conducts and evaluates knowledge exchange practices.

For this case study, we investigate (1) who at CFS is involved in KE and how they perceive their roles, (2) the strategies for KE used in the CFS, (3) how KE practitioners define a "successful" exchange of knowledge, and (4) what conditions enable KE within the CFS. By assessing the role of CFS KE practitioners and how they put KE to practice, we identify areas of strengths and improvement for KE, and offer

empirical evidence and insights into effective KE. Additionally, we identify “bright spots” (Cvitanovic & Hobday, 2018) by highlighting impactful KE examples outlined by CFS KE practitioners (see Figure 3-3 Box 1 and Figure 3-4 Box 2 for examples). In following this line of thinking, we suggest that the CFS knowledge exchange practitioners effectively implement a series of practices and processes to enable the multi-directional flow of information between scientists and non-scientists.

Methodology

Key theoretical aspects of KE

A number of KE-related concepts associated with social context inform our study. *Boundary organizations* facilitate collaboration between scientific and non-scientific domains (Guston, 2001), and they engage in *boundary work* which involves actors creating knowledge in one domain and using often new-to-them knowledge from a separate domain in a distinctly new way across boundaries (Cash et al., 2003; Broniatowski & Magee, 2017). When artefacts are coproduced across these boundaries, it may result in *boundary objects*. Such artefacts are adaptable to different knowledge domains but maintain their identity across boundaries (Star & Griesemer, 1989; Nel et al., 2015; Karcher et al., 2021). Boundary objects help to overcome interpretative differences across the disparate knowledge domains (Boyes, 2019). This study analyzes the specialized role of knowledge brokers and their KE strategies which include coproducing boundary objects.

KE and boundary work can be approached through a social constructivist view on reality (Berger & Luckmann, 1966). In this view, individuals and groups who interact in a

social system generate concepts, ideas, and actions that, over time, construct an understanding of the world based on their shared assumptions of reality (Berger and Luckmann, 1966). Our interpretations of KE are therefore informed by participants' versions of reality at various levels of management within the CFS (Carlson, 1999).

Data collection

Our study involved initial and follow-up semi-structured interviews conducted by phone and/or video conference (see Appendix A and B for both interview guides). Five individuals with the job title of *Knowledge Exchange Specialist* or who work in the KE space were identified by CFS partners and interviewed. Four additional participants were identified through snowball. These nine participants completed the initial interview. Seven of the nine participants also took part in the follow-up interview.

Interviews consisted of a mix of open and closed-ended questions. The initial interview was approximately 40 minutes to one-hour in length with questions that addressed the academic and professional background of the participants, their individual and institutional perspectives on KE, their approaches to KE work, and the techniques they use to evaluate the effectiveness of KE. The follow-up interview was shorter, approximately 20 to 30 minutes in length and provided an opportunity for the participants to discuss a single successful KE project. Participants were asked what defined success at CFS, the strategies the participants employed for their project, what conditions (i.e., resources, expertise, capacity, etc) facilitated their success, and any barriers they may have faced.

The interviews were conducted by CB, JH, and TK. The phone and video conference interviews were audio-recorded and analyzed using NVivo software (version 1.3.2). All interviews were transcribed and anonymized.

Thematic coding

We first followed an inductive coding approach that involved labelling themes found in the transcripts (Saldana, 2016). The codes were not determined in advance to allow themes to emerge from the data itself (Van den Hoonaard, 2011). Coding was consensus-based, where four authors (MF, JH, TK, VN) individually followed an inductive coding approach to develop initial codes, then compared codes to develop a final codebook (Appendix C). Consensus-based coding was an important practice to ensure that all possible themes in the transcripts were identified given the varied background knowledge and experience of the authors (Van den Hoonaard, 2011). The major themes identified in this round of coding were the specialized roles of CFS KE practitioners, the strategies they employ for engaging in KE, and how they evaluate the effectiveness of their efforts. All transcription and coding were compiled and analyzed using Nvivo (1.3.2).

A descriptive typology of KE

In a recent study, Westwood et al. (2021), developed a typology of Knowledge Exchange, which divides specific KE activities into four unique approaches (Table 3-1, adapted from Westwood et al., 2021). These approaches provide a framework through which scientists can view their own KE activities, lend an outline for developing evaluating techniques, and provide a universally accessible terminology for different

strategies. This case study is the first to use Westwood et al.'s, typology to classify which KE approaches are most commonly used by an environmental management agency. In this way, we test the applicability of this typology, in addition to providing a more qualitative assessment of KE in Canada's forestry sector.

Following inductive coding, we applied a deductive approach using Westwood et al.'s (2021) KE typology. Each KE activity described by the participants was categorized into one of the four approaches (participatory exchange, one-way exchange, solicited exchange, and network exchange). All KE typology codes were applied to the transcripts after the inductive codes, meaning that the inductive codes did not influence the deductive codes. All of the *KE activity* codes fit at least one of the KE typology codes.

Results

Who and what is involved in KE?

Seven out of nine participants had academic backgrounds in forestry. All the participants described their work as interdisciplinary – emphasizing the fact that they work with one or more fields of knowledge (i.e., science, economics, policy). The information they were responsible for exchanging was primarily scientific knowledge where the intended users were often professionals from a scientific discipline. The information exchanged was either for research programs within the CFS or for external organizations. Participants said the main use of scientific knowledge was to supplement research, develop new technologies, or develop research methods related to forest management and planning. Two participants emphasized the need to exchange scientific information with interdisciplinary sectors, such as policy and economics. However, the main goals of most participants' KE practices were to incorporate their knowledge into

existing scientific research programs for CFS, industry, or academia. This does not mean that the participants never engaged in exchanging scientific information with interdisciplinary knowledge users; rather, the participants described their work objectives as predominantly focusing on supporting the needs of scientific knowledge users, with interdisciplinarity as a secondary objective.

One participant suggested that the KE practitioners should exchange information with forestry practitioners or industry users unless the KE practitioner themselves possesses a forestry-related background. According to this participant, this field-specific knowledge is necessary for practitioners to explain the research accurately and thus increase the effectiveness of KE:

I'm the only forester [among the KE practitioners in the region]. I'm the only domain knowledge person. We don't bring people on with domain knowledge anymore in our branch. (Interviewer: So, I guess that relates back in the sense that, by having the team have more forestry information that increases the effectiveness of the KE process?) Yes...So, you're trying to convert from a scientific person and move their language to more common language. I shouldn't say dumb it down, that's not correct, but simplify it towards more of a grade 12 reading or below that if you can. So, having that domain knowledge helps you have that conversation with them (Participant 7).

Nearly all the participants (eight out of nine total participants) act as knowledge brokers, facilitating exchange across disciplinary boundaries. Participants reported strategies for exchanging knowledge with knowledge users by: (1) collaborating with knowledge users to modify KE work to addresses specific project goals, (2) modifying

research or in-person demonstrations to increase accessibility for knowledge users, and (3) sharing personal or team experiences across CFS regions, with private stakeholders, and with other relevant collaborators to expand or improve the understanding of KE work and strategies.

The CFS 's KE processes and practices

Inductive coding of how participants described their KE work yielded three unique strategies that all aspects of knowledge exchange at CFS can be broken into: KE planning, KE activities, and KE products. These are shown in Figure 3-2, and we discuss each in turn.

