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Parks and Protected Areas
Mobilizing Knowledge for Effective Decision-Making

Edited by
Glen Hvenegaard, Elizabeth Halpenny and Jill Bueddefeld

Printed Edition of the Special Issue Published in *Land*

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This is a reprint of articles from the Special Issue published online in the open access journal *Land* (ISSN 2073-445X) (available at: https://www.mdpi.com/journal/land/special_issues/parks_MK).

For citation purposes, cite each article independently as indicated on the article page online and as indicated below:

LastName, A.A.; LastName, B.B.; LastName, C.C. Article Title. *Journal Name* **Year**, *Volume Number*, Page Range.

ISBN 978-3-0365-1072-9 (Hbk)
ISBN 978-3-0365-1073-6 (PDF)

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About the Editors

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Editorial

Towards Mobilizing Knowledge for Effective Decision-Making in Parks and Protected Areas

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Citation: Hvenegaard, G.T.; Halpenny, E.A.; Bueddefeld, J.N.H. Towards Mobilizing Knowledge for Effective Decision-Making in Parks and Protected Areas. *Land* **2021**, *10*, 254. https://doi.org/10.3390/land10030254

Received: 22 February 2021
Accepted: 26 February 2021
Published: 3 March 2021

In November 2017, over 15,000 scientists issued a second letter to humanity that outlines how we are "jeopardizing our future" by failing to protect key ecological systems. Catastrophic climate change, our planet's sixth major species extinction crisis, diminishing fresh water resources, deforestation, and a host of other "alarming trends" were highlighted [1] Parks and protected areas are one of the most effective means for protecting ecological health [2]. However, parks have many other important roles. Parks and protected areas provide essential services and resources for a wide variety of purposes and groups, including nature conservation, visitor recreation, local economic opportunities, Indigenous cultures, human wellbeing, and the provision of ecosystems services such as flood mitigation and access to drinking water [3].

Park managers make difficult decisions to support their diverse mandates, and need up-to-date, relevant, and rigorous information. Evidence-based management is in vogue with politicians and practitioners; however, access to, and effective use of, current research provided by social scientists, natural scientists, local people, or Indigenous peoples, is an ongoing challenge [4–8]. One of the many difficulties that characterize parks and protected areas, whether governed publicly, privately, or through other forms, is chronic underfunding, which results in a lack sufficient resources to mobilize knowledge effectively. Globally, most park agencies have little capacity to produce in-house social science or natural science research, or to conduct meaningful knowledge exchange with Indigenous and local communities [9–11].

The majority of parks-related scientific effort has focused on the monitoring and management of natural systems and elements. However, the conservation of this natural heritage is intertwined with economic, social, and cultural interests, and thus knowledge from outside the natural science disciplines is needed as well to achieve effective park management. Unfortunately, the use of Indigenous- [12–14], local- [15–17] and social science- [18,19] sourced knowledge to inform park management remains limited.

Park-related knowledge mobilization challenges have been documented previously [20–22]. However, this dialogue has been focused largely on the (a) use of natural science research, and (b) achieving nature conservation rather than other park mandates such as social equity, recreation, and health promotion. Conservation organizations are realizing that equally important is an understanding of social forces that affect park management, and how parks in turn affect human outcomes. This is documented in early recommendations and strategies put forward by park researchers [23] and practitioners [24–27], and more recent overviews of the state of social science adoption in conservation efforts [4,8,18,19,28]. For instance, after a systematic consultation with its staff, the province of Alberta's park agency, Alberta Parks, determined that 65% of agency priority research questions cannot be answered by natural science [29], but rather are human-dimensions focused. This is not unique to Alberta [18].

This special issue explores knowledge mobilization in parks and protected areas, including research that addresses successes and failures, barriers and enablers, diverse theoretical frameworks, structural innovations, and more that support effective knowledge mobilization. Park agencies and other conservation organizations now realize that understanding how social forces affect, and are affected by, park management are as important as knowledge of natural systems. Realizing that park-related knowledge mobilization is needed for effective park management, and that human factors have been neglected, the goal of this special issue is to enhance the generation and use of knowledge, especially knowledge derived from social science and the humanities [30], local, and Indigenous sources, for parks and protected areas policy, planning, and management.

To begin with, Grove et al. [31] examine Frojám, Spain and Ladydown Moor, England, two pastoral landmarks in western Europe, to demonstrate the degradation of heritage sites over time. The authors describe biological cultural heritage and its importance to preserving landmarks which show the connections between historical societies and nature. The study looks at the value of long-term conservation of pastoral enclosures and the relationships between these structures and the surrounding environment.

Múnera-Roldán et al. [32] address the need for a multidimensional understanding of the relationship between temporal and spatial aspects of protected areas and how knowledge governance can aid in management of these spaces as climates change. With examples from Colombia and South Africa, the authors evaluate the influence of time on protected areas and note that as climate changes, so too must the management of the area. They also address how different kinds of knowledge and their governance can be utilized to increase decision-making efficiency. Lastly, the authors compare their suggested framework to existing strategies for adaptive management used in other parts of the world.

Needham et al. [33] explore how knowledge from trappers, hunters, loggers, and farmers can be utilized to identify wildlife locations and movements near the Chignecto Isthmus in in eastern Canada. This information can be used in establishing effective corridors for populations of various types of wildlife as their habitats undergo changes from climate and other disturbances. The study aims to not only increase confidence in establishing effective corridors, but also enforce the connection between environmental issues and social issues. The authors aim to integrate local knowledge in order to strengthen collaboration and encourage a more unified conservation effort from Indigenous people, researchers, recreationalists, and industries.

Bloom and Deur [34] examine the Yosemite Ethnographic Database in the USA, and its role in helping identify culturally significant landmarks, traditions, and flora and fauna. The database serves as a tool that park planners can utilize to understand the knowledge and perspectives of Indigenous peoples regarding the cultural value of the park. Security of the database is a concern as some information is sensitive and not meant to be shared with the public, even with other Indigenous groups, and as such, the authors recommend proper encryption and limited access of the database to those with granted clearance.

An analysis of knowledge mobilization for the purpose of effective decision-making in the oil sands in Alberta, Canada is supplied by Hood [35]. The paper examines the industry's ecological and social impacts observed along the Athabasca River. The author notes that integration of knowledge from various sources is essential but more so that the information must be accessible in order to be successful. Restriction of data, documents, and models makes knowledge mobilization difficult. Knowledge mobilization is critical to address complex and rapid land-use changes that impact the environment and communities.

Murray et al. [36] examine knowledge mobilization and collaborative practices within the British Columbia parks agency (Canada), with a focus on the effectiveness of research on decision-making processes. The most important information sources were internal to the agency, but respondents who collaborated with outside groups rated external information sources more positively. Practitioners consider research important and would like to see more collaboration with scientists.

Atkinson [37] examined the challenges and opportunities of using Indigenous knowledge in the National Park Service's efforts to manage threatened caribou herds in Alaska's western Arctic. The study outlines a method of mobilizing Indigenous knowledge. Potential benefits include improved educational materials, better understanding of the resource, and a greater chance of adherence to regulations informed by Indigenous knowledge.

Blye et al. [38] studied how the Beaver Hills Biosphere in Alberta, Canada mobilizes knowledge, the effectiveness of that mobilization, challenges faced, and the attitudes towards diverse sources of knowledge. The authors found that not all knowledge was equally accessible, understood, or valued. Effective knowledge mobilization is complex, often takes a long time to develop, and needs to be diverse in format, types of knowledge producers, and cultural perspectives. The study expresses the importance of maintaining an "open system" when it comes to partnerships, and community integration should be included in discussions about management and conservation.

Milligan et al. [39] examines efforts to improve the ecological and recreational quality of the Franks Tract State Recreation Area in California, USA based on iterative participatory mapping and web-based public surveys. The authors analyzed the complex process of negotiating multiple realities and perspectives through reciprocal iterative change, concluding that shifts in stakeholder preferences can occur through iterative revision of design concepts that address a broad range of stakeholder values and concerns.

Carruthers Den Hoed et al. [40] explore how knowledge and information are used in decision-making processes about managing human-wildlife interactions, based on a case study of grizzly bear management practices in the Kananaskis Valley of Alberta, Canada. The authors evaluate how knowledge was mobilized in the decision-making process and how that process changed over time. Findings suggest that the role of managers toward knowledge mobilization shifted—some managers acted as barriers to knowledge mobilization while others were enablers of research. Despite the barriers and complexity of bear management in the area, the innovative and collaborative approach to decision-making in the parks demonstrates the importance of information diversity.

Last, Hallstrom and Hvenegaard [41] outline how Alberta Parks facilitated a Social Science Working Group to develop a Social Science Framework to support evidence-informed decision-making within the provincial system of protected areas. The framework links data-specific needs with existing and emerging policy and research priorities, with a focus on inter-organizational collaboration. The authors also provide a history, theoretical background, and potential benefits and liabilities of this approach.

The articles in this special issue demonstrate how park and protected areas are using an evidence-based approach to manage these ecologically integral places. The diversity of approaches and challenges discussed in this special issue offer insight into the practical application and barriers to knowledge mobilization in managing parks and protected areas around the world. This special issue attempts to recognize more holistic approaches of evidence-based management that mobilizes knowledge from a wide variety of sources: natural and social sciences and local and Indigenous knowledges. In an era of increasing urgency to address "alarming" environmental issues and wicked problems (Ripple et al., 2017), the recognition of multiple ways of knowing and doing will be integral in effective decision-making and equitable planning and management strategies.

Funding: This research was funded by the Social Sciences and Humanities Research Council of Canada, Alberta Environment and Parks Innovation Fund, and the University of Alberta.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: We wish to thank all of the authors, submitters, reviewers, editors, and support staff that helped create this collection of papers. We also thank C. Cook for help with editing.

Conflicts of Interest: The authors declare no conflict of interest.

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Article

Grizzly Bear Management in the Kananaskis Valley: Forty Years of Figuring It Out

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Received: 30 October 2020; Accepted: 4 December 2020; Published: 8 December 2020

Abstract: Case studies offer rich insight into the way knowledge is gathered, understood, and applied (or not) in parks and conservation contexts. This study aims to understand how knowledge and information have been used to inform decision-making about human-wildlife co-existence—specifically what knowledge has informed decisions related to grizzly bear management in the Kananaskis Valley. Focus groups of decision-makers involved in the valley's bear program painted a rich account of decision-making since the late 1970s that was coded thematically. Our findings suggest there are typical impacts on knowledge mobilization, such as management support (or lack thereof), other agencies, capacity, and social and political pressures. In addition, the special context of the Kananaskis Valley and the forty-year timespan explored in focus group conversations provide unique lenses through which to understand knowledge mobilization. This case study reflects the barriers identified in the literature. However, the findings also include unique aspects of decision-making, such as the evolution of decision-making over a period of time in a multi-use landscape, the successful creation of networks to mediate knowledge and practice, and the creation of knowledge by practitioners.

Keywords: knowledge mobilization; protected areas; evidence; wildlife; management effectiveness; grizzly bears

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1. Introduction

Evidence-based decision making allows for more effective conservation management by integrating ideas from academic literature, Indigenous knowledge, and local knowledge. Yet, the potential benefits of evidence-based approaches have not been fully optimized in Canadian conservation planning. Instead, managers rely on internal information and institutional knowledge to develop plans and make decisions about protected areas [1].

1.1. Conservation Planning and Evidence-Based Decision-Making

As global conservation efforts shift from creating new parks to maintaining current ones, evidence-based approaches become more important to effective management [1]. A lack of evidence-based decision-making can undermine conservation and reduce its support in the face of economic challenges [2]. The research focused on the use of evidence in decision-making has found managers rely more on knowledge created internally than on empirical research, Indigenous knowledge, and local knowledge [1–3]. Personal experience often guides decisions [4]. Empirical evidence is valued by managers [3], but knowledge exchange between researchers and decision-makers is lacking [5]. Furthermore, there is often no framework to integrate research into management plans [2].

Decisions in conservation are often required immediately, before data can be gathered for analysis [2]; but there are barriers to accessing different types of evidence. Issues like limited financial resources and staff, the urgency of the decision, and a lack of communication between researchers and managers create a gap between evidence and decisions [1]. Additionally, cultural differences between researchers and managers, accessibility of knowledge, barriers within institutions, and a lack of experience in interpreting research and information can impede the use of evidence [4,6]. Gaps in knowledge can be addressed by embedding knowledge producers in conservation planning [5] and providing more accessible summaries of important literature [7]. Improving the accessibility of various forms of knowledge is critical to effective conservation planning.

1.2. Local Knowledge

There is an absence of local, traditional ecological, and Indigenous knowledge use in policy, research, and management in conservation [8]. These forms of knowledge are complementary to Western science and can be mobilized through collaboration [9]. Epistemological differences between Western science and Indigenous knowledge create challenges and, as a result, scientists may find it difficult to include other ways of knowing in ecological research because of their own philosophical underpinnings and methodology [9]. However, different forms of knowledge can complement and evaluate each other, leading to a co-production of conservation knowledge [9,10].

Knowledge co-production is important to conservation because community members, researchers, and governments have different values that can be integrated into management and policy. Inclusion of local knowledge is important for relationship- and trust-building and can also address gaps in the literature and help to prioritize conservation goals [11]. Co-learning and finding creative ways to weave in knowledge is key to producing new ideas, evaluating current scientific approaches, and finding solutions to environmental and conservation challenges [12].

Despite these benefits, issues with integration remain. In a review of current literature, Benyei, Arreola, and Reyes-García found Indigenous knowledge holders often do not participate in research beyond the provision of their knowledge, with researchers designing and leading the projects [8]. The role of knowledge holders has been criticized by other authors as a surface-level integration of local and Indigenous knowledge [12] or as a method to "educate" the knowledge holders instead of mobilizing and engaging them with the research [8]. These issues further the tension between different ways of knowing and limit the benefits of co-producing knowledge for conservation planning and management.

1.3. Grizzly Bears in the Kananaskis Valley

The geographic extent of the present case study includes the Kananaskis Valley, oriented north to south along the eastern slopes of the Canadian Rocky Mountains from the Bow Valley to the Highwood Pass (Figure 1). It is part of Kananaskis Country, a provincially managed multiple-use area located west of Calgary, Alberta, that includes 51 parks with various levels of protection [13]. Parks within this study area include Bow Valley Provincial Park, Evan-Thomas Provincial Recreation Area, Elbow Sheep Wildland Provincial Park, Peter Lougheed Provincial Park, Spray Valley Provincial Park, and various other provincial recreation areas. Management of these sites falls under the West Kananaskis Area Manager and the Kananaskis Regional Director of Alberta Parks.

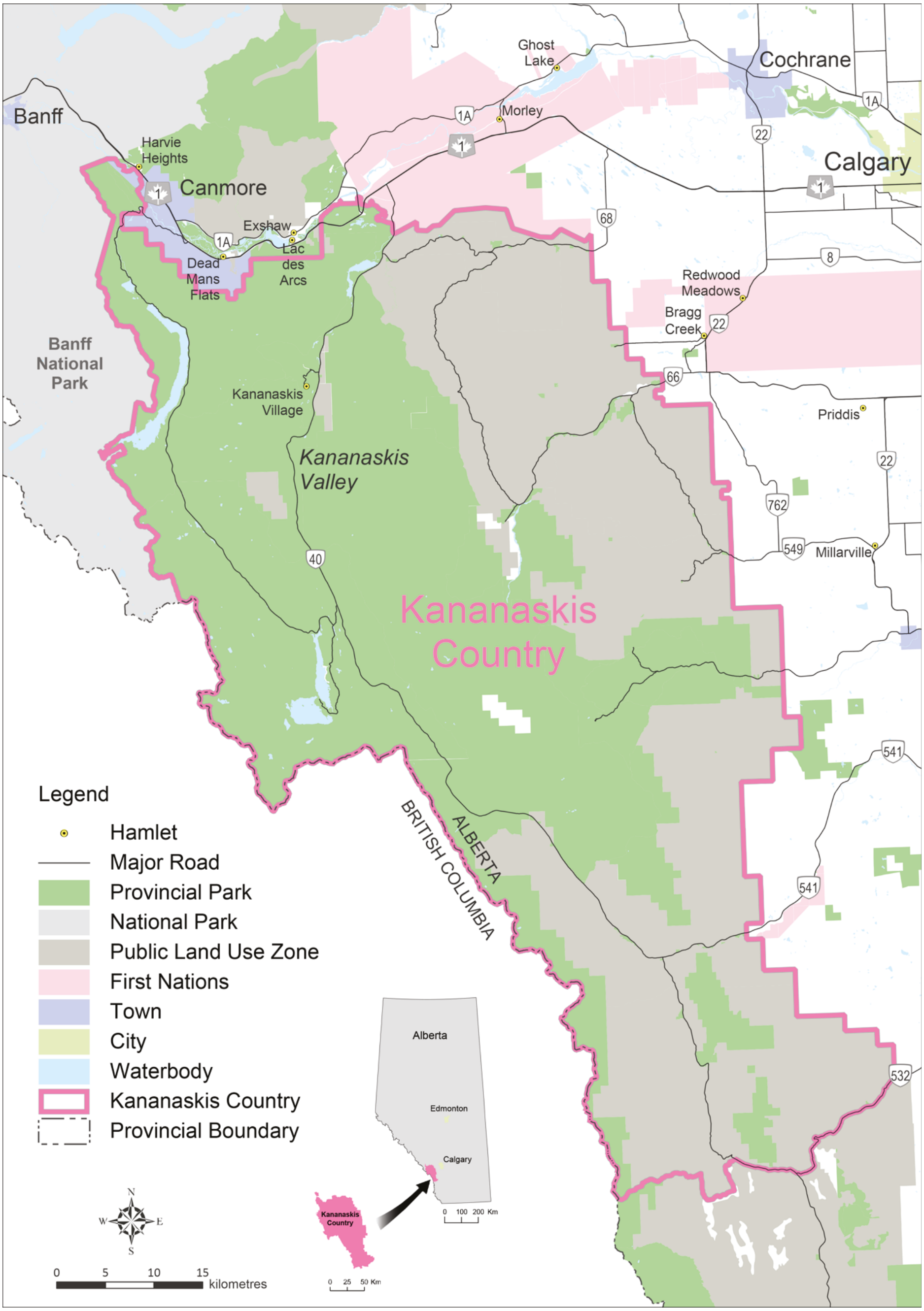

Figure 1. Map of Kananaskis Valley.