KE Planning

KE planning involves determining steps or developing a process to conduct a KE activity. For example, some activities are engaging in collaborative communication, building relationships, establishing project goals, aligning objectives, among others. The participants identified various ways of planning and conceptualizing KE activities, ranging from small-scale method development to large-scale community engagement. One of the KE plans that was identified by nearly all of the participants includes engaging in collaborative communication with knowledge producers and users to align project objectives, identify target audiences for the KE work, and establish long-term goals:

It's really about working together, that collaborative, the communication, the actual conversations with each other, learning from each other...that I think really made this project successful.” (Participant 4).

This quote highlights the importance of collaboration and open communication as part of KE planning to enable execution of KE projects. The KE planning described by the participant includes understanding and aligning the perspectives of knowledge users and producers, and encourages conversations that foster trusting relationships for more effective KE work.

Participants also frequently identified KE planning to include drawing upon established methods and strategies for executing KE activities. One participant utilizes an established mathematical tool for spatial climate modelling research where access to these systems is important for understanding historical data for research and KE purposes:

...We're not the creators of it (a mathematical tool), it's a guy named Individual 41, I knew him when I was in Region 31 and we brought him over here multiple times, and we're using the software we worked on with him. It's arguably one of the best methods in the whole world, cause his methods have been used by other people around the world. But we've got, you know, our own sort of twist on it. (Participant 2).

Sharing KE strategies and tools as part of planning enabled practitioners to incorporate new information into their work to improve upon it. Four participants identified that they practiced sharing ideas and providing feedback to other KE practitioners across the CFS regional centres, resulting in an internal bank of KE methods and strategies.

Other KE plans identified by the participants included establishing relationships with knowledge users to strengthen communication and performing in-person demonstrations of technology to increase the understanding and need for KE work:

...the key is to ensure that you interact with stakeholders in their environment at all levels... You need all levels of discussions to occur to create a vibrant knowledge exchange program. (Participant 5).

So, it's good to talk, but it's better to show. We had demonstration sites and field tours and things like that, and then we switched into even deeper analysis of what drove our clients away and what drove them to us. (Participant 7).

KE Activities

At the CFS, *KE activities* involve engaging in projects or actions to enhance or facilitate KE. KE activities involve engaging in and performing KE by creating or developing a KE product (i.e., a physical artefact or non-tangible outcome). These specific activities are the units of measurement on which Westwood's typology of KE can be applied (Table 3-2). Participants identified many activities or ways to engage in KE, such as outreach, training, research, writing, publishing of peer-reviewed articles, and work evaluations (Table 3-2). Our results indicate that participants most frequently performed outreach (referenced 44 times by all nine participants). Outreach referred to using materials (i.e., newsletters, brochures, emails, videos, field trips, workshops, citizen science, etc.) that could be exchanged without a targeted knowledge user in mind, and can be considered one-way exchange in this case. Outreach materials could also be

sourced by an organization, such as a school seeking citizen science programs, and can be considered solicited exchange. Alternatively, outreach materials could also be coproduced with the knowledge users and be considered participatory exchange. We also found that participants frequently engage in daily correspondence, academic writing and publishing, and secondary research (see Table 3-2 for full descriptions). As such, we found that participants often adopted a one-way or a solicited exchange approach. Only few participants described knowledge management activities, summative evaluations, or formative evaluations as KE activities resulting in fewer network exchanges.

KE Products

Participants also identified *KE products* as part of their KE work, which includes physical artefacts i.e., boundary objects (e.g., newsletters, factsheets, academic publications, etc.). *KE products* were identified as a tangible result of *KE activities* and help with *KE planning* by providing example deliverables of how KE practitioners can make knowledge accessible to specific users (i.e., participants learn and use KE products as feedback for future KE planning and work; Figure 3-2). Some of the KE products outlined by the participants included factsheets, guidebooks, websites, blogs, videos, publications, interviews, research maps, citizen science programs, conference presentations, e-lectures, lesson plans for schools, climate models, field tours, operational demonstrations, self-guided tours, articles in magazines, newsletters, and webinars. The variety of *KE products* that can be developed highlighted the uniqueness of each KE project and how *KE products* often cater towards the specific needs and objectives of the knowledge user, which are often identified during the *KE planning*. *KE products* can aid

in *KE planning* by functioning as boundary objects to improve communication strategies, initiate new relationships, share research methods and expertise, and align project objectives.

Based on our analysis, the three components or processes the participants identified for putting KE to practice (planning, activities, and products) are cyclical and can provide a general strategy for conducting KE at the CFS and can be described as follows: (1) *KE planning* – determining steps or developing a process to conduct a KE activity, (2) *KE activities* – engaging in projects or actions to enhance or facilitate the exchange of knowledge, and (3) *KE products* – developing physical artifacts or boundary objects that improve user uptake as a result of conducting a KE activity (Figure 3-2). The general approach for implementing KE outlined by the participants highlighted the interdependent nature of KE planning, activities, and products.

Evaluating and assessing impact of CFS KE work

How is KE evaluated?

When asked how the impact of KE work is evaluated at the CFS, participants described indicators that can be categorized by their quantitative and qualitative nature. The participants were not aware of a singular definition for how to interpret the success of KE work at the CFS, focusing instead on the various indicators that can help interpret impact. Successful impact of KE was primarily described based on participant experiences working in this field.

Participants described quantitative indicators for KE evaluation that included: number of website clicks; number of people attending a seminar, workshop, or conference; number of papers produced or published through peer-review, and the

number of times a CFS paper is cited. Participants explained that these quantitative indicators were easily counted at the CFS. Further, participants identified adoption of a new technological product or policy by the knowledge user as an additional quantitative indicator for evaluating the impact of KE. However, the adoption of a technology or policy by the user was not something that the CFS actively quantified despite it being a tangible measure of success in KE.

Participants explained that qualitative indicators evaluating KE were difficult to measure. Some attempts to qualitatively capture the impact of KE work included: assessing the influence that KE work had on human behaviour by considering whether individuals were inclined to act in a certain manner due to an increased understanding of a topic, evaluating whether modifying a research project resulted in an increased number of positive outcomes, and observing whether a KE project influenced or encouraged similar work elsewhere in Canada.

Many participants considered KE to be impactful when there was uptake of the knowledge by the user. Notably, uptake was defined differently by each participant, resulting in varied interpretations of successful and impactful KE across the CFS regional centres. For example, one participant described knowledge uptake to involve knowledge being incorporated into decision-making, where the background knowledge of a specific topic can grow, and new insights or findings can be developed as a result:

... I actually think the research [people conduct] can contribute to the stock of knowledge that's out there about a subject. Researchers can also produce technology, that kind of

thing, or data, things that are more involved mechanically into a decision process or something like that.” (Participant 2).

In contrast, another participant described knowledge uptake to be successful when new technologies are adopted and put to use by the knowledge user:

Successful knowledge exchange has to link with the end users. So, the idea is to link technology with the end users and have potential uptake. So, success is having uptake by the end users of the knowledge or the technology that you're exchanging with them.” (Participant 5).

These two views on KE uptake demonstrate how KE impact can be clearly interpreted by qualitative indicators (i.e., increase of knowledge domain, adoption of new tools).