Elevations in the Kananaskis Valley range from 1600 m along the valley bottom to tall mountain peaks over 3000 m along the western boundaries of Kananaskis Country near the continental divide [14].

The valley is a movement corridor for wildlife like ungulates, carnivores, and small mammals; as well as for humans traveling along highway 40 to campgrounds, day-use areas, and hiking trails. The landscape contains important habitat for grizzly bears (*Ursus arctos*), a species that is an indicator of ecosystem health and is classified as threatened in Alberta because of small population size, habitat destruction, and human-caused mortality [15,16]. While not protected in Canada under the Species at Risk Act, grizzly bears were listed as a Species of Special Concern in 1991 [17] and as Threatened by Alberta Government in 2010. Managing human-caused mortality rates has been identified as key to the survival of grizzly bears who live along the front ranges of the Canadian Rocky Mountains [18]. Though their geographic range once extended from central Mexico to the Arctic Ocean and from the Pacific Ocean to the Mississippi River, grizzly bears are now mostly found in the mountain and foothills of Canada and Alaska. Habitat has shrunk into peninsular shapes that isolate local populations and create more space for contact with humans, increasing their risk of local extirpation [18]. Accurate population estimates of bears are difficult to obtain. In 2010, it was estimated that Alberta had between 700 and 800 grizzly bears [16]. In Kananaskis Country, approximations from 2006 place the population between 50 and 75 individuals [14].

Grizzly bears hibernate throughout the winter. Emerging from their dens in the spring, they can be found along valley bottoms, near rivers, and into upper alpine and sub-alpine zones in search of roots and sometimes moose, deer, and elk. By mid-summer, they concentrate their feeding to lower elevations, searching for high-energy buffaloberries (*Sherpherdia canadensis)* while occasionally consuming various ungulates [14,19]. Decades of fire suppression have increased the density of forests and reduced open-canopy habitat [20,21], limiting important berry crops to open slopes, meadows, and disturbed areas like those located near human facilities (campgrounds, picnic sites, trails, etc.) [18]. To reduce the occurrence of human-bear interactions, buffaloberries are managed by removing bushes near facilities and encouraging their growth elsewhere [22]. While most bears prefer to avoid human activity, less-dominant bears (such as sub-adults and adult female bears) will forage in areas closer to human facilities to avoid predation by adult males [23].

Grizzly bears have been studied intensively in Kananaskis Country. The Eastern Slopes Grizzly Bear Project (ESGBP) was an 11-year project that focused on species conservation in the Bow River Watershed, which includes all of Kananaskis Country. This research identified management actions that would reduce bear mortality rates and minimize human-grizzly bear conflicts [18]. Recreation and tourism are growing in Kananaskis Country with direct impacts on grizzly bear habitat security, which creates the potential to habituate bears to human activity, increasing the likelihood of human-bear conflict [24]. Research over the last several decades has stressed the importance of proactive management to reduce conflicts with humans. Management actions like trail closures, seasonal closures, and aversive conditioning are supported in the literature; whereas there is a consensus that actions like relocation and destruction of problem bears should be reduced [25,26].

2. Materials and Methods

We hope to understand what knowledge and information have been used to inform decision-making about human-wildlife co-existence—specifically what knowledge has informed decisions related to grizzly bear management in the Kananaskis Valley. This study included three phases, (1) collaboration with a local liaison to refine the scope of the research, (2) a review of academic literature, reports, news articles, and meeting minutes related to the topic of grizzly bear management, and (3) a series of focus groups with decision-makers who reflect the decision-makers involved in grizzly bear management in the Kananaskis Valley.

2.1. Case Study

We adopt a case study research method to explore grizzly bear management and knowledge mobilization in the Kananaskis Valley. By applying this research design, an in-depth and complex understanding of a phenomenon can be developed about a specific case [27] and new knowledge about a real-world circumstance is created [28]. Temporal and contextual conditions of a phenomenon might be of particular interest, and these can be examined through exploration, description and explanation, or evaluation [28]. In the present study, we describe a unique approach to grizzly bear management and explore how different forms of knowledge are utilized in decision-making. Limitations of case studies include generalizability and limited transferability of findings from single cases to other situations [29]. This case study is part of a larger study that examines knowledge mobilization cases in different parks across Canada.

2.2. Identify Key Management Issue with Local Liaison

The local liaison for the case study was the West Kananaskis Area Manager, responsible for park operations in the Kananaskis Valley including the parks human-wildlife conflict prevention program. While well-versed in the current grizzly bear management issues, the individual was relatively new in the position and interested in understanding the history of grizzly bear decisions prior to her tenure, which began in 2015. In addition, the case study lead previously worked with Alberta Parks in the Kananaskis region and was able to provide input on the context of the case.

The study examines grizzly bear management decisions in the Kananaskis Valley, a critical wildlife corridor and habitat for grizzly bears that is highly visited for tourism and recreation. It is a site where the only land management agencies are provincial and have a history of collaboration through the Kananaskis Country Interdepartmental Coordinating Committee (KCICC). Notably, many of the original Kananaskis Country facilities—such as campgrounds and trails—were developed in the late 1970s in areas that were not known at the time to be important grizzly bear travel corridors and habitat.

The Kananaskis Valley is also part of a unique grizzly bear and human-wildlife conflict management program, the epicenter of which is viewed as a success as it is a valley with increasing human use, multiple recreational facilities, and a growing grizzly bear population with very few reported negative human-wildlife incidents. The liaison identified several key turning points in the history of the Kananaskis Valley that may have influenced decisions around grizzly bear management: most notably were the creation of Kananaskis Country and Kananaskis Provincial Park (now Peter Lougheed Provincial Park) in 1977; the ESGBP in the mid- to late-1990s; the G8 Summit hosted in the Kananaskis Valley in 1998; and the subsequent creation of the dedicated Human-Wildlife Conflict Prevention Program, ongoing government and community education programs (interpretive programs and the wildlife ambassadors with WildSmart); and two incidents involving bears—referred to as the Nakiska bear, a grizzly that was removed and sent to the Calgary Zoo after a non-fatal encounter; and the Picklejar Lakes incident, in which a bear was left on the landscape after a fatal encounter. The Kananaskis Valley was also the study site for a novel cultural monitoring study and report led by the Stoney Nakoda and shared with park agencies in 2016.

2.3. Document Scan

Focusing on grizzly bears in Kananaskis Country and nearby protected areas, we reviewed academic literature from the natural and social sciences, newspaper articles, and media, as well as relevant policy, management plans, government documents, external agency reports, and meeting minutes from Alberta Parks and related non-governmental organizations. We identified (a) policies and events/occurrences related to grizzly bear issues in the Kananaskis Valley, (b) the influence of local and broader human-wildlife conflict prevention strategies, and (c) changes in how grizzly bear management was framed over time (e.g., terminology shifts from "problem wildlife" to "human-wildlife coexistence" or changes in management from site-based and activity-based to landscape level). Documents were not explicitly coded or interpreted but were noted as significant if they were referred to in subsequent materials or minutes, addressed specific grizzly bear management decisions or incidents, or represented direct policy (or policy changes) related to grizzly bear management in the Kananaskis Valley.

Three reports and two incidents were identified as important guiding documents. The ESGBP Report presented major science-based research findings from an 11-year study of a 40,000 km squared area known as the Central Rockies Ecosystem (CRE), which includes Kananaskis Country [18]. The 2008–2013 Alberta Grizzly Bear Recovery Plan [30] and Response Guide [31] define long-term policy and acute responses to grizzly bear management across the province. The two important incidents include the relocation of a grizzly bear from the Kananaskis Valley to the Calgary Zoo after a non-fatal human-wildlife encounter in 2000, and the 2014 decision to *not* remove a grizzly bear after a fatal encounter in the Picklejar Lakes area. The latter incident was discussed in detail by focus groups in the present study.

The 2016 Stoney Grizzly Report, an Indigenous-led report on enhancing grizzly bear management with cultural monitoring and traditional knowledge was included in the literature review study, but to date, the organizations responsible for grizzly bear management have neither officially responded to the report nor incorporated any of the recommendations. Only a few participants were even aware of the existence of the report, and even fewer had reviewed it.

2.4. Focus Groups with Decision-Makers

In addition to gaining insight into decisions made regarding grizzly bears in the Kananaskis Valley, this review helped to guide focus group composition and development of interview questions. The individuals listed in the meeting minutes for decisions related to grizzly bears as attendees or guests were grouped into categories (Table 1) of educators (government and community), government managers, and field staff from Parks and Fish and Wildlife (including conservation enforcement, ecology, and planning staff). The distinction between field ecology staff from Fish and Wildlife and Alberta Parks reflects the two distinct government departments that play a role in managing grizzly bears in the Kananaskis Valley. Of note, there were no Indigenous people identified as being involved in decisions about grizzly bear management in any of the literature or documentation explored in the study. One mention was made of three First Nations bands responding to the consultation process for the Alberta Grizzly Bear Recovery Plan [30], but there was no indication which First Nation provided the feedback, what the feedback was, or whether this feedback was incorporated into decision-making.

Table 1. Categories of decision-makers identified in documents.

Educators (involved in delivering bear management messaging)	Community Educator (e.g., WildSmart, Friends of Kananaskis Country) Government Educator
Government Manager	
Field Staff	Parks Conservation Enforcement Parks Ecology Field Staff Parks Planning Staff Fish and Wildlife Ecology Staff

Originally, a focus group for each category of decision-maker was created, however, scheduling conflicts only accommodated focus groups with a mix of participants from each category. In addition, most categories were represented by both current and retired individuals.

The team held six focus groups with sixteen individuals in total. Each focus group was two-hours in length and followed a semi-structured interview format with question topics drawn from a script developed for similar case studies (see Table 2). This conversational structure was followed in each focus group. Each participant was given a chance to answer the question while also encouraged to build on the responses of others. Interviews were transcribed and each participant was given a chance to review and make changes.

Table 2. Focus Group Guiding Questions.

Background information	"Please share your professional and educational background related to decision-making about grizzly bears"
Types of information used in decision-making	"How has knowledge typically been integrated in planning and management here?"
Decisions made about grizzly bears	"Describe important management decisions you were involved in related to grizzly bear management"
Experience applying knowledge to decisions	"Describe a decision where natural science, social science, or Indigenous knowledge was used to help with the decision-making process"

2.5. Thematic Analysis

Focus group data were analyzed using NVivo software and Braun and Clarke's thematic analysis approach [32]. This method examines, analyzes, and reports themes (or patterns) in the data and allows for a rich description of the data set. Themes represent important responses found in the data and there are different ways to uncover them (semantic/explicit or latent). The present study uses a semantic or explicit approach to identify patterns at a surface level without looking beyond what is directly said by the participants. This method complements the case study to create a rich description of a phenomenon and interpret the data for future practical uses. The thematic analysis allows for a description of how different types of knowledge were found, used, and applied in the Kananaskis Valley grizzly bear decision-making context by presenting overarching themes from across the focus groups.

We sought to define themes that connected the overarching conversation across focus groups, as opposed to creating detailed accounts, and hoped to lay a foundation for future inquiry. With NVivo, the three research team members individually familiarized themselves with the data and generated initial codes (Braun and Clarke's Phases 1 and 2). We collaborated to review themes for internal homogeneity and external heterogeneity, define and name the themes, and to produce the report (Phases 3 to 5). After reviewing transcripts individually and defining initial codes, the team met to consolidate/compare codes and discuss internal homogeneity and external heterogeneity, as per Braun and Clark [32].

2.6. Ethics

Ethics for this case study were obtained from the University of Alberta Research Ethics Board (I.D. RES0039462) and the Mount Royal University Human Research Ethics Board (Ref # 6725).

3. Thematic Analysis Results

While there is room to interpret themes further and to look at broader aspects of decisions related to grizzly bears in the Kananaskis Valley, adjacent protected areas, and beyond, we see value in sharing observations based on this case study and feel that themes presented in the results offer significant insight into knowledge mobilization in general, grizzly bear management in particular.

Three overarching themes resolved immediately and remained relatively stable. First, that *decisions were impacted by things other than knowledge,* such as management/manager choices, other agencies, politics, and pressures on capacity. Second, that social science, natural science, and Indigenous knowledge are acknowledged as important, but these *different knowledge frameworks are generally not available nor integrated* into decision-making. Third, that *knowledge about bears was created by field staff and the special context of the Kananaskis Valley*. These themes each included sub-themes that clarified particular aspects of knowledge mobilization for grizzly bear management in the Kananaskis Valley and were determined through several rounds of iterative individual and collaborative coding until the research team agreed on the fidelity of these themes. The third theme was split into two top-level themes of *the special context of Kananaskis Country informed decisions* and *knowledge created internally by figuring it out* (See Table 3).

Table 3. Themes and Sub-Themes. Representative quotes are provided to illustrate the kinds of statements shared by participants in each theme.

Themes	Sub-Themes	Illustrative Quotes from Focus Group
Section 3.1. The Special Context of Kananaskis Informed Decisions	Section 3.1.1. Creating Kananaskis Shaped Decisions	*"where's the best views? What's gonna attract the most people? What's, what's the least-cost construction? You know, what's already there that we could utilize because there were some existing facilities, those kinds of things, but little to no sort of ecological data that was integrated into that planning at that phase."*
	Section 3.1.2. The Focus of Decision-Making Shifted over Time	*"there was a sort of transition or shift in the culture of parks that occurred in the mid-nineties, from that sort of real strict recreational focus to, at least somewhat of a more ecological conservation focus for the park system in Alberta."*
	Section 3.1.3. Decision-Making Changed as Local Bear Populations Changed	*"it wasn't until, you know, we saw the opening up of the Valley with trail development, road development, buildings, that type of thing that we created that better habitat and better protection of grizzly bears to start seeing them on the landscape.""the clientele, the CO's, the legislation, the level of development seems to allow for grizzly bears to be able to … we're growin' grizzly bears here and it's been fairly successful."*
Section 3.2. Decisions Were Impacted by Things Other than Knowledge	Section 3.2.1. Management Impacts Decisions	*"most management, up until around almost probably 2005, I would say, came up through either the conservation or Fish and Wildlife officer ranks and that composed of the largest number of folks that were in management decision-making roles.""talking to my cohorts in national parks and, and elsewhere, there's a real dysfunction happening between upper levels to lower levels. And it's not, I think what we've, we've lost sight of is, they're talking two different languages more and more. Um, and how do you get the people in between to interpret those languages?"*
	Section 3.2.2. Other Agencies Impact Decisions	*"the bear world is a small world, like you know, you can call Kerry Gunther in Yellowstone or John Waller in Glacier or somebody in the Smokey Mountains and just ask "hey, what do you think?" and you're getting input from a variety of sources that ah, have got decades and decades of experience with this stuff."*
	Section 3.2.3. Capacity Impacts Decisions	*"the lack of funding when you are trying to deal with these kinds of issues, it's the difference between hope and promising outcomes and absolute disasters and desolation.""management decisions often are required, you know, next week or the next month or something's changing […] if you want to go out and get the science and do some science to inform that decision, it's going to take a much longer timeframe"*
	Section 3.2.4. Social and Political Pressures Impact Decisions	*"[Kananaskis Country] was more about, you know, 'what did the public want? What did recreating Calgarians want?' And less of a concern about conservation, which I think was, you could probably extend that across the board for most parks.""maybe ultimately it's not natural science or social science or traditional knowledge that informs decision-making, its politics."*
Section 3.3. Different Knowledge Frameworks Are Generally Not Available Nor Integrated	Section 3.3.1. Natural Sciences Is Used	*"it's way easier to make a decision based on natural science because that's our comfort zone."*
	Section 3.3.2. Social Science Is Needed	*"What's the biggest bang for our buck for money spent on research? I would say certainly in this valley, social science research is going to give you the kind of data and the kind of understanding that's going to be necessary to deal with the problems and the challenges associated with limiting people use in this valley."*
	Section 3.3.3. Indigenous Knowledge Is Not Being Integrated	*"the barriers are, like, it doesn't agree with my science, I'm a scientist and if your telling me something and it's not supported by science, I have a hard time of getting out of my decision framework of saying 'well that's not, that's not the case.'""there needs to be a method by which we can arrive at a conversation that's based on something other than numbers and data."*
Section 3.4. Knowledge Created Internally by Figuring It out	Section 3.4.1. Self-Education	*"we were cast into the position of participating in making recommendations and doing all of that kind of work without being very well prepared"*
	Section 3.4.2. Gain Experience in the Field	*"you can only watch bears eating sherpherdia in the middle of a campground so long to realize they're not there for the picnic baskets."*
	Section 3.4.3. Bears Inform Knowledge	*"All the sudden we know what this bear's been doing for a year, for two years, for three years. And a bear shows up and it's like it's not red alert, it's like "oh, that's this bear. We know that she pops in here" and I think that kind of knowledge going to management and to managers, all the sudden your tolerable risk levels go down"*

3.1. The Special Context of Kananaskis Informed Decisions

The research team identified several factors that seemed unique to the creation of Kananaskis Country and change in the Kananaskis Valley over time. Some of these confirmed findings in the document review, such as the impact of the ESGBP, the grizzly bear recovery plan, and the shift in language from "problem wildlife" to "human-wildlife conflict." Participants also added the impact of the changed grizzly bear status, restrictions on hunting, and the G8 Summit. These turning points in grizzly bear management occurred alongside a cultural shift from a recreation focus to a conservation focus in the valley and the broader park agency. Participants involved at the beginning of Kananaskis Country emphasized that the rapid designation, development, and opening of 4000 square kilometers of multi-use recreation area over just a few years occurred prior to meaningful research or knowledge. While the strong vision of Premier Peter Lougheed was antithetical to integrating different pieces of knowledge, it accelerated decision-making, and created the still-active KCICC.

3.1.1. Creating Kananaskis Shaped Future Decisions

The designation of Kananaskis Country in the late 1970s began with the rapid development of facilities between 1977 and the early 1980s. Participants recalled build-out as occurring prior to any research on bear habitat suitability and absent of any research on grizzly bear ecology. Instead, participants suggested facilities and trails were built based on aesthetics and views, existing game or recreation trails, previously built facilities, and cost and efficiency. A participant explained this by stating: "you need to go back to the very start of Kananaskis, and how little knowledge was utilized in the original planning of Kananaskis Country from an ecological perspective, and particularly from a grizzly bear perspective."

This lack of consideration of ecological information was attributed to a lack of available ecological information. Participants who had worked in the valley in the early 1980s recalled studies on grizzly bear habitat suitability by Stephen Herrero and Wayne McCrory completed after facility development with most of the construction already completed. The habitat data illustrated fundamental issues with the development of Kananaskis Country, notably that many facilities were built in the same places grizzly bears needed. For example, on the one hand, Elkwood Campground was identified by participants as being located "in the middle of one of the best grizzly bear habitat patches." On the other hand, participants also recalled an attempt to mirror approaches taken in the adjacent Banff National Park—an even busier area also containing critical grizzly bear habitat. Knowledge and expertise were imported from the nearby national park and other local agencies, resulting in a forward-looking approach that mandated standards such as bear-proof garbage bins.

A final observation on the special context of Kananaskis Country was that it initially functioned as an integrated program informed by an overarching vision. The overarching vision of former Premier Peter Lougheed was executed through top-down direction from a centralized Calgary office, and an integrated, inter-departmental governance system (KCICC) generated collaboration and streamlining of decision-making across often-rivalrous government ministries.

While the context of Kananaskis Country has changed, both people and bears live with the consequences of decisions made in the past and can build on the foundation for successful management of grizzly bears in the Kananaskis Valley that persists today.

3.1.2. The Focus of Decision-Making Shifted over Time

As discussed in the previous section, there was an evolution of available information that, in hindsight, may have resulted in different decisions, such as avoiding placement of facilities within the prime grizzly bear habitat. The focus group participants confirmed several other turning points over the history of the Kananaskis Valley that either changed the direction of decisions related to grizzly bears or changed the access to knowledge. These included a cultural shift towards science-based decisions, increased availability of grizzly bear research and information on specific incidents, and a reframing of the focus of grizzly bear management as human-wildlife conflict.

Participants noted that in the mid- to late-1980s there was a perceived shift toward more use of and access to natural science knowledge, primarily fueled by the work of Herrero and other prominent biologists. Participants felt the science affirmed many of their intuitive decisions and reinforced the expertise of those making decisions.

In the 1990s, a second shift occurred as the Alberta Parks system moved from recreation-focused to conservation-focused management. This shift correlated with the final report of the 10-year ESGBP. This report was identified as significant in our initial literature review and participants suggested that the creation of knowledge was influencing and supporting decisions and practice.

In the early 2000s, and partly supported by legacy funding from the G8 Summit, there was a shift in decision-making from being based on grizzly bear science, such as the ESGBP, to science focused on human-wildlife conflict. The latter was described as a program that included "collaring bears for management purposes, shepherding them, [and] making sure that they were staying out of areas that were dominated by people." The program comprised a unique combination of infrastructure that is made to be bear-proof, legislation that allowed for key enforcement actions (e.g., ticketing for leaving coolers unattended), and interpretive and education programs that informed public behavior.

There was also a change of language among practitioners, a deliberate choice that was meant to set a new goal for grizzly bear management away from the term "problem wildlife" and toward "human-wildlife coexistence" language to focus on the relationship between people and wildlife. This shift was reflected in subsequent literature [25] and practice, including updates to the 2016 Bear Response Guide [31] and the development of management plans specific to human-wildlife conflict prevention and grizzly bears.

3.1.3. Decision-Making Changed as Bear Populations Changed

The context of the Kananaskis Valley, and by extension the focus of decision-making, appears to have changed alongside changes in the local ecology of bears. Participants recalled that, prior to 1977, bears (both black and grizzly) were infrequent in the Valley. One first-hand account was that "for me to see a black bear even back then was just was ... it was rare." However, a combination of factors supported a growing grizzly bear population, including the cessation of the grizzly bear hunt and internal management and development actions such as effectively creating bear habitat through clearing for trails and facilities and supporting a growing grizzly bear population through the success of the human-wildlife conflict prevention program. The management decisions, conservation actions, and even educational messages needed to change because the bears themselves had changed.

3.2. Decisions Were Impacted by Things Other than Knowledge

While the document review identified a variety of management plans, policies, and frameworks that were clearly intended to guide decisions related to grizzly bear management in the Kananaskis Valley, the focus group discussion revealed a number of other impacts to decision-making, including management, other agencies, capacity, and both social and political pressures.

3.2.1. Management Impacts Decisions

Managers in the study area are responsible for enacting the management plans for a particular park or species and for guiding the operations of field staff. The participants in the focus groups—who were not all managers—described some managers as facilitators of knowledge-based decision-making, while others were seen as impeding the gathering and use of evidence.

Between the 1980s and 2000s, managers in the area—generally perceived as having come up through the system—were supportive of using natural science knowledge to inform decisions about grizzly bears. This management support was credited to their previous first-hand experience as field staff prior to becoming managers, as well as their trust in the local knowledge of current field staff.

In recent years, newly hired managers were seen as having less-relevant backgrounds—and examples of these included those with MBAs or experience from other ministries but no experience in parks of conservation. In some cases, it was felt they had little to no field experience. Participants suggested these managers exhibited less trust for field-based decision-making, were less effective at communicating issues and information, and even overrode information with their own personal perspective. A statement from the focus groups that illustrates these concerns is:

> We currently don't have a management team that maybe understands or trusts natural science, or how it can be incorporated into the decision making. If they don't trust science, or don't value science, there's a barrier. They don't really understand how to use it.

While participants expressed both the positive and negative impacts managers can have on decision-making, the most discussion was about the disconnect between management and field staff or ecologists, and the need to ensure managers are open to evidence that supports decisions.

3.2.2. Other Agencies Impact Decisions

Other agencies were viewed as sources of knowledge. Experts or resources from Banff National Park were engaged during the development of Kananaskis Country, and an entire community of grizzly bear experts from various agencies would frequently collaborate in the ensuing decades. At times, however, other agencies were seen as sources of frustration or conflict. For example, participants described other agencies producing inconsistent public information on whether bear spray should be carried by park users as a defensive tool in case of bear encounters, which complicated education messaging and compliance programs.

There was also ongoing conflict centered on different approaches to grizzly bear response between the provincial Fish and Wildlife program and the Parks program. Fish and Wildlife were described as having the mandate to deal with problem wildlife across the province, *including* within parks and protected areas managed by Parks. In cases where a decision needed to be made related to a grizzly bear incident, these two agencies—Fish and Wildlife vs. Parks—often took different stances. Fish and Wildlife took a more hard-line approach that Parks staff disagreed with. Over time, positive collaborations developed between Fish and Wildlife and Parks within the setting of the Kananaskis Valley. Participants attributed the change in tone to factors such as the local setting—and the likelihood that staff from either agency might live in the park as neighbors, the integrated decision-making generated by the KCICC, and the empowerment of Park field staff in conflict management through the grizzly bear management plan. In time, people from both sides were able to appreciate that each agency held their perspective for a reason. A description of this shift in relationship from adversarial to appreciative was provided by a Park staff member and presented here to illustrate this theme:

> [Fish and Wildlife] are folks who have seen the absolute worst of what bears can do to people. And, you know, after hearing about their experiences and seeing some of the photos of fatalities ... I had a much better understanding of the position that they're coming from and why they make some of the decisions that they do. And I think we can all say that we might do it differently, but until you've been in their shoes [...] it gave me a different perspective for decision making regarding to bears, but also relating to those people. Because we were so far apart before, but once you understand people's perspectives and the knowledge that they go on to make their decisions, you can kind of create bridges a little easier.

In some focus groups, this topic of conversation led to discussions about the importance of fostering cross-pollination across agencies—not just Fish and Wildlife, but also Parks Canada, the Crown of the Continent agencies, across other Alberta Parks' regions, and so on—to share ideas, training, and work toward consistency in approaches to management and messaging.

In several focus groups, there was also an illustration of effective interagency cooperation during the significant bear incident at Picklejar Lakes. Though we cannot share specifics of the incident, it is generally seen as a pivotal moment when it was decided to leave a bear on the landscape after a fatal mauling. The agencies involved had lengthy discussions about how that decision was made collaboratively with a deliberate, iterative process to establish and agree on facts of the situation, to gather as much input as possible from each involved agency, and to come to a decision that everyone supported.

3.2.3. Capacity Impacts Decisions

Focus group participants suggested that the capacity to gather or apply knowledge impacted the availability and use of knowledge to inform grizzly bear management. Capacity pressures were categorized as funding, time, pace, or human capacity. The clearest capacity pressure was *funding*. Participants explained there was rarely enough funding to engage in research or knowledge-gathering, and even less available for social science and Indigenous knowledge-gathering relative to natural science.

The second capacity pressure was *time*, notably the lack of time for decision-makers to consider different sources of knowledge among competing work pressures. Managers in particular spoke of time-consuming internal processes. For example, urgent Action Requests (ARs) to higher levels in the organization would often take priority over knowledge gathering or applying evidence to decisions, which was seen as a self-perpetuating cycle where decisions were not based on evidence and could lead to bad decisions or even more ARs.

The third capacity pressure also related to time but focused on the *pace* at which decisions were made vs. the pace at which research moves. Participants explained that management decision timelines were often immediate and required action within weeks or months, while research required much more time and process. This incongruence creates decisions that are too reactionary to allow time to adequately gather information. Knowledge creation was not proactive enough to keep up with what is happening on the ground.

The fourth and final capacity issue was *human* capacity, or specifically the loss of human capital as people leave the organization over time. The timespan of this case study and the involvement of retired individuals sparked discussion on how key people leaving the organizations impacted the knowledge available for decision making. The following statement captured this loss of people connected to the Kananaskis Valley: "we're losing that sort of institutional knowledge, or people would be moved around, or they're not being dedicated to it as much." There were also comments about the younger staff being more aware of new knowledge sources or having more recent training, especially in terms of their openness to considering social science or Indigenous knowledge. However, the overarching sense was that integrating evidence and knowledge became harder as the people who knew the context and issues of the Kananaskis Valley left the organization.

3.2.4. Social and Political Pressures Impact Decisions

The final area of impact on decision-making around grizzly bear management is the combination of social (or public) and political pressures. Social pressures included external, citizen-driven demands, and support for decisions in parks while political pressures were the internal machinations of government that may impact a decision. Many of the participants in the focus groups either stated or agreed that recreation and social/public interest were prioritized over conservation, noting that much like most parks in the Alberta Parks system in the late 1970s, the creation of Kananaskis Country was seen as rooted in meeting recreation needs with little obvious concern for conservation.

There was also discussion about how social pressures could support conservation, such as the general public support to restrict the grizzly bear hunt in Alberta (which had an impact on grizzly populations in Kananaskis). Though some groups, such as ranchers, supported grizzly bear hunting, general public opinion influenced specific grizzly bear management policy. The importance of public influence on decisions confirmed the value of including educators in this case study. All participants, whether educators or not, recognized the importance of interpretation and education programs to increase compliance and support public safety, as well as the importance of education to foster public buy-in for grizzly bear management decisions.

Political pressures, sometimes referred to as "political interference", were linked to the social pressures that influenced grizzly bear management decisions. The perceived political desire to maintain public support of decisions could undermine the use of available information. Some participants suggested the top-down directives from Ministers made knowledge-gathering irrelevant, and that decisions did not always reflect available science or the advice of experts. The disconnect between decision-makers and subject matter experts was attributed to the four-year election cycles of government and too cautious management by government officials unwilling to risk unpopular or incorrect action.

Managers in the case study acknowledged that part of the decision-making process had taken a "manage up" approach by ensuring both field staff perspectives and research reached the political levels of government. However, the general feeling among all the focus groups was that political pressure could influence, change, or even overturn good decisions. A salient comment that sums up these felt pressures is: "On a good day I would say that natural sciences have been part of making conservation decisions on the landscape. On a good day. Most days are not good days. Most days, most days the decisions are made based on politics, based on economics, based on, on social agenda."

3.3. Different Knowledge Frameworks Are Generally Not Available Nor Integrated

One of the main areas of focus for this case study was how natural sciences, social sciences, and Indigenous knowledge had been used in decisions about grizzly bears in the Kananaskis Valley. Participants felt that all types of knowledge were underused or unavailable, though they recognized the value of each and were eager for ways to incorporate different knowledge frameworks. Decision-makers primarily relied on natural sciences knowledge, felt there was a lack of opportunity to incorporate social science, and had no successes integrating Indigenous knowledge.

3.3.1. Natural Sciences Is Used

Natural sciences were used in grizzly bear management over the course of this study timeframe. Though, as mentioned in the first theme, research data was not available until after Kananaskis was created, and, as mentioned in the second theme, there were multiple capacity pressures to gathering knowledge. The monitoring of grizzly bears through wildlife radio telemetry collars, remote cameras, and collecting observation reports was noted as an ongoing aspect of park operations in the Kananaskis Valley. Participants explained that the human-wildlife conflict prevention program (now referred to as the bear management program) relied on ongoing data collection for field operations.

3.3.2. Social Science Is Needed

Few participants could identify any examples of social science being used in decision making, though they expressed a crucial need for such research. Individuals involved in the early days of Kananaskis Country could not recall any related social science research being completed, though they did recall expressing an urgent need for it. Today, the need seems to be equally pressing, even more so than natural science because current management decisions related to grizzly bears may in part require interventions on human behaviors, such as restricting or redirecting human activity.

The lack of social science research was also blamed for challenges or missed opportunities in effectively managing people and bears—the "human" side of human-wildlife conflict. One participant characterized their approaches to providing information, changing behaviors, or shifting human use as "social science guesses." Another appealed to the research team to include in this paper that "Kananaskis is a gold mine for social science [. . .] we're desperate."

3.3.3. Indigenous Knowledge Is Not Being Integrated

Participants in the focus groups were eager to talk about Indigenous knowledge and the barriers they saw both institutionally and personally that made Indigenous knowledge so difficult to gather, understand, and integrate. Participants remarked on the biases and racism in our culture, as well as the lack of understanding, lack of willingness to engage with Indigenous knowledge, and even shame about not knowing how to acknowledge their lack of understanding and lack of action. Moreover, no participant could think of a time when Indigenous knowledge had been used to make a decision about grizzly bears in the Kananaskis Valley.

Even when the knowledge was available it was more common for decision-makers to find reasons *not* to use it than to try to integrate it. As an example, one participant referred to the 2016 Stoney Grizzly Bear Study, pointing out there had still been no formal response, aside from the interpretation and education program that included Stoney Nakoda speakers and elders to participate in public education events such as Bear Days. Even though the Stoney Nakoda First Nations made their knowledge available, acceptance by Managers and decision-makers was (and remains) subject to fitting the information into a Western science framework.

The desire to increase acceptance of Indigenous knowledge was explored at length in conversations, particularly among the ecologists who generally expressed their skepticism towards Indigenous knowledge because it did not fit their own worldview or known data. They also felt uneasy digging deeper into what Indigenous knowledge holders share. For example, participants were interested in how shared Indigenous knowledge relates to scientific knowledge like telemetry data that tracks bear movements, but they worried about asking respectfully or productively. The focus group conversations did reveal an awareness of the importance of building relationships and trust to support knowledge exchange with Indigenous people to find a place of intersection.

As a final note, none of the participants represented Indigenous perspectives on grizzly bears in the Kananaskis Valley, nor were any Indigenous people involved in decision-making about grizzly bears in the Kananaskis Valley. As such, this sub-theme only represents one side of the conversation around incorporating traditional knowledge into decision-making about grizzly bears.

3.4. Knowledge Created Internally by Figuring It Out

The research team agreed there was a need to distinguish the sort of local knowledge generated by staff and managers through various sources, field experience, and from the bears themselves. There was a clear sense that everyone involved in grizzly bear decisions was creating new knowledge every time they solved a problem. There were multiple characterizations of decision-making as a process of "flying by the seat of your pants" or "[going] with our gut." This reactive approach led to people utilizing several informal methods of gathering knowledge internally or within the context of their role as decision-makers.

3.4.1. Self-Education

Participants felt unprepared for the grizzly bear management aspect of their work and felt there was a culture of proactively seeking new or additional information in order to effectively manage the changing grizzly bear populations in the Kananaskis Valley, post-park creation. The focus on recreation in the early days meant and that many of the people involved in decisions were educated in recreation and did not know how to access required ecological information for conservation. In order to remedy this knowledge gap, some people sought new information by reading published papers, getting involved in research projects (specifically the ESGBP), learning about the status of grizzly bears, and talking to colleagues in ecology. In some cases, they even pursued related formal education such as graduate degrees.

3.4.2. Gain Experience in the Field

Focus group conversations indicated that working in the Kananaskis Valley offered opportunities to observe bears (and people) over time. Managers in particular explained a reliance on the observations of field staff to understand bears and inform decisions. An example of this approach is a quote from a participant:

> We rely very heavily even up to today on our long long-term conservation officers and people in the field. You're talking about people with 25, 30 years' experience, and we still rely very heavily on what they're seeing, what they think, that type of knowledge.