Although difficult to measure, qualitative indicators can provide greater insight than quantitative measures into the effectiveness and applicability of KE work (Fazey et al., 2014).

One participant emphasized that impactful KE goes beyond positive outcomes such as knowledge user uptake and policy adoption, and that in order for KE work to be considered successful, it must encompass constructive feedback to improve KE practices:

So, a negative result is also a valid result, because I've had someone say that to me before in a way saying, 'it's good that you tried this Participant 7 cause now we know it doesn't work'. So, both negative and positive results are equally valuable to the forest sector to improve the way to manage Canada's forests. (Participant 7).

What is impactful KE?

One way to learn about successful and impactful KE is to discuss and highlight ‘bright spots’ which are situations where environmental science has successfully influenced policy and/or practice (Cvitanovic & Hobday, 2018). When the participants were asked to describe a perceived successful KE project that they previously worked on, all participants identified that building trusting relationships and aligning objectives with knowledge users enabled their KE project to be successful and achieve the most impact. One participant outlined that obtaining social license (i.e., the approval or acceptance of a community; Lowey 2016) to conduct a KE project contributed to its success as it required the participant to build trust with the knowledge user (Figure 3-3, Box 1).

Additionally, all the participants outlined the importance of collaborating with both knowledge producers and users to build strong relationships that further establish trust. As one participant explained:

I think one of the key elements of success was that we were able to share information with all companies. We also worked closely with the region’s government, and because of the collaborative nature, we were able to work together to deliver something that was needed and appreciated. We didn’t just have this information and go ‘here it is, now use it’ ... No, we tailored the information towards the knowledge-user. It’s the listening and working collaboratively that was a key element of this success. (Participant 4, female).

Others explained that collaboration with knowledge producers and users is necessary to align project values and objectives (as part of KE planning) to develop KE products that have long-term usability (Figure 3-4, Box 2).

At the CFS, building and maintaining trusting relationships enabled impactful KE by fostering open communication and collaboration with all project stakeholders. In turn, this enabled the development of boundary objects that were relevant and accessible to the knowledge users.

Discussion

We have provided the second-known empirical study of the KE activities undertaken by professionals in forestry and forest sciences (the only other example we are aware of being Klenk and Hickey, 2011). We provide empirical evidence and practical insights for learning about KE in practice by understanding the role of CFS KE practitioners, how they implement and operationalize KE, and how they evaluate and perceive successful KE. In this section, we discuss lessons learned and perceived strengths of the KE work undertaken by the CFS. We also look to best practices in the literature to make recommendations for strengthening relative KE efforts. Further, we highlight potential insights for other knowledge brokers throughout. We conclude by identifying areas for future research.

Role and characteristics of CFS KE practitioners: Knowledge brokering

We observed that CFS KE practitioners act as facilitators responsible for exchanging scientific knowledge across disciplinary and organizational boundaries, much

like the roles of knowledge brokers (Naylor et al., 2012). Their roles included supporting knowledge producers to promote scientific knowledge – mainly through outreach activities, conducting secondary research, directing knowledge users to the appropriate knowledge, and collaborating with knowledge producers and users to co-produce applicable tools and KE products. In the literature, knowledge brokers act similarly by utilizing a multi-directional approach to linking, collaborating, mediating, and exchanging context-specific knowledge with diverse knowledge users (Fazey et al., 2013; Bednarek et al., 2018), often through the use of boundary organization, social connections and networks, and knowledge co-production (Armitage et al., 2011; Cvitanovic et al., 2015; Karcher et al., 2021).

Current strengths of CFS KE

While knowledge brokers can be conceptualized differently and operate differently in various disciplines and settings, the defining feature of their role is to develop relationships and networks with knowledge producers and users to facilitate the exchange of knowledge and build capacity for evidence-informed decision making (Hoppe, 2009; Bornbaun et al., 2015). This requires knowledge brokers to build and maintain relationships (Cvitanovic et al., 2017), possess a strong understanding of the scientific knowledge they are exchanging, and possess an in-depth understanding of the knowledge users they are engaging with (i.e., their operational environment, what KE products will best influence their research and capacity) (Michaels, 2009; Saarela & Soderman, 2015). CFS KE practitioners highlighted the value of interpersonal skills and connections that allow them to interpret and frame knowledge user needs with knowledge producers. This is important in removing barriers to evidence-informed decision making

and promoting a culture that values using the best available scientific knowledge for decision making (Cvitanovic et al., 2017; Dobbins et al., 2009; Meyer, 2010).

Opportunities for strengthening CFS KE

Most knowledge exchanges at the CFS occurred among the scientific community, with only few participants citing KE for non-scientific audiences resulting in potential implications on the knowledge base of knowledge users across organizational boundaries. (i.e., disciplines outside of the natural sciences). Addressing environmental management concerns requires knowledge brokers to draw on a wide range of disciplines and collaborate across organizations to align objectives with knowledge users and build capacity (Michaels, 2009). As such, opportunities may be missed to involve non-scientific actors, which could consequently limit policy development, industry objectives, and the capacity for knowledge brokers to build relationships or collaborate across research and policy areas (Dobbins 2009; Bornbaum 2015). Based on our analysis, it is uncertain whether the KE practitioners' roles at the CFS formally extends to influence disciplines and organizations outside of the natural sciences. It is also unclear whether the lack of uniformity around defining roles around KE may limit these opportunities.

Approaches to KE

CFS KE practitioners employ each KE approach identified by Westwood et al. (2021) in various capacities (Table 3-2). Each of the KE Types has unique aims and offers unique results. As such, it is important that knowledge practitioners, generally, are aware of the four KE Types and their potential uses to effectively identify which KE

activities may best supplement an approach or achieve a particular objective, and which KE products would be most impactful.

At the CFS, outreach was the most frequently cited KE activity. The nature of how outreach was described, however, resulted in outreach activities being used as one-way exchange, solicited exchange, or participatory exchange, based on the context of a given KE project. Outreach materials could be exchanged without a targeted knowledge user in mind (one-way), materials could be sourced by an organization (such as a school seeking citizen science programs) (solicited), or materials could be co-produced with the knowledge users (participatory). Based on our analysis, when performing outreach, the information being exchanged was not always tailored to a specific audience, but practitioners wanted for it to be easily understood by all knowledge users.

Our observations demonstrate that simply knowing the type of a KE product does not determine which category of KE it falls into within the typology. To assess that, more must be known about the context through which the product was developed, how it was selected, and how knowledge users participated (or not) in the design of the KE product. KE practitioners should be aware of, and consider, which KE type is most relevant to their work to inform their decisions about KE activities and products. Taken together, this suggests that more research is required to validate and elaborate on Westwood et al.'s (2021) typology.

Current Strengths in KE Approaches

The KE strategy (Figure 3-2) the CFS KE practitioners employ really embeds interpersonal trust and relationship building at all stages of their process, from KE

planning to products. The KE strategy involves a cyclical process among KE planning, activities, and products. This feedback loop is an important aspect of KE work as it encourages practitioners to continually evaluate and refine their work to maintain or improve trust and relationships with knowledge users. Developing and maintaining trust and relationships is an iterative process that requires learning and improving from past actions and outcomes (Fazey et al., 2014; Cook et al., 2020).

To date, research suggests that participatory approaches to KE are most effective (Bautista et al., 2016; Saarikowski et al., 2017). One form of participatory exchange (as defined by Westwood et al.'s (2021) typology) is co-production, which scholars recommend as one of the best forms of research for actionable science as it involves designing, conducting, and disseminating research in relationship with partners (Beier et al., 2017; Westwood et al., 2020) The cyclical nature of the KE strategy employed by CFS KE practitioners is a participatory approach to KE that encourages collaborative exchange with all project stakeholders to produce actionable science.

Opportunities to strengthen KE Approaches: Use of KE Typology to contextualize KE activities and Products

We found a heavy reliance by CFS practitioners on one-way exchange and solicited exchange, which may limit opportunities to collaborate across diverse disciplines. The KE Types are context-dependent and as such, a single KE Type cannot be considered more effective than the others without considering the perspectives and context of the knowledge producers and users. However, the unique positioning of CFS as a government organization with extensive connections both within and outside the government offers opportunities to engage in collaborative exchange with a variety of

knowledge producers, knowledge users, industry, and community stakeholders and employ a variety of KE Types.

Evaluation of KE

KE can be evaluated through quantitative and qualitative lenses. While quantitative measures can provide instantaneous results that indicate the short-term impacts of KE, qualitative indicators often require more time to observe their impact or success (Bowen & Martens, 2006; Fazey et al., 2014). In fact, previous assessments have determined that it often takes three to nine years to notice any observable impacts in interdisciplinary science, policy, and environmental management work (Cvitanovic et al., 2021), and as such, many studies do not empirically assess the effectiveness of KE work (Westwood et al., 2021). It is therefore important to identify ways to evaluate qualitative indicators to assess the long-term impacts of KE.

Current strengths of KE evaluation

CFS practitioners are experts of their work and possess tacit knowledge of knowing when a KE project is impactful based on their extensive experiences, relationships, and interactions with knowledge users. The cyclical strategy that they appear to employ has its own evaluation embedded into the feedback loop such that the KE products that are developed and its effectiveness supports KE planning. This encourages practitioners to continually evaluate their relationships and understanding of knowledge user operations to learn and improve upon past experiences and outcomes. Additionally, CFS practitioners use both quantitative and qualitative indicators to

evaluate the impact of their KE work. However, more qualitative tools and practices are needed to ensure the full scope of a KE project can be evaluated, from short- to long-term successes.

Opportunities to strengthen: Aligning evaluation methods with how KE is performed helps to ensure impactful KE work

Potential qualitative indicators that CFS may consider include social capital, such as trust, mutual respect, collaborative capacity, and implementing and sustaining new practices (Szulanski, 2000; Fazey et al., 2014). Although these indicators were not explicitly mentioned by the participants, CFS practitioners allude to their KE work being more effective when they had the opportunity to establish trusting relationships and align project objectives with knowledge producers and users. Further, the varied interpretations of impactful KE by the participants reiterates the importance for organizations to work alongside KE practitioners when evaluating KE due to the highly context-dependent work that is required to implement effective KE practices.

With a heavy reliance on quantitative indicators by government institutions, there is natural incentive to perform KE activities that can be quantitatively evaluated. As such, there may be a disconnect in how impactful KE is evaluated and how it is actually performed in the CFS (i.e., KE is often quantitatively evaluated when it is often performed via collaborative work, relationships, and building trust). This can limit our understanding of the more humanistic and complex benefits of KE and can consequently limit improvements for future KE research that must consider the impacts of interpersonal relationships (Reed et al., 2020).

Some ways that researchers have evaluated qualitative indicators include *social impact assessment methods* which involves evaluating interactions that achieve certain pre-determined goals (Reed et al., 2021; Spaapan & van Drooge, 2011), and *evidence synthesis approaches* which involves conducting a review of existing data and literature to assess whether new research will provide impactful outcomes (Collaboration for Environmental Evidence, 2018; Reed et al., 2021). These methods have been successful in evaluating the qualitative indicators of KE by tracking progress towards a planned impact and providing formative feedback for KE practitioners, thus increasing the likelihood of producing impactful KE (Reed et al., 2021). Quantitative evaluation methods may provide important insight into how impactful KE is from a practitioner's perspective. However, evaluating KE through both quantitative and qualitative lenses is important in understanding different perceptions and interpretations of KE work by KE practitioners, knowledge producers, and users (Karcher et al., 2021).

Enablers of effective KE: Interpersonal relationships and trust

It was clear from our findings that building and maintaining interpersonal relationships and collaborations with knowledge users enabled successful KE projects, primarily because these actions built trust which is an important component to effective KE work (Chapman et al., 2017; Cadman et al., 2020). When conducting KE, specifically engaging in participatory approaches, trusting relationships with knowledge producers and users allowed KE practitioners to co-design research projects to define clear and useable outcomes, participate in a two-way dialogue to keep knowledge users engaged (Cash et al., 2006; Beier et al., 2017), and encourage ongoing communication which can

be important when determining the long-term impacts of KE work (Fazey et al., 2014; Laatsch & Ma, 2016).

Maintaining transparent dialogue with knowledge users allowed the participants to engage in open communication and further develop trust (Frantzeskaki & Kabisch, 2016; Lemos & Morehouse et al., 2005). This is because transparency with knowledge users helps clarify limitations of a project and can help users overcome uncertainties by contextualizing the work (Ellison, 2010). The participants also used informal face-to-face interactions to build trust by engaging in casual conversations in a safe space to promote commitment and ensure they have the knowledge user's best interest in mind (Holton, 2001; Few, 2003; Cvitanovic et al., 2021). The level of trust that is established amongst knowledge producers, users, and practitioners affect the extent to which knowledge is accepted and used by knowledge users (Andrews & Delahaye, 2000; Szulanski et al., 2004). Building and maintaining interpersonal relationships and trust are integral components to how practitioners design and implement KE, influences how KE work is evaluated, and is necessary is for conducting effective KE.

Conclusion and recommendations

We have provided empirical evidence and practical insights for learning about KE in practice by understanding the role of CFS KE practitioners. We have identified a general strategy that practitioners at the CFS employ to implement and operationalize KE, which can be applicable and useful to KE practitioners in other disciplines and sectors. This study emphasized the importance of identifying and utilizing the KE typology (Westwood et al., 2021) to develop and execute relevant and accessible

boundary objects. Additionally, we make clear the need to evaluate KE through both quantitative and qualitative lenses, emphasizing the need for organizations to adopt more qualitative evaluations to assess the full scope and impact of KE work. Finally, our findings recognize the integral role of relationships and trust in all aspects of KE work. At the CFS, we recommend more opportunities for KE practitioners to expand their work to different audiences outside of the scientific community to take full advantage of their unique positioning within a government organization with extensive research and knowledge user connections. We recommend KE practitioners in forestry or forest science engage with stakeholders from multiple disciplines and sectors to establish broad networks and opportunities to share expertise across organizations. Further, we recommend practitioners maintain communication systems with other KE practitioners within their organization to ensure the best available strategies, expertise, and knowledge are available to implement KE.

We encourage KE practitioners from all disciplines and sectors be familiar with the KE typology (Westwood et al., 2021) to inform their decisions about KE activities, products (i.e., boundary objects), and planning. We recommend practitioners consider the context of their KE work to determine which KE type from the typology is most applicable to develop relevant and accessible KE products for knowledge users. Additional research is needed to understand how robust the KE types are and to validate their use in KE.