Years of staff, stakeholders, and user groups observing and reporting on bears, habitat, and people integrated with decision making as managers gleaned information from observational fieldwork to ensure human-wildlife coexistence in recreational areas.

3.4.3. Bears Inform Knowledge

Finally, through years of monitoring work, specific bears in the Kananaskis Valley (and beyond) were given number tags and fitted with radio telemetry collars. Field staff became familiar with individual bears and their offspring, and over time, there was a shift in the understanding of bears. Their personalities and previous behaviors and encounters were assessed when managing for risk. A participant noted, "they are all individuals and they all have good days and bad days." Specific bears, their personalities, and their unique behaviors were frequently mentioned in the focus groups and it became evident grizzly bears had become an important source of knowledge for decisions.

At the same time, while the connections between field staff and bears were seen as a positive contributor to decision making, one participant expressed concern that this relationship may be losing objectivity, with the potential to become complacent. Despite this concern, the relationship with individual bears was viewed as part of a cultural shift in bear management in the Kananaskis Valley that was appreciative of bears and drifted away from the idea of problem bears. Even if some sources of knowledge suggested higher levels of risk by keeping grizzly bears on the landscape, the philosophical approach had changed to one of accepting that risk for the sake of the bears in the valley.

4. Conclusions

The findings of this grizzly bear case study reflect previous observations in the literature related to knowledge mobilization in parks and conservation. These connections include the impact of managers on knowledge exchange, knowledge access barriers (e.g., capacity limitations), funding shortages, time pressures, and the imperative to take action even if evidence is not available [1,3,6]. In the grizzly bear case study, there were accounts of managers ignoring or impeding knowledge application and dictating decisions supported by their own views or political and social pressures. Additionally, there was a notion that managers may use personal anecdotal experiences or look within their organization rather than to research, as Lemieux et al. [1] describe in their work. Of note, however, participants, in this case, indicated that they feel *less* supported in knowledge mobilization in recent times despite calls in the literature and policy for *more* evidence, and despite accounts that meaningful support for informing decisions with social science and Indigenous knowledge had not even started.

Conversations also included descriptions of past times when managers acted as enablers of research and created a culture of accepting evidence and trusting the field staff, which were contrasted with recent times where managers were seen as impediments to knowledge mobilization. The suggestion of a deterioration in manager capacity calls for the study of current *and* historic management approaches to evidence-based decision making. It also could lead to an examination of whether pathways into park management roles have changed significantly and what supports are currently provided to managers to generate evidence-based decision-making. Future work (and this case study) could also inform training for managers on moderating political and social pressures, prioritizing workload demands, and on how to effectively promote natural science, social science, and Indigenous knowledge-use in decision-making.

Initial consideration of the changing context of grizzly bear decision-making over time could draw upon Nguyen, Young, and Cooke, who developed the Knowledge-Action framework to explore more generalizable relationships between Knowledge Production/Co-production, Mediation, and Action/Inaction spheres [33]. Using the Knowledge-Action framework to consider the overall findings of this study demonstrates a general alignment to the model (at least in terms of natural science knowledge): grizzly bears have been managed in Kananaskis Country by *producing* knowledge (i.e., the Eastern Slopes Grizzly Bear Project), *mediating* the use of the knowledge (i.e., staff learning about the study and sharing knowledge with colleagues and the public), and *acting* on the knowledge (i.e., the human-wildlife conflict prevention program). However, the change in support for decisions in the Kananaskis Valley over time could potentially be explored by applying the Knowledge-Action Framework to different periods within the case study context. For example, in the inception of Kananaskis Country, *action* was taken with little consideration of, or opportunity for, *production* or *mediation*. In the 1980s through to the late 1990s, once knowledge was *produced* there was ample and meaningful *mediation* and *action*. Finally, in later years it appears the *action* sphere has become less positive, with a perceived trend toward less management support for *production* or *mediation* and decision-making *action* driven more by political and social pressure. This potential application of the Knowledge-Action Framework could illuminate the factors that may lead to declines in support for evidence-based decision-making over time.

In addition, literature exploring ways forward in knowledge mobilization for conservation is abundant with recommendations for knowledge co-production and networking [1,33,34]. The unique multi-decade cross-ministry collaborative structure in the study area (e.g., KCICC), the ongoing engagement with the community of grizzly bear "experts" across jurisdictions, and the sharing of information between researchers, community partners, and field staff offer a compelling case to study collaborative networks in practice. The findings also point to the role of field staff in monitoring bears, gathering occurrence reports, and communicating ecological knowledge within and beyond their organization. This role echoes Fleishman and Briske's suggestion of Professional Ecological Knowledge, or PEK [35], that can frame and activate knowledge produced within conservation organizations. However, this approach risks glossing over the lack of Indigenous participation in networks and the resistance to recognizing TEK, or traditional ecological knowledge.

With healthy populations of bears living relatively close to increasingly growing numbers of outdoor recreationists (with limited conflicts or incidents to date), grizzly bear management in the Kananaskis Valley is a unique model within the bear management community and, arguably, a success story. Despite a hurried development of facilities and trails in the 1970s, subsequent ecological monitoring and research and evidence-based approaches to human-wildlife conflict prevention programs have helped the Kananaskis Valley implement an innovative and collaborative approach to decision-making in parks and protected areas. Though recent trends may indicate degradation of decision-making effectiveness due to management, capacity, external, social and political pressures, there is a culture of collaboration and a clear understanding of the value of various forms of evidence, even if those other forms of evidence are not available nor integrated.

This case study shows the value of exploring specific challenges facing decision-making in parks and protected areas as a means to improve understanding and acknowledge the need for evidence-based decisions. This case contributes to growing evidence of common challenges and pressures and offers generalizable insight. Developing an understanding of decision-making related to grizzly bears in the Kananaskis Valley reveals a complex, long-term co-evolution of grizzly bears, parks, and the people who make decisions about both. Further investigation of this protected area and the wildlife issues at hand should generate useful and relevant insight.

Author Contributions: Conceptualization, E.A.H.; methodology, E.A.H., D.P. and D.C.D.H.; original draft preparation, D.C.D.H. and M.N.M.; writing, reviewing, and editing, D.C.D.H., M.N.M. and D.M.; supervision, D.C.D.H.; funding acquisition, E.A.H. All authors have read and agreed to the published version of the manuscript.

Funding: This project was funded in part by a Partnership Development Grant from SSHRC (2018–2021), awarded to the Canadian Parks Research Network, administered by Elizabeth Halpenny, at the University of Alberta.

Acknowledgments: We thank the editor and the reviewers whose comments helped to improve the manuscript. The authors wish to thank all the members of the larger knowledge mobilization study, notably Glen Hvenegaard, Clara Jane Blye, Donelda Patriquin, and Elizabeth Halpenny, who developed the methodology and focus group questions. We also wish to thank the Kananaskis Region Public Engagement section for hosting focus groups in the Peter Lougheed Discovery Centre and the current and past Alberta Parks and Fish & Wildlife staff of Kananaskis Country for their time participating in this study as well as their dedication to protecting grizzly bears. Finally, we would like to acknowledge that this research was supported by the Social Sciences and Humanities Research Council of Canada.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Article

Park, Fish, Salt and Marshes: Participatory Mapping and Design in a Watery Uncommons

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Received: 2 October 2020; Accepted: 15 November 2020; Published: 17 November 2020

Abstract: The Franks Tract State Recreation Area (Franks Tract) is an example of a complex contemporary park mired in ecological and socio-political contestation of what it is and should be. Located in the Sacramento-San Joaquin Delta, it is a central hub in California's immense and contentious water infrastructure; an accidental shallow lake on subsided land due to unrepaired levee breaks; a novel ecosystem full of 'invasive' species; a world-class bass fishing area; and a water transportation corridor. Franks Tract is an example of an uncommons: a place where multiple realities (or ontologies) exist, negotiate and co-create one another. As a case study, this article focuses on a planning effort to simultaneously improve water quality, recreation and ecology in Franks Tract through a state-led project. The article examines the iterative application of participatory mapping and web-based public surveys within a broader, mixed method co-design process involving state agencies, local residents, regional stakeholders, consultant experts and publics. We focus on what was learned in this process by all involved, and what might be transferable in the methods. We conclude that reciprocal iterative change among stakeholders and designers was demonstrated across the surveys, based on shifts in stakeholder preferences as achieved through iterative revision of design concepts that better addressed a broad range of stakeholder values and concerns. Within this reconciliation, the uncommons was retained, rather than suppressed.

Keywords: co-design; transdisciplinary practices; public participation geographic information system (PPGIS); softGIS; parks planning; Delta; structured decision-making

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1. Introduction

1.1. Background

The Franks Tract State Recreation Area occupies two flooded areas of formerly reclaimed land, Franks Tract (3000 acres flooded since 1938) and Little Franks Tract (330 acres flooded since 1982), hereafter collectively referred to as Franks Tract, located in the Western Sacramento-San-Joaquin Delta of California (Delta) (Figure 1). These shallow, tidal lakes-novel to the Delta-were created after multiple levee failures, after which they were abandoned. They have since evolved into a major water recreation and navigation hub for the entire Delta. The tidal lake has also become the home of expanding numbers of aquatic introduced weeds that blanket its surface and fill the water column, making navigation difficult and deeply affecting local ecology. Franks Tract is dominated by predatory introduced species that thrive in these altered conditions, such as black bass, which support economically significant tournaments, but reduce the habitat value for critically endangered species such as Delta smelt and

Chinook salmon. As some have claimed, Franks Tract is more akin to a lake in Arkansas and its associated fish species, than a California Deltaic environment [1]. There are fishing tournaments year-round here. During March, April and May, there is a tournament every weekend, the largest of which can generate a half a million dollars in economic activity [2].

Franks Tract is also a problematic source of salinity intrusion into the western Delta from the saltier Bay. In increasingly frequent drought conditions, salinity threatens water supply reliability of regional diverters and contentious Delta exports [3,4]. These exports provide water to the Southern Bay Area, San Joaquin Valley agriculture, and Southern California cities, often at the expense of Delta ecology and local communities [5]. Franks Tract Futures (FTF) is the latest in a string of planning efforts seeking to address water supply reliability issues related to Franks Tract. Tied to water supply reliability are restoration mandates, which are "heavily driven by the detrimental effects of water exports and the reengineering of the Delta as logistical infrastructure for its conveyance" [6]. Restoration mandates across the Delta call for the recreation of tidal marshes, which were 98% eradicated during the diked reclamation of the region in the late 19th to early 20th century [7], along with the eradication of what was left of nomadic to semi-nomadic native American Delta tribes, which had been largely decimated by colonial persecution and European-introduced diseases prior to that time.

Current ecological restoration mandates for Franks Tract are guided by multitudes of scientific and legislative literature. A Delta Renewed [8] is an influential state-funded science-based guide that draws from extensive research on historical ecology [7], landscape change [9] and future scenarios to "discuss where and how to re-establish the dynamic natural processes that can sustain native Delta habitats and wildlife into the future" [8]. The guidelines in A Delta Renewed were specifically applied in initial FTF planning efforts to help set performance goals for conservation, including the size and design of tidal marshes and their dendritic channels.

Unlike previous planning efforts [10,11], the FTF effort has expanded goals of providing enhanced recreational opportunities and community benefits and benefiting native and desirable species by reestablishing lost ecological habitats and processes (The project website: https://franks-tract-futures-ucdavis.hub.arcgis.com/). Thus the FTF effort exists within a dynamic context of interconnected efforts of landscape-scale mitigatory restoration, coordinated adaptation planning on public lands, and a massive and controversial proposed water conveyance project.

Similar conveyance projects, which originated as part of the State Water Project (SWP) and Federal Central Valley Project (CVP) but were never implemented, have been proposed several times. The current project entails a tunnel underneath the Delta that would allow water exports to draw water from the fresher Northern Delta, mitigating issues related to salinity intrusion, water quality and export restrictions related to the endangered species act. Over the course of the FTF project, a new governor took office and downsized the current proposal from two tunnels to one. Yet the project remains contentious, seen by many Delta locals as a water grab, and many FTF stakeholders were skeptical that the Franks Tract project was connected, for example by serving as a repository for *tunnel spoils*. As noted by Milligan and Kraus-Polk, regarding the Delta's indeterminate future water infrastructure, "Many plans to alter or sustain these logistical works are uncertain (both in execution, budget, and timeline) and likely to be changed and superseded by new propositions. Given the dominant agency of this planning arena, it renders planning in all others challenging and unpredictable" [6].

Early 1900s *Reclaimed for farming between 1902 and 1906. Occupied by Native Americans prior to reclamation*

1937 *Levee breaches occur in 1936 and 1938. 1938 breach was never repaired.*

1950s *Tract used as Navy bombing target from 1943 to 1952.*

1970s *CA State Park established in 1959.*

1993 *Urbanization of adjacent Bethel Island.*

2019 *Levees (orange) and grid of regulated hunting blind locations.*

Figure 1. Co-evolution of Franks Tract: 1900-present.

We understand Franks Tract as a contested part of the Sacramento-San Joaquin Delta's far-flung infrastructural landscape, a boating highway, a world-class bass fishery, a novel ecosystem and a chronically underfunded state park. As such, we approach Franks Tract as an uncommons [12,13], meaning there are divergent realities and presuppositions of what the landscape is, all of which exist simultaneously and in relation to one another. Accordingly, our work attempted to engage with the diverse and entangled "ecologies of practice" of this place [14,15].

In practice, we contend that working within an uncommons, of which there are multitudes in the socio-political and ecological crises characterizing the current neo-liberal, late capitalist dominated Anthropocene era, entails accepting that planning and design processes begin and possibly end with a diversity of participant perspectives on what a landscape is and should be [16,17]. This acceptance requires the development and application of methods to "establish a shared understanding of knowledge for action across multiple knowledge domains," [18] or what is referred to as boundary objects [19–21]. Boundary objects are coproduced and adaptable to different viewpoints, but yet are also robust enough to maintain identity across those viewpoints. In co-planning and design contexts the creation of boundary objects can "allow local understanding and interests of participating groups to be reframed in the context of some wider collective activity, which can promote cooperation among stakeholders." [18] Franks tract, as the spatial milieu of an uncommons, is itself a boundary object. It is a place that is empirically present and aesthetically accessible to all who enter it. Yet it is used, valued and interpreted in radically different ways. To quote from Joan Nassauer, "While we might 'see' the landscape through different disciplinary or experiential frameworks, we can point to the same locations or relevant characteristics in a landscape or in a spatial representation of the landscape, and describe what we see there" [10].

In this manuscript, we will present a series of public surveys and co-mapping efforts as landscape boundary objects that facilitated the *boundary work* of "bridging boundaries between groups of people with differing views of what constitutes reliable or useful knowledge in a co-design process" [18,22] to engender mutual learning and equitable cooperation [23].

Some see Franks Tract as "nature" or "natural." Some understand Franks Tract, colonized with a fluctuating mix of native and introduced aquatic weeds, as ecologically broken. Those that rely on South Delta exports and diversions perceive Franks Tract as a threat to water supply reliability. For others, Franks Tract is working just fine, and any State-led intervention is unnecessary or malicious meddling: "If it ain't broke don't fix it". These and other ontological differences are part of the 'politics of nature' that defines many conservation challenges in the Anthropocene [24] in general and the Anthropocene Delta [25] in particular.

1.2. The Need for Co-Design and Effective Transdisciplinary Practices in Park Planning

Both national and state US park plans have a history of being imposed by outside actors with little to no regard for endemic inhabitants and their co-formative relationships to place, for example, Native Americans [26,27]. While there have been many examples of planners and designers of parks and protected areas considering affected communities, there remain many that have not [28]. There are several motivations driving a recent emphasis on public and stakeholder engagement. However, they can broadly be said to concern issues of social justice and ecological efficacy or some combination thereof, based on the understanding that communities affect and are strongly affected by park management [29]. Research on these social dimensions of parks has focused on collecting, analyzing and utilizing social knowledge. Methodologies include visitor counts, participatory mapping, surveys, interviews and focus groups, text analysis, meta-analyses, scenario planning, structured decision-making [30,31] and co-design.

Co-design broadly refers to designers and people and publics not trained in design, working collaboratively in the design development process [32]. In co-design, the team of participants design with, rather than for those who will use or inhabit the designed landscape, through meaningful and integral stakeholder engagement in the process [33]. We see co-design for parks and protected areas as challenging opportunities to improve upon transdisciplinary processes [34], in that a successful process must integrate and share knowledge from a variety of disciplines (such as engineering, design, social and physical sciences), with the knowledge and values of locals, publics and other stakeholders [35,36].

When properly employed, design research [37–44] can expose differences within the affected communities themselves, and find ways to integrate and design for those differences, especially in complex cultural landscapes with diverse social actors [6,37–39]. However, faulty or insufficient research may fail to discern differences [39,40]. False ascription of homogenous non-scientific perspectives, while perhaps convenient, can threaten the trust necessary for transdisciplinary collaboration. Grappling with difference is harder, but necessary for socially just and ecologically efficacious co-design [41].

Planners, designers, and managers have used participation geographic information systems (PPGIS) as one method to give voice to diverse user values in park and conservation planning [42,43]. Brown and Weber describe PPGIS as, " ... the practice of GIS and mapping at local levels to produce knowledge of place" [44]. PPGIS was developed to engage and empower user communities, especially marginalized populations [45], and deepen understanding of perceptions, preferences and spatial issues [46]. However, effective public participation can be challenging due to uneven power relations, level of participation, technological access and experience [47,48]. Moreover, as with other participatory methods, PPGIS can be "superficial, obligatory, or token" if no broader, meaningful engagement is encouraged by planning proponents [45]. These challenges persist despite methodological advances, expanded options and greater acceptance by academics, practitioners, and the public [45].