Our findings suggest that there may be a disconnect in how we quantitatively evaluate KE versus how it is performed (i.e., KE is often evaluated by quantitative indicators that do not capture the impact of interpersonal relationships and trust). As such,

we must adopt additional qualitative indicators to evaluate and fully grasp the impact KE work has. At the CFS, and potentially among other organizations, KE practitioners have unique positions and knowledge as they are intimately embedded with knowledge users. This is an important opportunity, at an organizational level, to work with KE practitioners in evaluating and ensuring impact of research.

Building and maintaining relationships and trust with all project actors is the backbone of KE work. KE practitioners must continue to foster relationships and trust amongst knowledge producers and users to ensure that effective and impactful KE is designed and implemented, and that continued communication is fostered for qualitative evaluations. Greater recognition and value of this type of work is needed at institutional levels to protect these activities that foster trust. Our findings, which highlight the knowledge of expert practitioners in KE in forestry and forestry sciences, may apply equally in other domains.

Tables

Table 3 - 1 Westwood et al's (2021) KE typology outlining four KE approaches.

| KE approach | Definition |
|------------------------|---|
| One-way exchange | Where scientists independently produce a report/paper and deliver it to knowledge users. |
| Solicited exchange | Where a knowledge user expressly invites knowledge producer to answer pre-identified knowledge gap. |
| Network exchange | Where two or more knowledge producers or users connect to share the knowledge that they have each produced independently. |
| Participatory exchange | Where prospective users of science are engaged and involved in the process of generating knowledge. |

Table 3 - 2 A list of the activities identified by the CFS participants when conducting KE work. Frequency (not mutually exclusive) is the number of times a participant mentioned a KE activity, and the number of sources represents the number of interviewees who referred to the KE activity. The KE Type represents how the authors categorized each KE activity, where a KE activity can be classified as a different KE Type based on the context in which it was performed.

| KE Type | KE Activity | Description | Frequency | # of Sources |
|---|---------------------------------|--|-----------|--------------|
| One-way exchange Solicited exchange Participatory exchange | Outreach | This may include newsletters, brochures, emails, videos, field trips, workshops, citizen science, etc. | 44 | 9 |
| One-way exchange Solicited exchange Network exchange Participatory | Daily correspondence | Involves answering emails, phone calls to address requests etc. | 15 | 6 |
| One-way exchange Solicited exchange | Academic writing and publishing | Involves publishing peer reviewed articles, writing academic literature | 9 | 6 |
| Solicited exchange Participatory exchange | Research | This may include gathering data, conducting research to help the knowledge producers, etc. | 9 | 5 |
| One-way exchange Network exchange | Training | This may include seminars, workshops, or conferences with CFS peers where individuals are learning | 7 | 4 |
| Network exchange | Knowledge management | Efficient handling of information and resources within CFS | 2 | 2 |
| Network exchange | Summative evaluations | Individuals reflect upon the merits or successes of KE activities at end of project | 4 | 3 |
| Network exchange | Formative evaluations | Involves reflection at end of KE project to improve and refine project activities | 1 | 1 |

Figures



Figure 3 - 1 The flags identify the six CFS centres located across Canada in Victoria BC, Edmonton AB, Sault Ste. Marie ON, Ottawa ON, Quebec City QC, and Fredericton NB. The one additional CFS office that is located in Corner Brook NFLD is also identified by a flag marker. The three CFS research forests are identified by triangle markers located in Petawawa Research Forest (ON), Valcartier Research Station (QC), and Acadia Research Forest (NB).

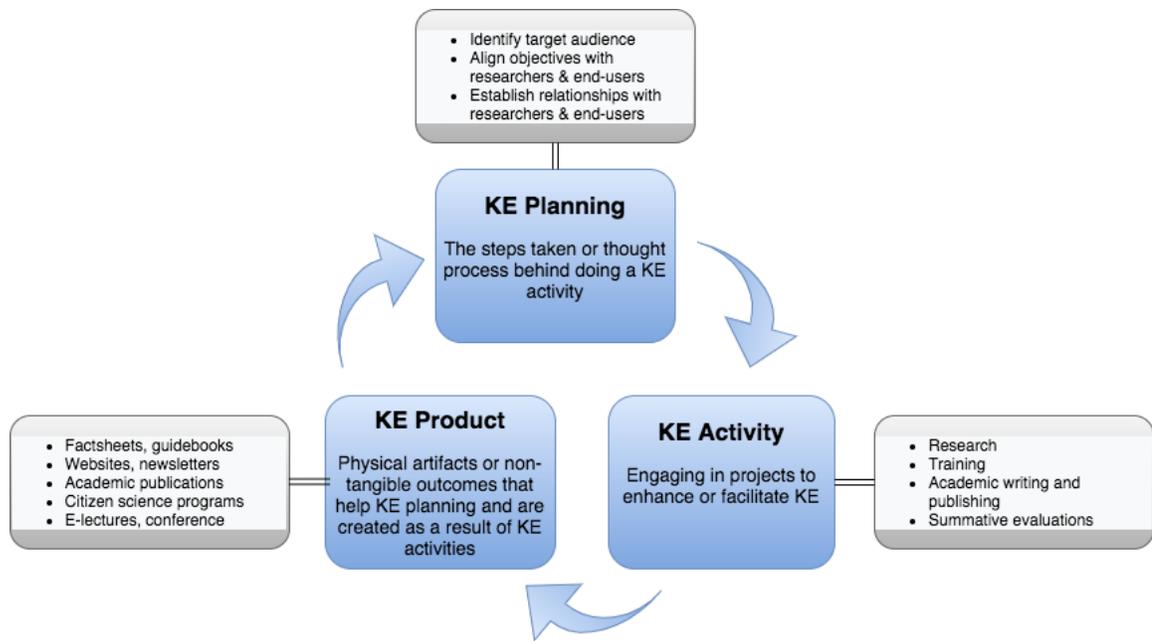


Figure 3 - 2 The general approach for performing KE work at the CFS, where definitions describing the three components (blue box) of the strategy were derived from the transcripts and were used in the codebook. Examples for each component were provided by the participants in the white boxes. This strategy involves cyclical process among KE planning, KE activities, and KE products, where each step in the strategy is interdependent on the other.

Box 1. Bright spot: Transparency to obtain social license

One participant described a successful KE project which involves addressing community concerns about impacts to a local watershed due to forestry-related uses of herbicides, pesticides, and insecticides. The KE practitioner first worked to develop relationships with community leaders, municipal councils, fisherman’s associations, and woodlot owners. Relationship-building allowed the participant to identify areas of concern for the community, minimize knowledge gaps, re-evaluate herbicide application with the research team, and implement long-term water testing for continued safety – practices that were not established prior to conversations with the community. The participant emphasized that transparency with the community was an important component to obtaining social license to conduct this project: “...*We tell people this (how high levels of herbicide effect wildlife), because If we don’t, they’re going to come back and say ‘well, how about this?’ ... And that’s the big thing it’s transparency. And coming from CFS, our job is providing the science.*” (Participant 1). In addition to obtaining social license, the participant felt that transparency helped establish trust, allowing the community to collaborate with knowledge producers to design an effective and useful project that addressed their specific needs.

Figure 3 - 3 Box 1. A bright spot highlighting the importance of transparency to obtain social license when engaging in KE work.

Box 2. Bright spot: Adoption of a new technology

The goal of this KE project was to communicate alternatives to traditional clearcutting. The participant outlined that open discussions with the knowledge users was a key component to identifying what technology would help address their specific research needs. Through a hands-on demonstration, the participant communicated the need for a particular technology to all project stakeholders (knowledge producers, knowledge users, private industry, provincial government, and NGO’s). By bringing together collaborators with varying backgrounds and perspectives, the participant was able to promote a shared value for the technology and align the objectives of all potential knowledge users. Developing a collective objective and value of a technology attributed to the success of this KE project: “*That was the important part of it and that’s why it was successful because we brought the groups at different levels together, they could sit and look. Like an operational guide can look at it and go, ‘yeah, that’s a good idea we should try this!’ And a supervisor could say, ‘are you crazy? We’re not paying that!’ And vice versa. Or ‘Yeah, I agree this is a good idea and we should try this!’ So, it opens and starts the conversation at different levels with the industry as well as at different levels with us and it showed context.*” (Participant 5)

The participant used quantitative indicators (i.e., adoption of a new technology) to frame the success of this project. The project was also impactful in terms of qualitative indicators (i.e., building social capital and changing human behaviour), although these were not easily measured or accounted for by the participant – highlighting the difficulty of qualifying the impact of KE work.

Figure 3 - 4 Box 2. A bright spot highlighting the adoption of a new technology.

Appendices

Appendix A: Interview Guide

Part A: Background Information

Understanding the respondent, getting to know them at the individual level

Objective: the goal of these questions is to understand how the respondent got to where they are, and whether their background may influence their perception, interpretation and work around KE.

First, I'd like to know a little bit more about your background before coming into this position and how you got here.

1. What is your role within your organization?
 - a. What is the mandate of your position?
2. How long have you been working in your current position?
3. Can you tell me a bit about yourself and what led you to work in the KE space?

Additional Questions (if they did not mention):

- a. What is your educational background? (What level of education? What subject? Any additional expertise developed prior to your current role)
- b. What did you do prior to your current position?

Daily Work Questions: *objective here is to understand and characterize what exactly they do and how that may impact their work on KE (adapted from Walsh et al. 2019)* In this next part, I'd like to understand your role and work within the organization.

4. Who do you interact with most on a daily basis in your work? (Scientists, policy, community, upper management). (Probe: in what way do you interact with them?)
5. How often do you communicate with other KE specialists? (daily, weekly, monthly, yearly)
 - a. Internal to CFS vs External to CFS
 - b. How do you communicate with others? (Conferences? Collaborations? Informal groups, meetings and emails? Through the KEG? etc.)

6. Can you please briefly describe your most pressing file?
 - a. Why is it pressing?

Part B: Perspective on Knowledge Exchange

Understanding individual and institutional definition of knowledge exchange and linking it to approach to KE (translation of KE to practice)

7. How do you define Knowledge Exchange/ Mobilization in your work?
8. Why is knowledge exchange the term used in your organization?
9. Has your perspective around KE changed/shifted in any way since you began your work in this position?
 - a. How has it changed?
 - b. In your organization, how has the dialogue around KE changed/shifted?
10. Do you see the work/dialogue surrounding KE shifting in the near future? If yes, how so? If no, why not?

Part C: Approach to and process of knowledge exchange

Need tool/instrument that can capture decision-making process, and approaches to KE and why they chose these approaches.

11. What are your work objectives related to your role as a knowledge exchange specialist?
12. Who is your primary audience/ user group?
13. What are your key KE activities or strategies used to achieve those objectives?
14. How do you choose what strategy of KE to use?
15. How do you share information?

To the best of your knowledge, how often have you and your research team performed the following activities related to the chosen project (in total)?

Please choose the best category that describes your response.

| | Non | 1-3 | 4-6 | 7-9 | 10-15 | 15 + |
|---------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | e | times | times | times | times | times |
| Presented at a conference | <input type="radio"/> |

| | | | | | | |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Published a refereed article | <input type="radio"/> |
| Published a non-refereed article (e.g. technical report) | <input type="radio"/> |
| Attended a stakeholder workshop/consultation meeting | <input type="radio"/> |
| Lead a stakeholder workshop/consultation meeting | <input type="radio"/> |
| Attended a manager's meeting | <input type="radio"/> |
| Made media appearances/comments | <input type="radio"/> |
| Wrote a press release | <input type="radio"/> |
| Engage in new media/social media (twitter, blogs, website, etc.) | <input type="radio"/> |
| Engaged in public outreach activities | <input type="radio"/> |

Part D: Measuring KE success

16. In your opinion, what is successful knowledge exchange?

17. How do you (formal or informal) measure the impact of your KE work?

18. In your experience, what knowledge exchange/mobilization approaches/activities are the most effective?

a. Why?

19. What are the consequences of ineffective KE/mobilization?

20. Would it be helpful to have a framework for KE?

If resources (time, people power, money, etc.) were not a factor, what kinds of knowledge exchange/mobilization activities would you pursue?

Appendix B: Follow-up Interview Guide

Objective: to elicit factors that influence successful KE and to document lessons learned.

Script: *In this section, we want you to think back on a time (project, file, etc.) where you thought that KE was successful.*

1. Personally, how would you define successful KE?
2. Please tell me about a successful KE project/file.
Probes (if they have not touched on it/ CHECK OFF as they talk)
 - a. How did you become involved with this project?
 - b. What was the objective/purpose of this particular project/file/initiative?
 - c. When did it start?
 - d. Is it completed?
 - e. Who were the key players involved (offer a list?)
 - f. Who were the target audiences (if applicable)?
3. What KE strategies were used?
 - a. Can you walk me through how you developed these strategies?
 - b. Why were these strategies chosen?
4. What goals did KE achieve? (how was it successful or not successful)
5. Why was the project successful? (In other words, what are key events, aspects, relationships, feelings, or activities that made it successful)
6. What would you attribute its success to?
 - a. What conditions facilitated this? (conditions = resources, materials, support, expertise, capacity, interactions etc.)

- b. Do you feel that the geographic location or culture of your location influenced the success of the KE activity? If so, can you describe how?
 - c. [If applicable (if they don't mention face-to-face)] How did face to face interactions influence the success of KE activities?
 - d. If you were to run this project now, during COVID (with no in-person interactions and covid restrictions like travel, distancing, quarantine), how would you do it?
Probes: Can you imagine or describe alternative ways to conduct KE?
6. Did you experience any barriers/challenges to your KE work for this project? If so, could you describe these barriers? (Probe: ask for example/specificity)
- a. How did you try to overcome these barriers? (Probe: what was the result?)
8. What are key lessons that you have learnt from your experience on this project?
9. [If applicable, if they have not touched on this] Based on your experiences in this project, what capacities/resources do you think are required to better enable KE?
10. [If applicable] If you ran this project again, what would you do differently? Why?
11. Regarding the people, groups, and organizations that you currently work with, who have you not been able to reach out to or make a connection with because of covid?

Appendix C: Codebook

Below is a list of codes created during the first coding meeting on December 11, 2020.

The coding team consists of Vivian Nguyen, Jenna Hutchen, Tyreen Kapoor, Kimberly Klenk, and Matthew Falconer. Codes are not mutually exclusive.