SoftGIS refers to an online PPGIS survey approach developed in response to some of the identified challenges associated with PPGIS, particularly the one-way interaction between communities and planners [49–52]. The "soft" refers to subjective, qualitative and experiential local knowledge as opposed to the "hard" knowledge of technical professional expertise [49,52]. A rationale for softGIS is that attaching soft knowledge to place by means of a planner-produced map-based survey renders it legible and thus usable in a planning context, where it can be processed alongside other spatial information [49]. For our purposes softGIS had the additional appeal of supporting relatively easy survey set-up and online data visualization. SoftGIS has primarily been deployed in urban planning contexts, however, it is applicable to conservation contexts [53], as well as park planning [49,50], as we will show.

Structured decision making (SDM) is a participatory decision analysis support tool that is considered a conservation social science method [31] and has been used by park planners [54]. SDM relies on clearly articulated objectives, recognition of scientific prediction and uncertainty and the transparent response to societal values to guide decision making [55]. SDM integrates technical information with value-based deliberation and seeks to provide a clearer picture of tradeoffs and uncertainties associated with complex decisions. Most importantly, the SDM approach focuses on reciprocal co-learning and knowledge production for all involved in the project.

The Franks Tract Futures planning effort highlights an innovative application of SoftGIS (in the form of map-based surveys), choreographed into a mixed-methods SDM process to create diverse knowledge for the co-design of a complex and politically fraught park landscape. Our effort proceeded with an awareness of some of the critiques of collaborative and communicative planning related to neglecting power and difference [56]. While we were drawing from established urban SoftGIS approaches, our application was adapted to the parks, public, and infrastructural context of Franks Tract as well as its diverse stakeholders and their varied familiarity with the process. Thus we created survey questions that were widely accessible, and assumed limited project background. While charting a path for collective future action and place remaking, the process and tools also gave representation to ontological differences and 'uncommon' understandings of what the park is or could be and applied those differences, rather than suppressing them.

We write as researchers and designers who participated in the Franks Tracts Futures planning effort's engagement and co-design components. While together we have more than a decade of experience working in the Delta, we began without any significant personal or research-related connection to Franks Tract. When planning and designing with Franks Tract, we recognize that we are engaging a wide array of people, including those who see Franks Tract as central to the way of life and livelihoods. We also sought to engage with, or at least consider potential or prospective users, such as those who might frequent Franks Tract should public access options expand or new recreational features be created. We recognize there is no way of determining this stakeholder population, and thus no way of conducting representative sampling. However, we did assume, based on previous experiences in the Delta, that stakeholders would hold particular sets of interests and many perspectives not held in common about what Franks Tract is, its past and its potential futures.

2. Design Research Methods

In this section, we detail the SoftGIS and other co-design research methods that were applied in the FTF park planning effort. We describe these methods in relation to the process, timing and sequencing of how they were developed and deployed. We feel this is the most effective way to detail the methods, since the FTF case study is useful both in terms of what it did and did not do well (it got off to a difficult start), and to detail how learning and adaptation might occur in transdisciplinary co-design efforts.

2.1. Survey 1: First Feasibility Study

Public engagement for FTF began with an initial Franks Tract feasibility study of a previously developed State plan for Franks Tract. The first survey was conducted from 12 December 2017, through 22 April 2018, after the inadvertent public release of the State plan, and thus captured responses to that design concept. The process was backwards, from a co-design perspective, as the design preceded public and stakeholder output. In developing the survey, we intended for it to provide insights into the demographics and landscape values of a substantial group of people who live, work and play in and around Franks and Little Franks Tracts. (Community perspectives had been gathered as part of a 1985 State Parks planning initiative entitled the Optimum Plan [10]. Prior to that, there were community perspectives gathered as part of the writing of the State Parks general plan for Brannan Island and Franks Tract (which remain co-managed) [57], and as part of a Parks general plan for Brannan Island and Franks Tract (which remain co-managed) [57], and as part of a February 25, 1972, California Senate hearing on Natural Resources and Wildlife [58]. However, little information existed on present-day use). These insights would aid the design refinement of a project that recognized the multiple values of Franks Tract. Thus instead of creative input, we largely received critical feedback on a design concept that only met narrow, state defined criteria, actualized in a manner that was perceived as detrimental to those who live, work and recreate in the area (We attribute the large response numbers, relative to other surveys conducted in the area, to the availability of the early design plan, and the strong response it generated).

The feasibility study recognized its flawed process whereby public engagement came after plan formulation. As part of this recognition, the study highlighted an alternative plan developed by a local resident that was fostered by our outreach and interview efforts. The limited but positive reception of the "locally proposed alternative" indicated the potential for a design that addressed certain local concerns. The study's recommendations, supported by the Delta Conservation Framework, which was being developed simultaneously, called for early, consistent and transparent public engagement in any future co-design/co-planning process [59].

The feasibility survey was complemented by a series of in person, semi-informal interviews with multiple stakeholders, wherein we were able to ask similar questions, but also had the chance to ask follow-up questions and questions prompted by the online survey. The survey was anonymous and any identifying information that was provided was erased prior to analysis (Data was collected in a Google Sheet that was synced to the live Google Form. The Google Sheet was converted to .csv and .xlsl for analysis in various platforms including Excel, Qualtrics, MaxQDA, Kepler.gl, and R. Each tool allowed for a different view of the data and we found that using one would raise certain questions that would inform our use of the other. After considerable experimentation, we decided to use Qualtrics XM and RStudio 1.1.463 for the majority of the quantitative and qualitative analysis. The geospatial analysis was conducted in Kepler.gl and Excel 2019). Quantitative analysis was conducted using Cross Tabs in Qualtrics and pivot tables in Excel. Self-defined user category was the primary variable used to group responses. Analysis of quantitative variables such as age, length of relation to Franks Tract, and visitation frequency was then conducted within and between groups). See Appendix A. for initial feasibility study survey results.

Our recommendation at the end of the feasibility study stated that the, "community is wary of significant change to the region as well as any top-down decision-making that does not take their interests into account" [60]. And that "local communities are highly interested in being involved in the design and planning process for any potential changes to Franks and Little Franks Tracts" [60]. The study resolved that "more detailed restoration planning will take into account the social, economic, and recreational interests of the affected local communities and user groups" [60]. Reflecting on the conclusion of the feasibility study, we noted that the value of the survey remains contingent on the willingness and ability of facilitators, designers, planners and managers to integrate this information into this next phase of thinking about the coevolution of Franks Tract and the diverse group of people and communities who have a relationship to it.

2.2. Survey 2: User Survey

The second survey was part of a follow-up, and highly revised planning effort built upon the lessons learned from the previous efforts (see Figure 2). The survey was conducted from 11 July 2019 through 13 September 2019.

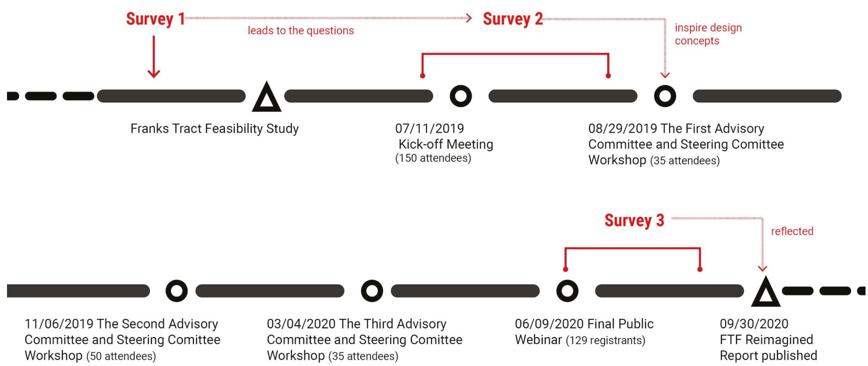


Figure 2. Survey sequence diagram showing the location of the surveys in the overall project timeline.

The primary focus of the second FTF planning effort was determining if a multi-value project could be designed to benefit local and regional communities (by addressing concerns raised in the first effort and via the creation of recreational amenities), and to minimize detrimental impacts of the project to these same communities, while still meeting ecological and water quality goals. The FTF engagement process started in June 2019 and ended in September 2020 (For more information see Final Report Appendix A. Public and Stakeholder Engagement: https://ucdavis.box.com/s/hl3qpglcu9ibf919sfby1txeb8qu6unl). The effort began with creating a steering and advisory committee, which participated in regular design charrettes and reviews. At the packed, public kickoff meeting (approximately 150 attendants), the team openly solicited feedback on the objectives of the project, described the structured decision planning process and expressed a commitment to meaningful engagement with the public to co-design the project design concepts.

The project team pursued this design challenge by engaging the public and stakeholders throughout the design process. During the co-design process, a diverse group of experts in different realms were involved in the design development, including engineers, scientists, public agency representatives, boaters, fishers, hunters and local residents and business owners all contributing their own knowledge of the landscape as well as unique, i.e., uncommon, perspectives. The project team used multiple engagement methods, including two map-based surveys and a non-map-based survey, iterative stakeholder-driven research by design, group and individual interviews, and two public meetings, including a webinar necessitated by COVID 19 restrictions on public gatherings.

Structured decision making (SDM) was used as a decision analysis tool to develop and evaluate performance criteria related to these multiple interests and concerns. The SDM approach was also used to guide and integrate technical design and engagement results during planning. Design and engagement results were integrated using a research by design [61] approach in which design concepts were iteratively refined and narrowed down through inclusive rounds of review by participants, including advisory and steering committee members. Refinements occurred primarily during in-person meetings with the steering and advisory committee. Public meetings provided another opportunity for broader public participation. Map-based surveys were the primary platform for public participation in the co-design process. Surveys were conducted at the start and finish of a second planning round, after initial comments from the public kickoff meeting were integrated.

The user survey, launched at the public project kickoff meeting, was intended to collect information on where and how people recreate in Franks Tract and identify areas of Franks Tract that were deemed to need improvement and where tidal marsh might optimally (or least detrimentally) be located within the shallow lake. After extensive research on map-based survey platforms we selected Maptionnaire, "an advanced example of PPGIS methodology enabling the mapping of environmental experiences, daily behaviour practices and localised knowledge and ideas for spatial development" [50]. See Appendix B for a link to the no longer active survey (Quantitative analysis was conducted in google sheets and Excel. Spatial analysis was conducted in ArcGIS Pro 2.6.1). We chose this platform, in part, because it allowed for intensive customization and data transferability across other software platforms, per our specific needs. Asking demographic questions, informed by the previous feasibility survey, enabled an analysis of the relationship between demographic variables, such as age, income, area of residence, user category and perspectives. The maps created from this survey are crowdsourced and user-drawn rather than primarily authored, and composed or decided on by the consultant team (Figure 3). We also asked participants to rank concerns and state their perspective regarding climate change in relation to Franks Tract.

The project team used the information solicited from the second survey to revise design features, which were then presented and discussed in the following design charrettes and later publicly on the project website. During the design charrettes, steering and advisory committee members had another opportunity to modify the designs and ask questions.

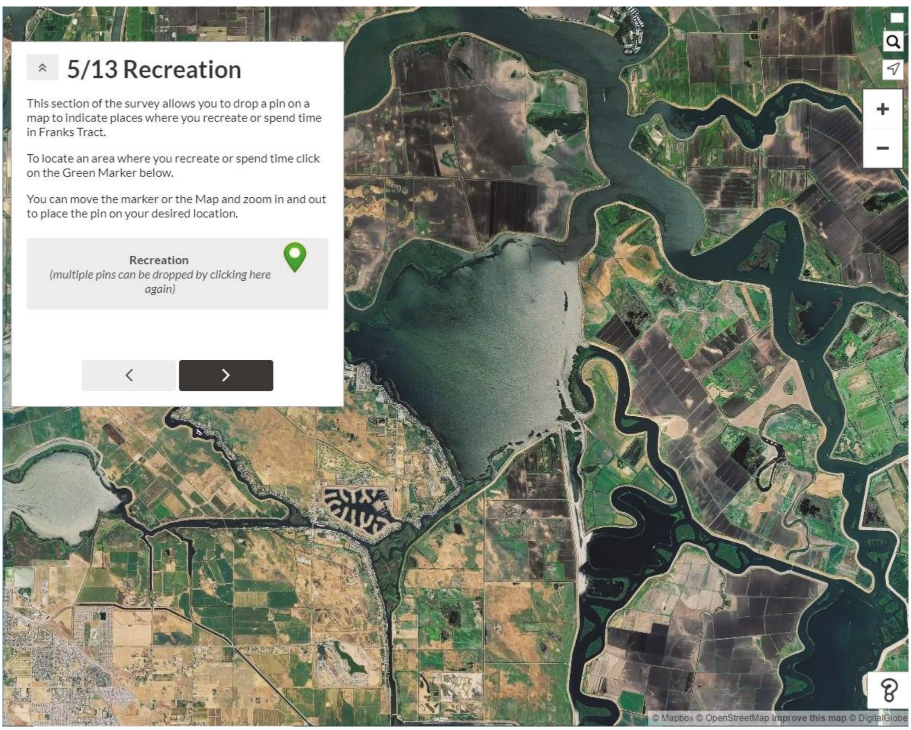


Figure 3. Image of the user survey interface.

2.3. Survey 3: Design Concept Survey

The design concept survey gathered feedback on three design concepts that were developed with input from the previous survey, and the FTF advisory and steering committees. Before taking this survey, we encouraged participants to attend or watch a recording of a live webinar (129 registrants), which presented all the design concepts and how they were developed.

We designed the design concept survey using an updated version of the same Maptionnaire platform for user familiarity. Photographs, rendered images, flyover videos (See Appendix D for links to concept flyover videos), and links to the previous survey results were embedded within the survey to provide project background and give a better sense of the proposed concepts. The survey was designed to allow participants to indicate what they like, didn't like and ask questions spatially.

After placing a like or dislike pin, follow-up questions related to location and access were asked in order to discern the reasons for liking or disliking a feature more clearly. A question pin could also be placed by participants to ask about a specific location or feature (Figure 4). The third survey also contained a final question where participants were asked to rank the design concepts and no action alternative. See Appendix C for a link to the defunct design concept survey. (3D models of the designs were created in Lumion 10 to produce animated flyovers. Detailed still renderings of site features-such as beaches, day use areas and waterfowl hunting ponds, were finessed in Adobe Photoshop CC 2019. Quantitative analysis was conducted in google sheets and Excel. Spatial analysis was conducted in ArcGIS Pro).

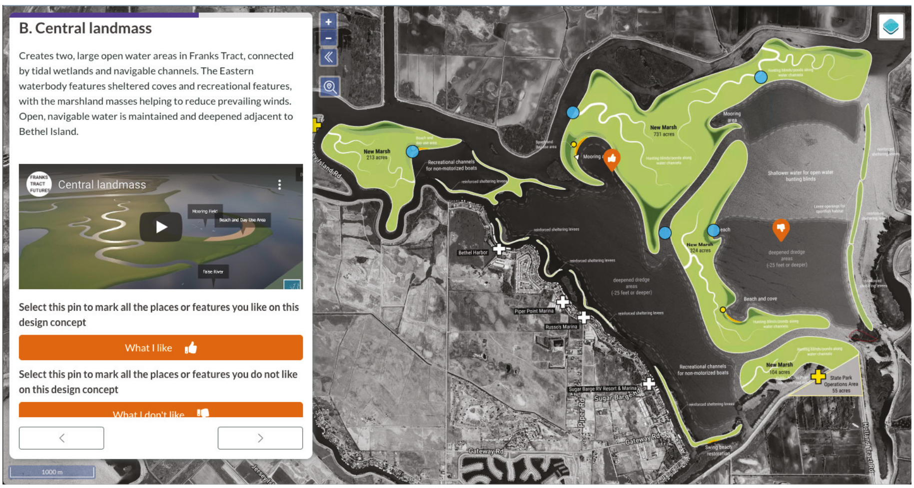


Figure 4. Image of the design concept survey interface.

3. Results

3.1. Survey 1. Feasibility Survey

Feasibility survey results provided a picture of participant demographics, the majority of which are older, local and identified as the boater or angler category (Figure 5). The majority of participants provided a local zip code of residence; however, participants were distributed across California as well as adjacent states. The presence of participants on Franks Tract is seasonally influenced and dependent on type of activity and affiliations, but overall is heavily used and recreated in year-round, with activity highest in the summer (Figure 6). Of note, approximately 45% of survey respondents (308 of 728) were firmly against the project, and preferred that Franks Tract be left as it is.

Extensive qualitative survey results captured the strong response to the initial state proposal map (Table 1) and a widespread desire for Franks Tract to be left alone (Table 2). Survey responses were coded inductively for themes and subthemes, although there were similar themes from the previous survey. The subthemes included in Tables 1 and 2 include major concerns that emerged through other modes of engagement.

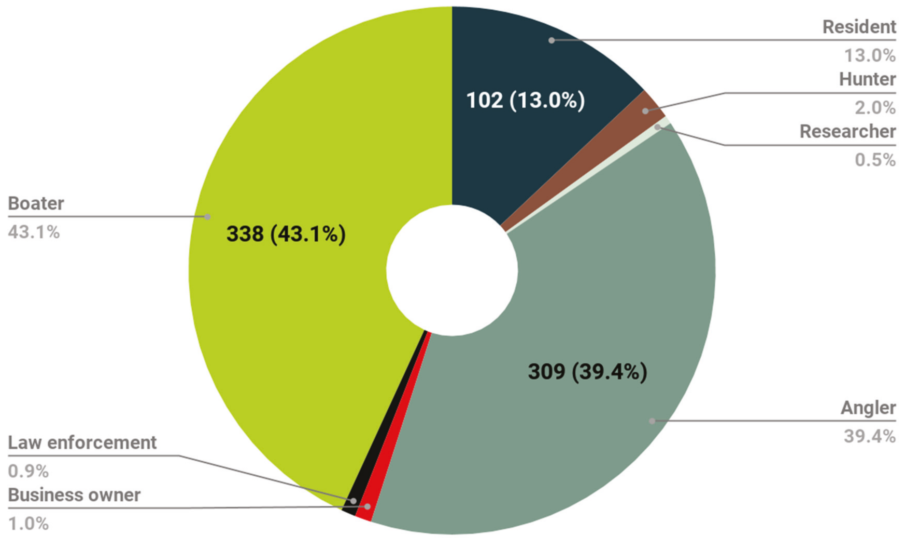


Figure 5. Which user category do you identify with most?

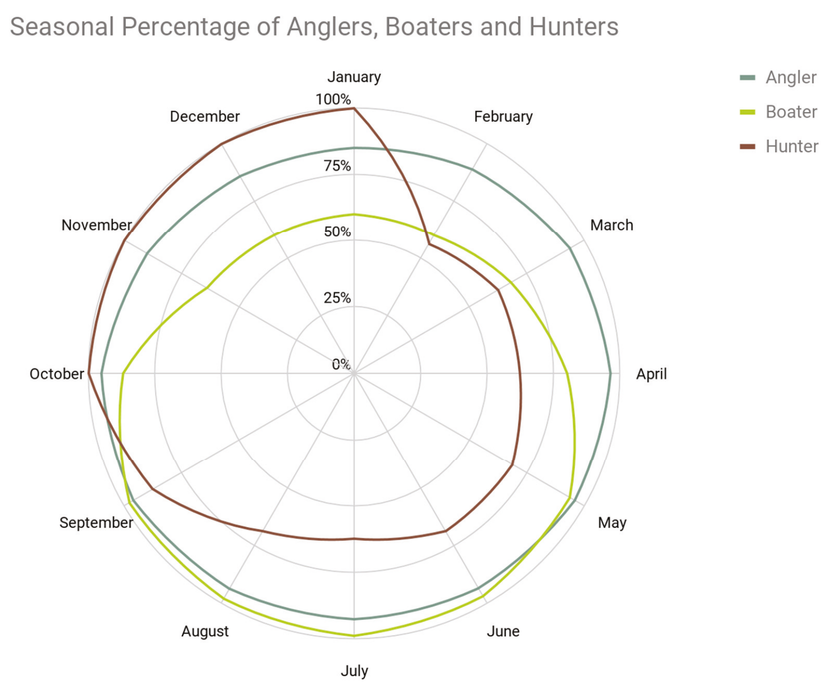


Figure 6. Calendar chart derived from categorized responses to the question: In what months are you out in Franks Tract or Little Franks Tract? Note October through November corresponds to the duck hunting season.

Table 1. Select sampling of state distrust/dissatisfaction survey responses.

Subtheme	Examples (from Multiple Respondents)
Water grab	We need protection from Southern California water grab schemes. The tract has been and should continue to be a natural water resource. Any plans to alter or convert the tract so that more water can be exported needs to be strongly resisted. We need to institute long term restrictions on any and all "PLANS" for development and/or conversion of Franks or Little Franks Tract for other uses than are currently in place.
Economic impacts	What's going to happen to the Bethel Island Marinas when you wall them off? Poker runs will no longer be stopping at Bethel Island and the bass fishing tournaments that go out from Russo's or Sugar Barge will dwindle down to none. The restaurants and marinas that will be walled off from Frank's Tract won't get the business anymore. Those businesses support Bethel Island and give people a reason to come out here and buy homes here. Our local businesses will be negatively impacted and our property values will be impacted.
Government inflicted harm	If Mother Nature plays a roll it will thrive... if the government keeps spraying an using pellets to kill off the grass it definitely does damage I can't believe you are considering filling in so much of a designated State Recreation Area, known throughout the U.S. as one of the primo bass fishing sites.
Non-intervention	Franks tract does not require a design or any management, save waterfowl blind placement. It should remain as it is and has been for my life. Little franks tract should be opened to waterfowl hunting, just like Franks tract. It is currently a wildlife sanctuary of some sort, all the signs are gone now. Please do not attempt to add islands or camping or anything else here. Some things are better left alone. These two very special places fit in that description. If the state can keep their hands out. I see mother nature reclaiming the area as a tidal marsh.

Table 2. Select sampling of "leave it alone" survey responses.

Subtheme	Examples (from Multiple Respondents)
Nature	leave it alone! It's natural nature! Leave it alone and let nature take care of itself like it has for the past 20 years. let nature take its course, leave it alone Don't change a running system-preserve a piece of nature as it is! Do not change the natural landscaping! I would suggest that these areas and others remain untouched by human hands!
Human intervention	Let nature take care of herself with out mans interference Leave it alone, except in cases of safety. Man tried to impound it before, nature took it back.
Design	Design? Manage?, Just leave it be. Design? Don't design it. Leave it alone but maintain boater access

3.2. Survey 2. User Survey

User survey results reassessed user demographics and types from the previous survey, and created new knowledge of geospatial use patterns in and around Franks Tract as well as divergent perspectives on Franks Tract's potential futures. See Table 3 for main geospatial takeaways and associated figures.

Table 3. Main geospatial takeaways.

Main Geospatial Takeaways	Figure Number
Activities are diverse and occur throughout the Tract. Primary activities are boating and recreational fishing.	Figure 7
The Tract is a major boating hub and includes highly trafficked routes that leave and return from Bethel Island destinations and routes that traverse the Tract to and from locations outside the project bounds	Figure 8
Public access was desired, especially along the shoreline	Figure 9
Respondents indicated that many parts of the Tract need improvement	Figure 10
Tidal marsh preferences appeared to overlap most in the Northeastern portion of the Tract, farthest away from Bethel Island homes and business	Figure 11

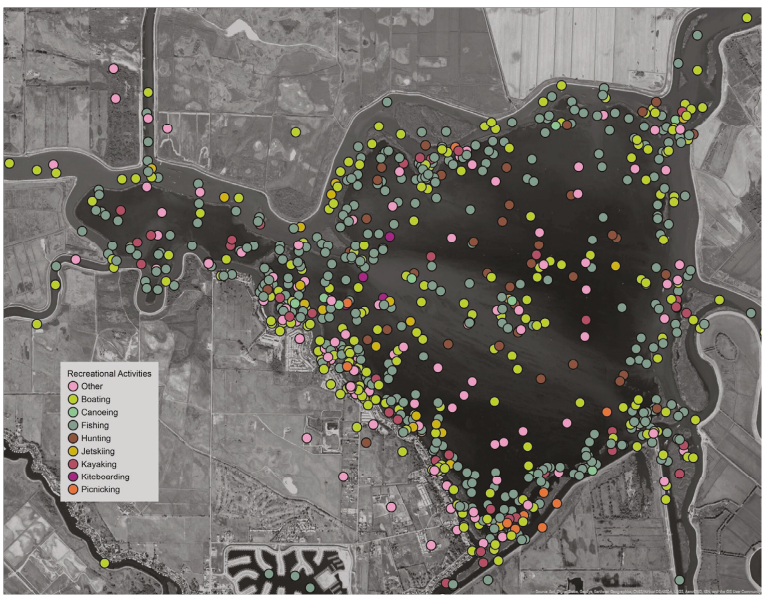


Figure 7. If tidal marsh areas are created in Franks Tract, where would they be best located? Where would they have the least detrimental impacts and greatest amenity value (such as new hunting opportunities, wildlife viewing, non-motorized boating, etc.) for how you and others use Franks Tract? How could tidal marsh be designed for recreational uses (I.e., hunting, fishing, kayaking, boating)?

The user survey had roughly the same demographic composition of participants as the feasibility survey. The user survey results related to activities and desires validated those of the feasibility survey and other methods of research and engagement while adding a spatial dimension that could more directly inform concept co-design.

The results from the public access-related questions both indicate (spatially) where public access is desired and allude to a tension between those who support greater public access (51.6%) and those who do not (48.4%). The relationship between distance from Franks Tract of participant's zip code and their public access perspectives proved statistically insignificant. However, a tension between locals and visitors became evident in later design charrettes, primarily related to the impact of new, free public access on existing businesses on Bethel Island that charge for access.

Results indicate the persistence of concerns related to the site and smell of tidal marsh that were raised in the initial feasibility study. Desired locations tended to be located in the Northeast of Franks Tract furthest away from the waterfront residence and business on Bethel Island, as well as in Little Franks Tract.

The map-based questions' results were directly integrated into the iterative concept design process, particularly the siting of public access, the preservation of highly trafficked boating routes, and the general preference for marsh placement in the North and Northeastern portion of Franks Tract. The geospatial data was analyzed in ArcGIS Pro and the preliminary results were presented in the August advisory and steering committee meeting before the design charrette. By overlaying the results on top of each other as semitransparent layers, a strong correlation showed up in terms of improvement areas (Figure 11) and preferred marshland best locations (Figure 12).

Figure 8. (**a**) Tidal marsh survey responses. (**b**) Superimposed on preferred alternative.

The visualizations of the first survey sparked conversation of meeting participants, allowing for more thinking on the pros and cons of proposed marshland configurations. The geospatial result was compared with other sources of spatially explicit knowledge that was co-produced during design charrettes and stakeholder interviews, and was also made available to the public through an online interactive map hosted on the project website. These maps allowed users to explore both the spatial data (points, lines, and polygons) and the associated qualitative data (map-based comments). Sharing the data in this way increased transparency and trust building, which is a critical factor in engendering equitable PPGIS approaches [50].

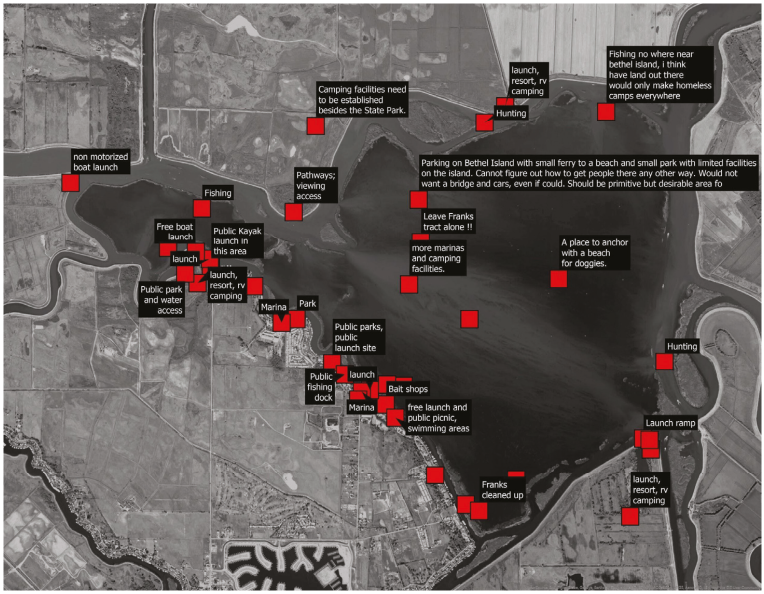


Figure 9. Where do you recreate and what activities do you do at this location? Results indicate the diversity of recreational uses and their use patterns across Franks Tract. Fishing appears to be most common along the vegetated remnant levees, which was validated in conversations with local anglers.

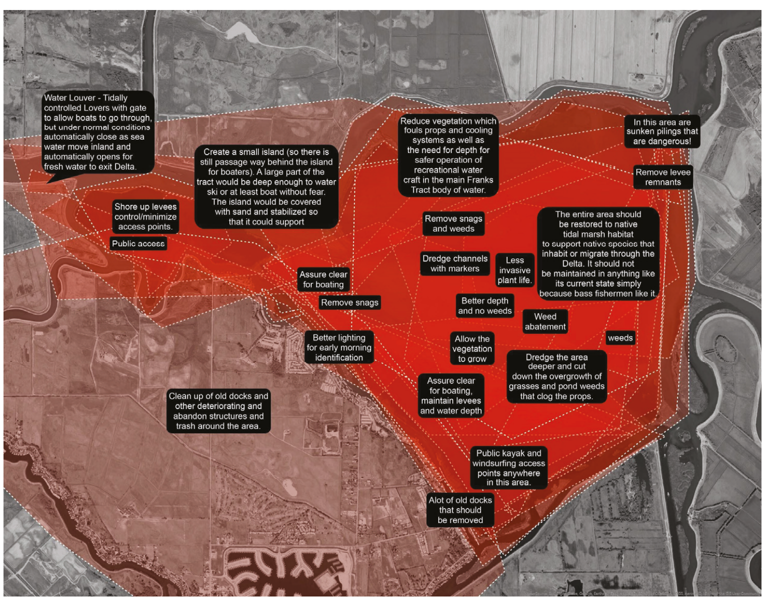


Figure 10. What are your regular boating routes across and within Franks Tract? Results indicate that Franks Tract is a major boating hub for both trips within Franks Tract as well navigation in the greater region. Results also reveal distinct traffic flow patterns across and within Franks Tract itself.

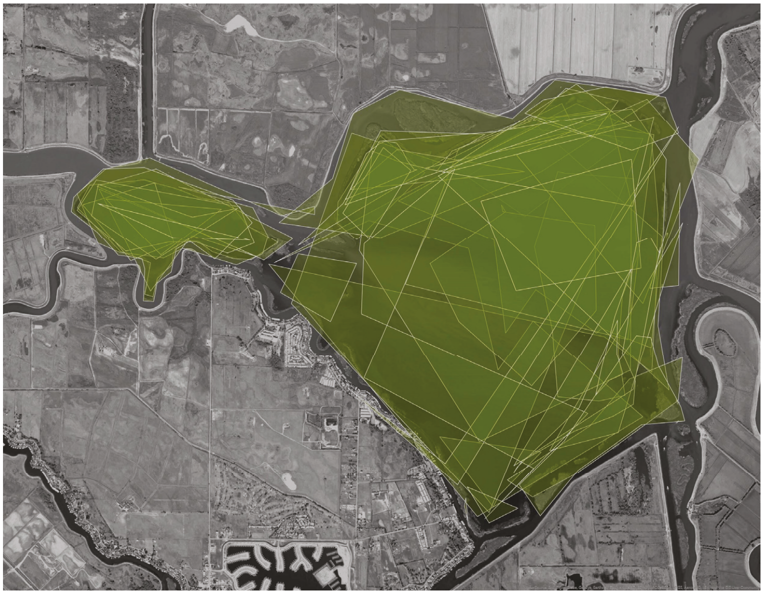
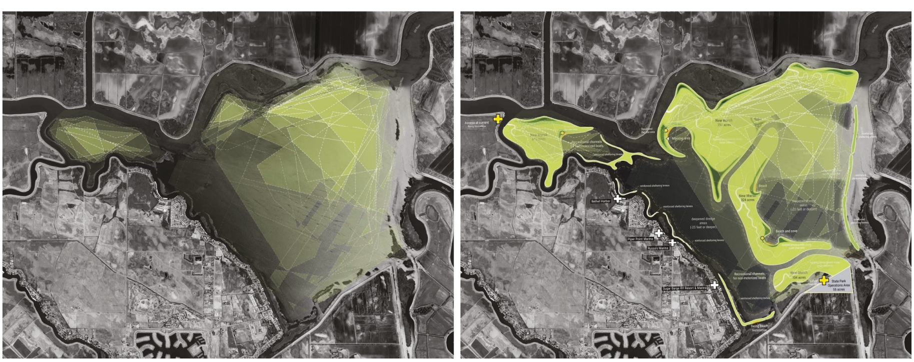


Figure 11. Where are desired sites for public access? What would you like to see? Results indicate that public access points are desired throughout Franks Tract, especially on the Bethel Island shoreline on Franks Tract's West side. Common types of access included non-motorized and motorized launch sites as well as general public access to the water, which is non-existent currently. Contradictory opinions were presented at a later design workshop by Bethel Island residents and business owners.



(**a**) (**b**)

Figure 12. Where are the areas in Franks Tract that most need improvement? What improvements can be made? Results identify many types of desired improvement throughout Franks Tract, with some comments in opposition. Common improvements include addressing boating hazards (which includes removal of weeds, snags, submerged levee remnants and deepening of shallow areas).

3.3. Survey 3. Concept Design Survey

Concept design survey results include substantial and detailed consideration (likes and dislikes) of the design concepts. This result alone represents a significant change from the feasibility survey, where nearly all the comments on the plan were negative. Participants still voiced similar concerns as those collected in the feasibility survey. However, there were also new concerns and detailed design questions (such as placement of features, the design of tidal marsh to optimize recreational and ecological benefits) that indicate an investment in a future for Franks Tract other than the continuation of a status quo.

The above figure (Figure 13) represents the average comparative ranking for each concept scenario, with 4 corresponding to the lowest ranking and 1 corresponding to the highest on average the Design Concept B (Central landmass) was the highest ranked (2.35). The NAA (No Action Alternative) was the lowest-ranked (2.66), but only by a small margin with Design Concept A (2.60). (Open water berm and channel) only closely ahead, and Design Concept C (Eastern Landmass) slightly more preferred (2.49).

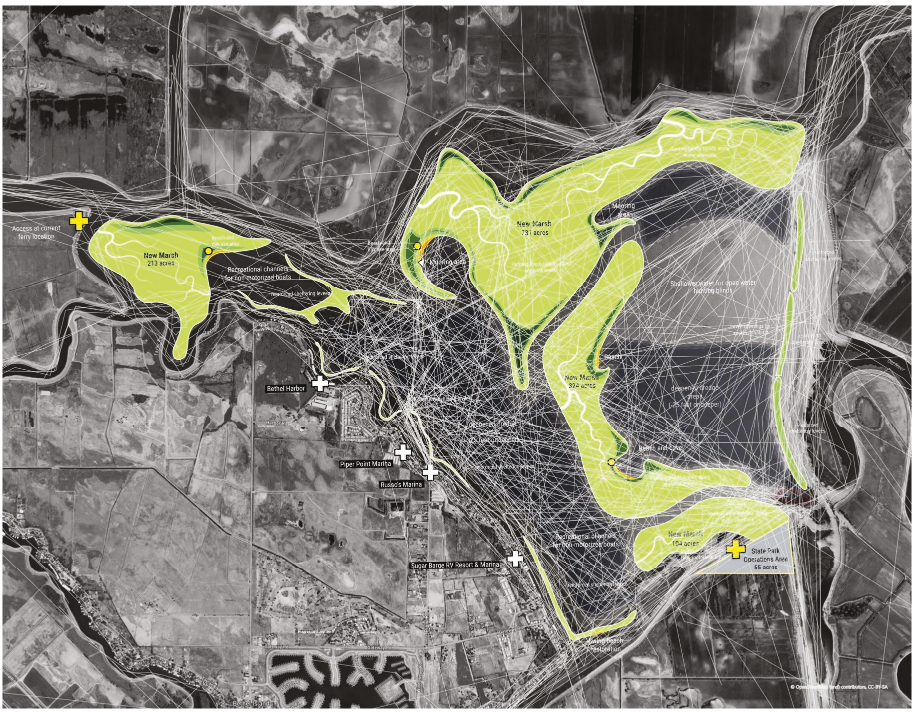


Figure 13. Boating route survey responses (white lines) superimposed on the preferred alternative.