DEMOGRAPHIC AND BACKGROUND

KE Role - The participant's description of a type of role

- *Job Description* - describing their own position
- *Interdisciplinary* - working with more than one field of knowledge when describing their own work
- *Knowledge Producer* - participant describes themselves as someone who creates knowledge for other people to use. Ex. they describe their role in federal government to produce knowledge for other jurisdictions to use, or they are the scientist producing paper

Academic background - Participants work and lived experiences related to specific disciplinary expertise.

Professional experience - Where they worked prior to KE and how long. Rationale for coming into a KE role.

Length of tenure - How long this person has worked in their KE role

Team mandate - The operational roles and responsibilities the team serves within the organization.

KNOWLEDGE EXCHANGE

KE Challenges - The barriers that prevent the uptake of evidence or the ability of KE experts to do their job

- *Resources* - The lack of internal resources available. E.g., staffing, control over websites, media access, etc
- *Time* - Time restraints on KE activities.
- *Finances* - Financial restrictions that limit the reach of KE activities, the start of new activities, the hiring of new staff, etc.
- *Travel* - The inability of the KE expert or their collaborators to travel for work. Restrictions placed on distance of travel, time of travel, etc.
- *Values* – mismatched values or understanding of need for KE between KE experts and management or stakeholders. This can result in a lack of support or interest in KE projects
- *KE Dreams* - The Participant’s dreams and ideal for what KE should look like

KE Definitions - The description of KE that the participant uses

- *Personal definition* - The participant provides a description of what they personally believe KE to be
- *CFS definition* - The participant uses a definition of KE specific to CFS including research programs
 - Note: This may be of interest if the participant is unable to provide (or does not know) that CFS has a definition for KE
- *KE framework* - The participant explicitly references the National Framework.

KE Activities - The act of engaging in (and performing) knowledge exchange, including the process of creating/developing a KE product. The participant needs to be present or be involved in the act.

- Example of KE activities: seminars, peer-reviewed papers, answering emails, etc
- *Outreach* – this can include newsletters, brochures, emails, videos, field trips, workshops, citizen science, etc
- *Research* – the KE specialist is involved in gathering data, conducting research to help the researcher.
- *Participatory approach (knowledge co-production)* – this involves the KE expert integrating stakeholder perspectives and decision-makers in all aspects of scientific research such as design, implementation, analysis, interpretation (Bautista et al., 2016 & Cvitanovic et al., 2016)
- *Loading dock approach* – one-way transfer of results. Limited opportunity for feedback, does not specifically address a target audience. Different from outreach because its main goal is not to increase engagement with potential

end-users, but rather supply technical or niche information with no customization (Rogga et al., 2021)

- *Solicited Exchange* – Knowledge user invites producer to answer pre-ID'ed knowledge gap. Related to 'knowledge broker', 'translation', 'boundary spanning'
- *Network Exchange* – Two or more actors explicitly connect to share knowledge each produced independently. Related to workshops, conferences, pro-networks, committees
- *Training* – can include seminars, workshops, or conferences with other CFS peers.
- *Knowledge Management* – efficient handling of information and resources within CFS
- *Daily correspondence* – involves answering emails, phone calls, etc
- *Academic writing / publishing* – involves peer-reviewing articles, writing academic literature
- *Summative Evaluations* – individuals reflect upon the merits or successes of KE activities at end of project (Fazey et al., 2014)
- *Formative evaluations* – involves reflection at end of KE project to improve and refine project activities (Fazey et al., 2014)

KE Product - The physical/tangible artefact that is created through a KE activity. A product may also be knowledge uptake by individuals, though this is challenging to measure and does not have a clean metric. This is something that can be accessed after the fact (i.e. after the act of creating it has occurred)

- Example of KE product: slides in a talk/seminar, reports, webpages
- Bilingual media, factsheets, guidebooks, websites, blogs, Q&A's, videos, publications, interviews, research maps, regulations (relating to the KE project), citizen science programs, presentations from conferences, e-lectures, lesson plans for schools, climate models, field tours, operational demonstrations, self-guided tours, articles in magazines, tech-transfer products, newsletters (printed and through email), webinars,
- Note if a product is bilingual, the expert will make sure to tell the interviewer. Probably because bilingual products are not as common and seems to be the work of 1 or 2 people at a few CFS centres.

KE Process – The steps taken or thought process behind knowledge exchange

- Example of: Understanding the question. If you don't understand the problem, you don't know how to make a deliverable
- Borrowing methods: individual draws on proven methods for conducting KE, not just their own personal experience. Methods can be borrowed from credible institutions or from theory.

KE Trust – CFS is noted as a trustworthy and credible source for scientific information

- *Relationships* – trust is built or acknowledged because of the relationships CFS individuals have with private or public stakeholders; they have taken the time to understand the stakeholder's perspectives, needs, and the context of their circumstances.
- *History* – the historical reputation of CFS increases its trustworthiness
- *Credibility* – peer-reviewed publications increases the credibility of CFS and therefore also increases its trustworthiness

KE audience - The intended audience for KE work

KE evaluation - How KE is measured or evaluated by the individual, their team, their managers, or CFS/NRCAN

- *Metrics* - A quantifiable measure of KE reach or success
 - Example of KE metrics: website clicks, number of people at a seminar, number of papers produced, number of times cited
- *Indicator* -The participant qualifies the ways to gauge success
 - Example of a KE indicator: continued contact with individuals, etc
- *Success* - How the participant defines success of a KE project. The participant MUST say that the activity was “successful”
 - Example of KE success: adoption of new products, increased public knowledge, etc
 - Note: this is not used often. Use this code VERY sparingly
 - *Influence Policy* – adoption of a new product or theory as stated in example for success. This also has the ability to influence human welfare (social, environmental, or economic conditions).
 - *Influence human behaviour* – individuals are more inclined to act in a certain manner due to increased knowledge or understanding of a topic.
 - *Improve [project (?)] outcomes* – a project is altered or modified to increase the number of positive results ex. improving restoration practices to increase positive outcomes.

- *National perspective* – addressing the goals of a KE project at a local/regional level allows individuals to identify issues in other parts of Canada and then bring it to the attention of other local governments.

KE Broker - Acting as an intermediary between producers and users of knowledge. The person displays characteristics of a knowledge Broker such as building relations (personal/professional)

- *Customizing objectives* – the individual collaborates with stakeholders to modify KE activities, products, or processes to address the goals of the KE project
- *Customizing data or experiences* – the individual modifies research or tangible demonstrations to make it accessible and fit the needs of knowledge producers or knowledge users
- *Sharing expertise* – the individual shares their personal or team’s expertise across boundaries i.e., with other CFS regions, industry, public, or academic institutions
- *Relationship building* – the individual is able to share information across boundaries because of the personal or company relationships they have built.

COVID KE - Current bucket term used to describe whenever the participant speaks about the effect of COVID on their KE work

- **Face to Face** - Participant stresses the importance of face-to-face interactions with collaborators and developing interpersonal connections
- **Risk of no KE** - any risks associated with not doing KE
- **Frequency** - The numerical questions, a numbered list of the questions

ORGANIZATIONAL STRUCTURE

Programs – Specific CFS programs that the KE expert interacts with in their role (e.g., First Nations, Health, Climate change...)