What is notable in the design concept survey is that there was, on average, similar support across the NAA and the design concepts (Figure 14). Such similarity implies that there was considerably more 'most preferred' voting for the design concepts (collectively) than for the NAA. Specifically, although 36 (39%) respondents chose the NAA as their most preferred option over two times as many (75) selected at least one of the three design concepts as their most preferred, suggesting significantly higher preferences overall for the design concepts over a NAA.

Supportive comments for the NAA focused on unique features such as open water, spawning areas, fishing, hunting, good flows and access. Some respondents were concerned that these features might be lost or diminished if a project were implemented.

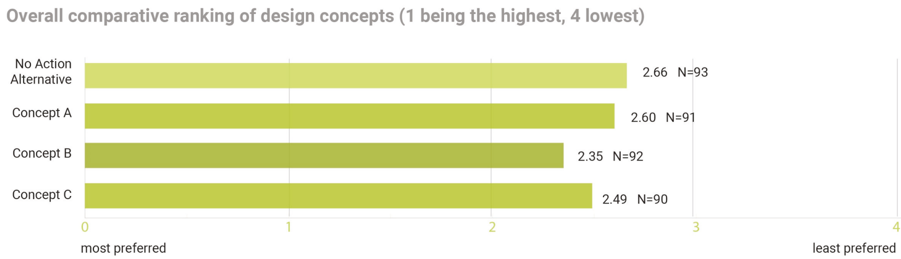
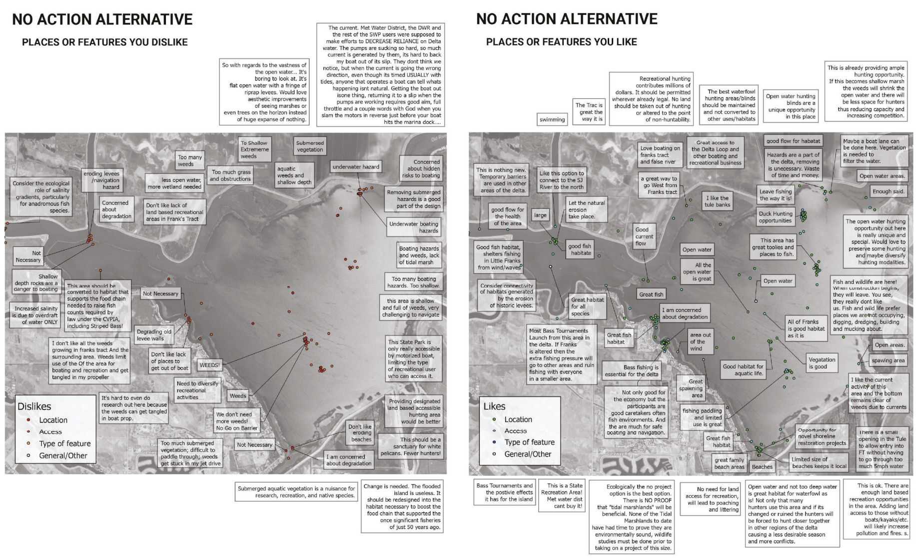


Figure 14. Overall comparative ranking of design concepts.

However, there were also supportive comments regarding potential modifications with the design concepts that could enhance these unique existing features, address current concerns and create new opportunities based on improved navigability, additional features and the general diversification of Franks Tract (Figure 15).



(**a**) (**b**)

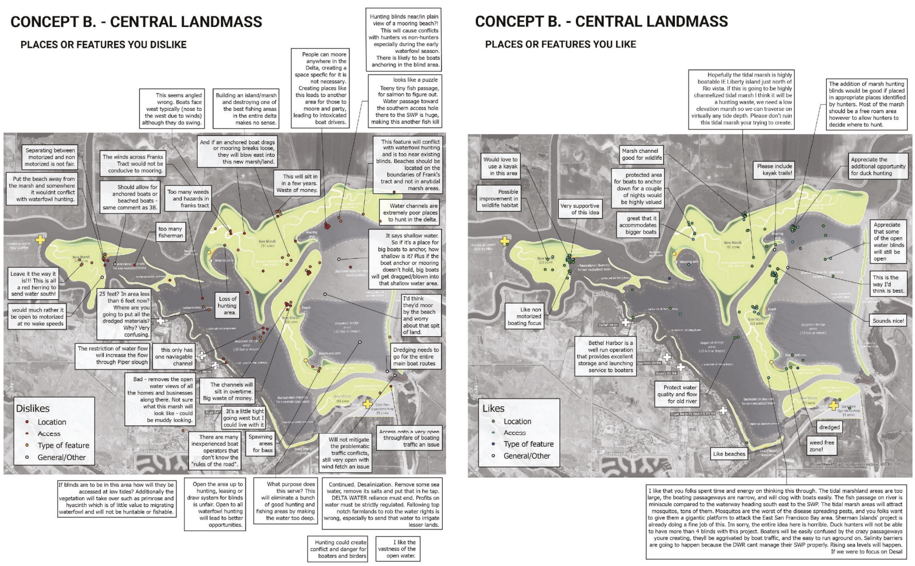
Figure 15. No Action Alternative (NAA) community comments. (**a**) Places or features you dislike for NAA (**b**) Places or features you like for NAA.

Beaches were a common liked feature across the design concepts. However, there were concerns voiced about their proximity to hunting areas and their potential to become too popular and thus an attractive nuisance. There was a recurrent concern voiced regarding the channel widths and navigability in the design concepts. Comments to this effect included potential problems with inexperienced boaters, the narrowness of the channels and the hazard created by adjacent tidal marsh. There were also concerns that channels would silt in.

In general, there was widespread support for the proposed modifications to Little Franks Tract (which were the same across all design concepts). There were concerns raised about the potential exclusion of motorized boats in the area. Some thought this unfair, while others questioned the accessibility of the area for non-motorized boaters. Others were supportive of the idea of a portion of Franks Tract in which motorized boats are excluded.

There were many comments across all concepts related to hunting. Several voiced concerns about the potential eradication of existing hunting opportunities, where others appeared supportive of new marsh-based hunting opportunities, often contingent upon the resolution of access issues, and the inclusion of hunter preferences in the marsh habitat design. There were also concerns about the potential conflict between hunting and other recreational activities, especially where hunting and recreational features might be nearby.

Comments diverged regarding the benefits of creating marshlands and dividing Franks Tract into two separate water bodies (Figure 16). While many supported the idea based on improved navigability, habitat, and recreation, others were concerned about navigation, local businesses, aesthetics and existing recreational opportunities. Participants commented on mosquitoes and the marsh smell, which had come up in previous surveys and elsewhere in the process.



(**a**) (**b**)

Figure 16. Concept B (the preferred concept)-Central Landmass community comments. (**a**) Places or features you dislike for Concept B (**b**) Places or features you like for Concept B.

As with the second user survey, geospatial results were shared with the public through an online interactive map hosted on the project website. Ranking results were also included. These results were shared shortly after the release of the final report, and although they were not integrated into the final designs, they are now available to the public and other stakeholders and can be used to inform future design development.

4. Discussion

The approximate demographic makeup of survey participants was consistent and similar across all three surveys (Figure 17). The majority of the participants were local, and most participants categorized themselves as boaters or anglers, which we understand to be the most prevalent Tract activities.

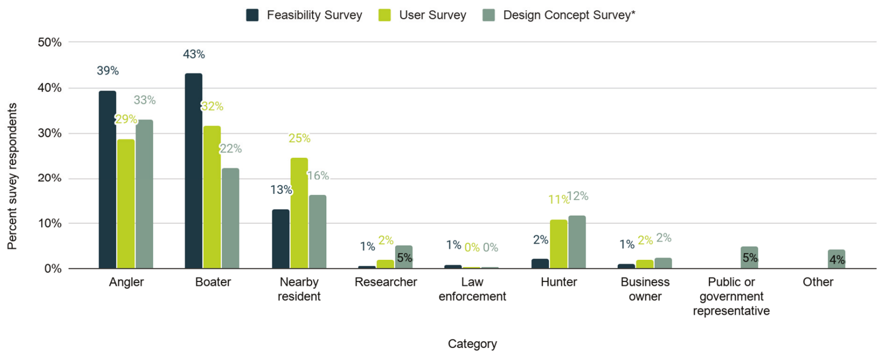


Figure 17. Comparing participant categories across surveys.

These surveys were some of our primary means of co-creating knowledge with a very broad public, and were combined with public and stakeholder meetings, design workshops, social media and other forms of stakeholder engagement. Echoing Kahila-Tani et al., these map-based surveys [50] were an important tool for the deliberative phase of a sensitive and complex planning project. Making the collected data visible allows for and catalyzes collective analysis and debate, during which for all involved, planners and the public alike, assumptions can be questioned, and perceptions can shift.

To our knowledge, no prior survey has been performed targeting those who live, work and play in and around Franks Tract. What little information exists from past surveys indicates that those who responded to our survey are quantitatively distinct from the average Delta recreationalist. Past engagement with Franks Tract users indicates a concern with safety, conservation, and recreation that resonates with the concerns of our survey respondents [10,58]. Our response numbers were substantial compared to other surveys conducted in the region. Whereas past surveys focused on regional boating and recreation [62–64], ours were more geographically specific and sought to identify broader use trends as well as perspectives related to landscape change.

We recognize we have no way of knowing whether we surveyed a representative sample of those who live, work or play in Franks Tract currently or may be inclined to do so in the future. We used an aggressive, multi-pronged approach to dissemination that included local and regional canvassing, social and conventional media, duck hunting forums and direct emails to hunting permit holders. Yet based on comments on social media and responses to the draft report, there remained some people who are unaware of the project or its particulars. Additional follow-up approaches to reach these people were not attempted due to time, limited financial resources and COVID-19 restrictions on attempting in-person survey methods.

Given our dissemination approach, we cannot discern a response rate. However, we did see decreasing participation numbers from survey 1 through survey 3. This decrease could be attributed to a variety of factors, including the length of time the surveys were open, which also decreased from survey 1 through survey 3, as well as accessibility associated with the map-based surveys (2,3). We also note the possibility that the decrease in participation could also be attributed to increased acceptance, or at least decreased outrage about the design of the project.

Looking across the sequence of surveys, we can observe a measurable shift in perspective away from a no-action alternative. The first survey unintentionally captured initial reactions to a remarkably unpopular State plan prepared without public input. When asked, "Are there any suggestions you have for the future design and management of Franks Tract/Little Franks Tract?" roughly 45% of participants responded that Franks Tract should be left alone. The second survey was launched at the beginning of a new round of public engagement and co-design. When asked, "What are your other concerns related to Franks Tract?" approximately 40% either expressed concern with a potential project or a desire for Franks Tract to be kept or left as it is. However, this survey also revealed more diversity in user opinions, as revealed when asked how Franks Tract could be improved or modified according to their desires, which resulted in a wide range of suggestions, some common and some not, and dissatisfaction with the status quo. The third survey asked participants to rank three design concepts and the NAA. Results showed nearly equal support across both the design concepts as well as the NAA. Though it is difficult to empirically draw firm conclusions from the surveys regarding increased acceptance of the project's ecological and water quality goals specifically, comments at project meetings and project presentations with stakeholders, the public and the advisory committee highly support this conclusion as being expressed in the final survey responses. Specific to ecological goals, as these were expanded beyond the state's initial focus on Delta Smelt to a broader and equal support for additional threatened species (with commercial value) and sport fish, as well as upland species, like waterfowl for hunting, ecological goals gained more acceptance.

While the three surveys empirically showed demonstrable shifts in attitudes and movement towards proactive design interventions for Franks Tract (in contrast to the NAA) what we also consistently read across the surveys was ontological diversity-a plurality of realities and notions of what Franks Tract currently is to various persons and constituencies. Those plural views configured themselves around proposed changes to the landscape. There remains a strongly voiced contingency that rejects any intervention on multiple grounds, ranging from the conspiratorial who see a "water grab", whereby Delta exporters are seeking to take more water (through the improved water quality the project would provide), to the skeptics who want examples of similar successful projects before they can support a project in the place they love. There remains a contingency that sees Franks Tract as *Nature* and intervention as hubristic and doomed to fail.

There were certain features that were identified in the user survey and design charrettes that prompted considerable design effort, with input from the advisory committee members and technical support from project team members. One example is a particularly dangerous blind corner located in the Southeast corner of Franks Tract, where multiple navigation routes intersect and wave and wind action are prevalent. The results from the concept design survey indicate recognition of efforts to make this corner safer as well as unresolved issues. We bring this up as an example of the benefits of and need for sustained and iterative co-design as well as the importance of humility. Rather than seeing persistent concern as a failure, we embrace it as an indication of engagement.

There appears to be a growing contingency that sees the FTF project as a way to advance or enhance their interests, or at the least, arrest an undesirable decline. We see in the growth of this contingency evidence of what Seijger et al. refer to as the affective and informal "soft implementation" related to shifting prospects for change that precedes the "hard implementation" of more formal and detailed project plans [65]. If our observation is correct, this in itself would constitute a success based on the objectives and expectations for the planning process.

We feel it is important to emphasize that the learning and knowledge creation involved in this "soft implementation" was in no way exclusive to the public. The placement of the surveys throughout the planning process exemplify different approaches to knowledge mobilization that provide lessons for the project team and the agencies involved. The flaws of the feasibility study were clear in the results of the feasibility survey and provided the impetus for the more participatory approach of the user survey. The design concept survey reaffirmed a commitment to co-design and the results validate its efficacy. Each survey alone would have had limited influence. However, cumulatively the surveys created, mobilized and applied knowledge, in what we hope will continue to be an iterative cycle of reflexive co-design.

In this way, the sequence of surveys informed and contributed to an iterative co-design process. Although the surveys were not the only means of collecting information that informed the design, they were the most inclusive of a broader stakeholder public. Additional information was solicited from an advisory and stakeholder committee and consultation with biologists, recreation consultants, economists, engineers and hydrologic modelers. In line with Brown and others, we recognize these methods of engagement as critical irrespective of the PPGIS [45].

5. Conclusions

In their review of two decades of PPGIS application, Brown et al. argue that "the mapping of place values will need to become more than a spatial technology enhancement to public participation, but a political force that can compete against powerful interests that currently dominate land-use decision processes at multiple levels of government [47].

Our role in the Franks Tract project was to use co-design research methods to inform multi-value project design in a complex and contentious park landscape. We employed softGIS surveys to bridge identified gaps, related primarily to ease of use and accessibility, between many research-oriented PPGIS methodologies and the practices of meaningful participatory planning [51]. SoftGIS supported the iterative creation of relatively inexpensive surveys by members of the planning team as well as the creation of online visualization tools.

The surveys and co-mapping techniques deployed in the FTF project provided tangible, co-generated representations of Franks Tract as a contested boundary object. It did so within a larger, multi-faceted co-design process (that included meetings, design workshops, structured decision making techniques, iterative design development and modeling, etc.) that allowed for the consultant team and all involved to perform the needed work of "bridging boundaries between groups of people with differing views of what constitutes reliable or useful knowledge in a co-design process" [18,22].

Rather than suppress diverse conceptions of what Franks Tract is, ways it is inhabited, and what it may become, we sought to find ways that those realities and virtual desires could co-exist in new design configurations. The map-based surveys were strategically timed within the design process, generating spatially explicit public feedback when it was most influential and usable. These surveys co-created knowledge about what Franks Tract is becoming and could become without design intervention and provided space for more qualitative descriptions of preference and desires, informing and being informed by categorical and spatial responses. This feedback was incorporated with input from advisor and steering committee members and technical experts into a structured decision-making framework. The concept designs that emerged sought to integrate these shared understandings in the form of desired design features.

Yet despite structured decision-making efforts to include these understandings and transparently address conflict and tradeoff, there remains some skepticism of the designs based on different understandings of what the landscape fundamentally is and how it should be used and inhabited. Rather than seeing the persistence of ontological differences or understandings not held in common (i.e., uncommons) as a failure, we recognize their inevitability in such complex and contentious planning processes. Furthermore, we advocate for the inclusion of the uncommons in this and other consensus-building processes, and exploring the degree to which the spatio-physical design of the landscape can embody and facilitate this diversity.

Questions of representation associated with survey sampling remain. Our non-probability sampling methods, which included convenience, purposive and snowball, were required based on our judgment, due to an unknown and sometimes hard to reach population. While our surveys had a diversity of participants, we cannot know whether these participants represent the diversity and distribution of those who live, work and play in Franks Tract currently or may in the future. This issue will likely occur in other applied project-based planning research.

Based on our study results (and above caveats) we conclude that the potential for a co-designed, multi-value design concept for Franks Tract that can preserve and enhance existing desirable features, while also emplacing new values, is "feasible", and becoming more widely embraced by stakeholders [66]. For this reason, we see the combination of map-based surveys and structured decision making as a viable approach for the co-design of multi-value landscapes, including parks and protected areas.