Collaboration - The participant references collaborating or working with groups and organizations outside of CFS

- *Networking?* - The participant expresses the importance of networks, partnerships, stakeholder engagements, or other ways of interacting within networks
- *Enabling questions?*

Workplace culture - Refers to the specific elements in their workplace that either help or hinder their KE work including support (internal/external)

- *Region to region* - Participant describes the interactions of different CFS branches or regions

Golden Nuggets - A really impactful and telling quote (related to the code it's co-coded at.)

Chapter 4: General Discussion

Through two complimentary chapters, I have illustrated what may be required in practice to support and facilitate effective KE using empirical evidence. More specifically, I have provided the second-known empirical study of the KE practices undertaken by professionals in forestry and forest science in Canada (the only other example I am aware of being Klenk and Hickey, 2011). In addition, I have expanded our understanding of how KE is performed and why long-term evaluations are necessary to improve how we engage in KE work. The results of this thesis should be applicable to individuals and organizations engaging in KE outside of environmental and natural resource sectors.

Findings and Implications

While prior research has focused on the barriers to effective KE (e.g., Walsh et al., 2018; Rose et al., 2018), Cvitanovic and Hobday (2018) have encouraged researchers to identify and develop solutions that integrate science for evidence-informed decision-making and practice. In chapter two, I identified and categorized the enabling conditions from empirical case studies into a *core capacity* framework (a framework first developed by Cvitanovic et al., 2018). This has organized the details of what is required to engage in effective KE from an organizational, individual, financial, material, practical, political, and social capacity. Given that most studies that have generated recommendations for conducting KE successfully are predominantly theoretical or suggestion based (Reed et al., 2019; LSE 2019; Westwood et al., in review), the additions to the framework presented here are particularly valuable as they offer practical insight into what enables

effective KE, the challenges to engaging in KE, and the outcomes and impacts of KE work. The synthesis of enablers, challenges, outcomes, and impacts that this empirical review provides can be used a broad resource for practitioners to identify what enablers may be missing from their KE work and in what capacity their work can be strengthened. In chapter two, I found that the major enablers to effective KE were the ability for practitioners (often boundary spanners) to establish trust with knowledge producers and users through their interpersonal relationships, and possess sufficient background knowledge and communication skills to facilitate collaborations across disciplines and sectors. These enablers align with those identified for KE practitioners in chapter 3. Given the heavy influence of interpersonal relationships and trust on effective KE, I recommend KE practitioners continue to establish broad networks across multiple disciplines and sectors by sharing expertise and being receptive to new or opposing knowledge and insights to strengthen KE practices. The best practices for establishing trusting relationships include face-to-face engagement, informal communication, and hands-on learning experiences to maintain ongoing communication. To date, research suggests that participatory approaches to KE are most effective (Bautista et al., 2016), and these practices encourage all project actors to collaborate equally, offers opportunities to discuss concerns away from management, offers equal access to information, and the ability for all project actors to shape discussions (Levesque et al., 2017; Beier et al., 2017).

Sustaining regular communication with all project actors is necessary to overcome challenges associated with communicating complex knowledge with end-users and aligning objectives with all project actors. In addition, regular communication offers

practitioners opportunities to receive feedback and improve their KE practices. This is especially important as it often takes three to nine years to observe the impacts of interdisciplinary science, policy, and environmental management work (Cvitanovic et al., 2021). It is evident from chapters two and three, that practitioners struggle with evaluating the effectiveness of their work due to the amount of time required to notice observable impacts. As a result, KE practitioners often perform quantitative evaluations that provide instantaneous and measurable impacts for the effectiveness of KE, but do not capture the impact of interpersonal relationships and trust. This is troublesome and perpetuates a disconnect in how KE is evaluated vs. how it is performed. I recommend that KE practitioners adopt additional qualitative indicators to understand the full scope and impact that KE work has. Some ways that practitioners qualitatively evaluate the impact of their KE work includes interviews and surveys with knowledge users and producers, *social impact assessment methods* which involves evaluating interactions that achieve certain pre-determined goals (Reed et al., 2021; Spaapan & van Drooge, 2011), and *evidence synthesis approaches* which involves conducting a review of existing data and literature to assess whether new research will provide impactful outcomes (Collaboration for Environmental Evidence, 2018; Reed et al., 2021). Conducting qualitative evaluations over long timescales is necessary to gauge the full scope and impact of the social aspects of KE.

In chapter three, I identify and organize the activities practitioners use to operationalize KE within a KE typology (a typology developed by Westwood et al., 2021). This typology can help inform how practitioners perform KE – one-way, solicited, network, or participatory exchange. I recommend that KE practitioners are aware of this typology to contextualize their KE work and inform which KE activities may best

supplement an approach, which boundary objects will be most impactful, and which approach will ultimately help them achieve a particular objective. Additional research is required to validate and elaborate upon this typology. However, this typology provides a stepping-stone that enables practitioners to contextualize their work in four different ways to determine which approach and supplementary activities and boundary objects may be most impactful. The KE typology can be relevant and useful to KE practitioners from any discipline or sector.

Future Research Directions

In this thesis I have contributed to our understanding of what enables effective KE at an individual and institutional level and have drawn attention to the disconnect in how KE is evaluated and performed using empirical evidence. The findings of this thesis have contributed to bridging the theory-practice gap by using empirical case studies to identify and confirm with the literature what the enablers and challenges to effective KE are. In addition, the findings of this thesis have elucidated another aspect of the theory-practice gap with respect to evaluating the impacts of KE work such that KE is often performed via collaborations, relationships, and trust, but is often evaluated by quantitative means that cannot capture the social aspects of KE and the impacts of interpersonal relationships. Although this thesis has broadly identified enablers to effective KE in environmental and natural resource sectors, future research may consider investigating empirical studies that aim to achieve an impact that is common across the case studies. This would encourage researchers to provide more details on what specific enablers are required to achieve a particular impact and what barriers directly challenge these enablers. Understanding what the intended impact of a KE project is can help researchers

discern what specifically enables or challenges practitioners to achieve the predetermined impact. Further, assessing the relationship between KE enablers and challenges with respect to a singular pre-determined impact can offer unique insight into what actions are required to transform a challenge into an enabler.

Additional research using in-depth empirical case studies is required to deepen our understanding of what strategies practitioners employ to engage in KE, what enables their work, and how they evaluate the effectiveness of their efforts. It is important that practical case studies continue to supplement and verify what researchers theorize about KE to minimize the theory-practice gap.

In addition, future research should continue to assess the roles, strategies, and evaluation techniques of CFS KE practitioners, specifically, to understand how KE practices evolve over time. It is possible that this thesis cannot fully capture the impacts of CFS practitioners' work due to the length of time (three to nine years) required to notice observable impacts in interdisciplinary, policy, and environmental management work. In addition, CFS practitioners employ a cyclical KE strategy that encourages practitioners to continually evaluate and refine their work to maintain or improve trust and relationships with knowledge users. Researchers can gain valuable insight by evaluating the practices of CFS practitioners over long periods of time to understand how practices are strengthened and improved. This future research direction would ultimately encourage researchers and practitioners to maintain communication and evaluate emerging qualitative assessments of KE work. This can improve our understanding of interpersonal relationships and trust in KE, especially because more time may be needed to discern observable impacts.

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