The FTF futures effort was a conceptual feasibility study, though a very thorough and detailed one at that. To move forward, state agencies will have to build support for the design concept and find ways to fund construction and long-term maintenance for a massive, unique type of eco-social-techno infrastructure. Also, like other feasibility and landscape planning efforts, additional rounds of more detailed planning and design will need to happen if the project does garner widespread support. How this will all be approached and whether or not there will be fidelity to the final FTF report, remains to be seen. Will all the recreational features carry through? Will long term Park maintenance remain a priority? The indeterminacy of what will happen leaves us with many questions about how co-design processes and the trust, knowledge and understanding they build can be sustained beyond conception through construction and long-term stewardship.

Author Contributions: B.M. and A.K.-P. contributed to conceptualization and methodology; A.K.-P., B.M., Y.H. contributed to formal analysis, Investigation, and writing original draft preparation; B.M. contributed to resources, supervision, project administration, funding acquisition; B.M. and A.K.-P. contributed to data curation; B.M., A.K.-P., Y.H. contributed to writing, review & editing; B.M., A.K.-P., Y.H. contributed to visualization. All authors have read and agreed to the published version of the manuscript.

Funding: Funding for the Franks Tract Futures project was provided by the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84). Alejo Kraus-Polk and Brett Milligan were funded by the California Department of Water Resources under grant number 4600012167.

Acknowledgments: The authors would like to acknowledge that this project took place on the traditional lands of the plains Miwok in the Delta. We would also like to thank our fellow Franks Tract Futures project team members as well as the members of the steering committee, advisory committee and public for their trust, knowledge sharing and co-making of the FTF conceptual designs.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The survey appendix from the initial feasibility study can be accessed here: https://ucdavis.box.com/s/wexg2o6atl8jd6ikznbbkmq3wzua244s.

Appendix B

The no longer active user survey (survey 2.) can be found here: https://app.maptionnaire.com/en/6547/.

Appendix C

The no longer active design concept survey (survey 3.) can be found here: https://new.maptionnaire.com/q/62k27e2783g6.

Appendix D

Concept A flyover: https://youtu.be/DEEQ9Xh0amU; Concept B flyover: https://youtu.be/T6h9FxsRFVg; Concept C flyover: https://youtu.be/xJQi7AMSQCQ.

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Knowledge Mobilization in the Beaver Hills Biosphere, Alberta, Canada

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Received: 1 August 2020; Accepted: 29 October 2020; Published: 31 October 2020

Abstract: This study explores how knowledge was and is mobilized to advance the objectives of the Beaver Hills Biosphere Reserve, located in Alberta, Canada. Established in 2016, a 12-year collaborative effort worked to establish the biosphere reserve and achieve formal UNESCO designation. Subsequent efforts to grow the newly established biosphere reserve have accelerated in recent years. Our study documented how different types of knowledge were accessed, created, curated, and shared between partners during these two time periods. Focus group interviews were conducted with 14 participants, who are affiliated with Beaver Hills Biosphere Reserve partner organizations, and revealed the following findings: (1) not all knowledge is equally valued or understood; (2) partnerships are highly valued, and were essential to successful knowledge mobilization, but were stronger among individuals rather than organizations; (3) fear of the loss of autonomy and potential complications due to the establishment of a biosphere reserve slowed the exchange of information and engagement by some regional actors; and (4) knowledge mobilization is and was impeded by staff and agency capacity, finances, and time scarcity. This was further complicated by entrenched norms of practice, existing successful working relationships impeding the development of new partnerships, and embracing alternative forms of knowledge.

Keywords: knowledge mobilization; social science; natural science; local knowledge; traditional knowledge; indigenous knowledge; parks and protected areas management; biosphere reserve

1. Introduction

Biosphere reserves, whose objectives include biodiversity conservation, sustainable development, and capacity building in support of education, research and learning, provide a rich context in which to study knowledge mobilization. Centered on protected areas with strong preservationist and conservation goals, biosphere reserves lie within highly modified landscapes that host evolving and diverse livelihood activities and complex human–environment interactions. Typically, biosphere reserves are managed regionally, by park and other governmental agencies, environmental non-government organizations (ENGOs), research institutions and other partners. Biosphere designation recognizes the capacity to share and generate new understandings of the socio-economic and natural aspects of the landscape among these partners, to achieve regional, coordinated land management through collaboration. This complexity demands the application of different types of knowledge to achieve sustainability and ensure the continuity and celebration of the "sites of excellence" contained within these biosphere reserves. Studying how knowledge is mobilized to achieve biosphere reserve objectives can support the efforts of partners engaged in the collaborative management of biosphere reserves, and is the focus of this paper.

Knowledge mobilization is defined here as the movement of knowledge into active service for the broadest possible common good [1]. Knowledge may include findings from natural and social science studies, or humanities and arts-based research, the accumulated knowledge and experience of these researchers, or the accumulated knowledge of stakeholders and rightsholders concerned with the issues that the knowledge is being mobilized to address [1–4]. Knowledge exchange [5] is a term that is frequently used by environmental management researchers to represent similar actions and meanings. A wide range of activities can be encompassed by knowledge mobilization, but may include knowledge transfer, knowledge translation, knowledge management, knowledge production and creation, and knowledge action [3,4]. In this paper we discuss knowledge that is generated through scientific methods, informed by disciplinary traditions of agreed to principles or processes of study, including reliability and validity [6]. We also include other ways of knowing about the landscape, including the local experience of recreation, work, and residence within a specific ecological setting [3,7,8], traditional ecological knowledge (TEK) [9], and Indigenous knowledge. We consider local knowledge as distinct from TEK in that "the former has been derived from more recent human–environment interactions (e.g., a few generations) rather than being embedded in deeper cultural practices" [6]. We define Indigenous knowledge as local knowledge held by Indigenous peoples, or local knowledge unique to a given culture or society [10]. We acknowledge that Indigenous knowledge and TEK share characteristics, yet TEK has an explicit ecological emphasis [11].

1.1. Study Objectives

Through this study, our research team documented the diverse experiences of agencies and partners within the Beaver Hills Biosphere (BHB)[1], in their engagement with different forms of knowledge. The BHB provided an excellent case study location, given its structure and governance. The group includes federal and provincial park agencies and five municipal governments who manage lands within the BHB, as well as research, ENGO and industry organizations with active interests in the landscape. The BHB is a voluntary collaboration of these partners, and members participate as time and capacity allows, on working groups and projects contributing to regional and more localized management objectives. Such projects offer the potential to share knowledge generated and maintained through social and natural science, as well as Indigenous (i.e., Canadian First Nations and Metis), traditional ecological and local knowledge systems. We asked how park and conservation agencies, as a central component of biosphere reserves, as well as other land managers within the BHB, such as municipalities and NGOs are able to (or not) access knowledge when making management decisions. In addition, we focused on how the Beaver Hills Initiative (BHI) in particular used knowledge to create a biosphere reserve, inclusive of its eventual successful designation in 2016 (i.e., the BHB), supported by the knowledge mobilization efforts of its partners and how being a biosphere reserve allows for the ongoing use of knowledge mobilization amongst partners.

Study findings highlight some of the challenges and successes the biosphere reserve partners have experienced when it comes to knowledge mobilization. Our observations will assist the BHB, other biosphere reserves, and similar collectively managed landscapes in their efforts to achieve more effective and efficient [5] knowledge mobilization to attain sustainability and sustainable development.

1.2. Literature Review

Parks and protected areas must manage for a diverse set of goals, including protection, conservation, and visitor enjoyment [12]. The majority of parks-related scientific effort has focused on the monitoring and management of natural systems and elements within park boundaries, e.g., [13]. However, the protection of this natural heritage is intertwined with economic, social, and cultural interests,

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1 The Beaver Hills Biosphere has chosen to call itself a "Biosphere", not a Biosphere reserve. We have therefore chosen the acronym "BHB" for the Beaver Hills Biosphere and will refer to Biosphere Reserves in more generic applications.

within and adjacent to their boundaries, and thus, park managers must access and use knowledge from a wide variety of disciplines outside of their normal information sources to make effective management decisions [14]. Unfortunately, the use of Indigenous [15–18], local [6,19,20] and social science [21,22] sourced knowledge to inform park and larger ecosystem management efforts remains limited.

Environmental management and park-related knowledge mobilization challenges have been documented previously [5,23,24]. However, this dialogue has largely focused on the use of natural science research and achieving nature conservation rather than other mandates such as social benefits. The importance of social forces that affect environmental and park management has been documented by park researchers [25,26], practitioners [27–30], and overviews of social science in conservation efforts [4,14,21,22,31,32].

In Alberta, a recent research priority setting exercise emphasized the need for social science research in protected area management [33]. Based on a series of regional and provincial workshops with parks staff and experts, 64% of the questions generated related to social science topics (including policy and economics). This trend is not unique to Alberta [22,34] or to protected areas [32]. Key gaps include an understanding of the processes that can facilitate knowledge creation and exchange [2,5], including interactions between actors [4], and the role of context as an influence on that process [2,4]. These researchers and others call for study further study of the factors that shape knowledge mobilization, including its creation, management, sharing, use.

In making decisions, many studies show that people and agencies more often draw on intuition, personal experience, collective experience, and other types of informal knowledge, rather than on empirical or evidence-based information [35,36]. Critical barriers have been identified as inhibiting knowledge exchange among scientists and decision-makers involved in land and park management [2,21]. These barriers include the inaccessibility of science to decision-makers, poor communication among knowledge generators and potential users, inadequate training, as well as capacity issues and cultural, institutional and personal perception (worldview) barriers that limit the extent to which scientists and decision-makers can participate meaningfully in knowledge exchange activities [2,35,37,38]. In Canadian parks, the top barriers for accessing and using evidence for management and planning were limited financial resources, lack of staff, lack of time, inadequate timeframes for decision-making, lack of monitoring programs, and the disconnect between researchers and decision-makers [39]. Barriers to knowledge mobilization will vary by type of knowledge (e.g., for Indigenous knowledge see [15–17] and, for local knowledge studies see [17,20,40]). Generation of, access to, and use of knowledge derived from Western science (natural or social science), local, or Indigenous knowledge are characterized by different barriers and potential solutions.

Various solutions have been proposed or used to mobilize knowledge more effectively and efficiently. These include educating knowledge generators about the policy-making process, educating decision-makers about the research process, reforms to institutional environments, using knowledge brokers, establishing job exchanges, and other informal mechanisms to share ideas (e.g., workshops, training events, and brainstorming sessions) [2,41].

1.3. Biosphere Reserves

UNESCO's biosphere reserves are areas designated based on their high social and ecological significance and their capacity to demonstrate sustainable development principles. Introduced under the UNESCO Man and the Biosphere (MAB) Programme in 1969, biosphere reserves are settled landscapes, with a core protected area or areas surrounded by a buffer zone of lower impact land use and beyond that, a transition area with higher levels of human activity. Importantly, these are areas where people live and work within a natural landscape: sustainable development is a key goal of land management in all zones, and requires collaborative land management among land management agencies. Globally, there are 691 reserves in 124 countries that form a World Network of Biosphere Reserves, including the 18 sites distributed across Canada [42].

Successful biosphere reserve nominations must meet the goals of the MAB Programme to provide key functions of biodiversity and cultural conservation, sustainable development, research, and education [43]. Further, biosphere reserves must be managed under an established system of regional governance capable of creating and sustaining on-going programs to deliver these functions. Established biosphere reserves are now evaluated every 10 years to measure their progress toward the MAB goals, expressed within specific Action Plan objectives intended to address topical issues (e.g., climate change), or to ensure balance among the biosphere reserve functions. Past Action Plans have focused on initiatives resulting from United Nations Conferences on Environment and Development (UNCED) meetings, including the 1992 Rio de Janeiro meeting that resulted in the Convention on Biodiversity, UN Framework Convention on Climate Change, and 'Agenda 21' [43]. They have also emphasized improved functional elements of biosphere reserves, informed by global assessments of the progress of biosphere reserves toward MAB goals.

Key policies guiding these evaluations include the 1995 Seville Strategy and the Statutory Framework that now guide biosphere reserve designation, management, and evaluation [44]. Critically, Article 9 of the Seville Strategy allows Member States of the UNESCO MAB Programme to withdraw biosphere reserves that do not meet the criteria of sustaining both the three biosphere reserve zones and a functional governance system. The 2008 Madrid Action Plan added additional, specific targets relative to climate change, the increasing loss of biological and cultural diversity and urbanisation, and the Millennium Development Goals (2000). The current MAB Strategy (2015–25) and Lima Action Plan (2016–25) build on these objectives and emphasize the need for biosphere reserve to focus on five strategic areas: (1) biosphere reserves as sites demonstrating effectively functioning models of sustainable development, (2) collaboration and networking, (3) partnerships and sustainable funding, (4) communication, information and data-sharing, and (5) governance.

Functional biosphere reserves rely on effective collaboration and measurable progress toward sustainable development goals. The current policy objectives address complex, 'wicked' problems that require pooled knowledge and expertise, as well as cooperative management strategies. biosphere reserves are implicitly founded on inter-disciplinary and trans-disciplinary approaches that such sustainability problems demand, yet their effectiveness in promoting this aspect of sustainability science is little understood [44]. The MAB Strategy (2012–25) now emphasizes sustainability science, and its unique, integrated problem-solving approach, drawing on a full range of scientific, local, traditional and Indigenous knowledge as a key means of achieving sustainable development through biosphere reserves. Further, the Strategy emphasizes the roles of coordinators, managers and scientists associated with biosphere reserves in operationalizing and promoting such approaches within their sphere of influence [44].

The Beaver Hills Biosphere (BHB) provided a relevant location for a case study exploring knowledge mobilization in the context of sustainable development. The 1600 km^2 Beaver Hills Moraine is a distinct ecological area, with rolling hills, abundant wetlands and forests, located immediately adjacent to the Edmonton Capital Region, one of the fastest growing metropolitan areas in Canada. It has over a century of conservation history, resulting in several federal and provincial protected areas embedded in a mixed agricultural and rural residential landscape, and a strong community, government and institutional interest in protecting this unique area from urban expansion [45,46].

The Beaver Hills Biosphere was designated in 2016, 12 years after the organization of its regional management board (the Beaver Hills Initiative, BHI). The board comprises representatives of federal, provincial and municipal government agencies, academic institutions, environmental non-governmental organizations industry, each with land management interests in the Beaver Hills moraine. The success of the BHB lies in its governance. The municipalities and park agencies retain independent jurisdiction over their respective lands, and participation by all partners in the group is voluntary. The BHB (and the BHI before it) offers the potential for shared resources, collaborative research and joint management programs where relevant to the respective agencies, but the BHB cannot require participation by any of its members. Critically, it must also involve local and Indigenous interests in management of the biosphere to meet designation requirements, but must recruit such involvement. Although the moraine was an important place for Indigenous peoples historically, reserves created in the late 1800s and settlement by Europeans, severely disrupted those ties. Restoring a relationship with local Indigenous communities has been a key challenge for the BHB, as well as addressing urban development, climate change and other sustainability concerns. With its first 10-year evaluation coming in 2024, it was timely to evaluate the progress of the BHB toward the Lima Action Plan (2016–2025) and in particular, its effectiveness in mobilizing the collective knowledge and expertise held by its members towards these sustainability goals. Since knowledge mobilization in the BHB relies on the willing participation of individual participants and their home organizations, barriers become even more evident.

2. Materials and Methods

Research design and project methods were guided by knowledge mobilization research questions posed in biological, ecological and conservation-related refereed literature, e.g., [5,6,24,33]. Proposed principles that can and should shape knowledge mobilization processes [47,48] also informed study design. These included Nguyen et al.'s [4] Knowledge–Action Framework and Bennett et al.'s [21] Framework for Collaborative and Integrated Conservation Science and Practice. We also recognized high levels of interconnectedness among all participants in the effort to translate knowledge into practice [49].

Recognizing the interconnectedness and complexity of the case study site, we approached this research through qualitative methods, as they are ideal to explore topics where little is known, make sense of complex situations, gain new insights about phenomena, construct themes in order to explain phenomena, and ultimately foster a deep understanding of the phenomena [50]. As researchers, we employed a pragmatic research paradigm to this study. Pragmatism, while relatively new to conservation literature, is a philosophy based on common sense, that simultaneously is dedicated to the transformation of culture, and to the resolution of the conflicts that divide philosophers and researchers alike [51]. Within this philosophical worldview we believe that in the single reality of the world with multiple perspectives and experiences of that reality, knowledge is therefore constructed and based on that reality [52].

Pragmatism reminds us that research questions are not inherently "important," and methods are not automatically "appropriate" [53]. Instead, it is we as researchers who make the choices about what is important and what is appropriate. Hence, our research goal of understanding how the BHB used knowledge to create a biosphere reserve, and continues to mobilize knowledge for effective conservation and land management practices through voluntary collaboration lends itself to a qualitative case study approach.

This study followed a case study approach [54] to further examine biosphere reserve actors' views regarding the use and access to biosphere reserve-relevant knowledge. Case studies are an effective method when research is exploratory, explanatory, and/or descriptive [54]; as such, this case study was an effective method for understanding and exploring the experiences of the various actors within the BHB and knowledge mobilization. This particular case study is a part of a broader research project partnership, focusing on knowledge mobilization in parks and protected areas. The research partnership includes park and conservation agencies and universities from across Canada. The BHB was chosen as it is uniquely positioned for such an assessment, given the objectives of knowledge sharing within a biosphere reserve to inform sustainable development, and the need of the various actors and partner agencies to exchange social, natural and cultural knowledge in order to achieve the biosphere reserve goals. Biosphere reserve actors will continue to require a knowledge-based approach to achieve their own goals, as well as to advance the biosphere reserve objectives, but must do this through voluntary, rather than mandated arrangements for sharing and co-production of knowledge.

We reviewed grey and peer-reviewed publications about research and decision-making in the BHB. Next, we developed a set of interview questions focused on respondents' experiences with different forms of knowledge (social science knowledge, natural science knowledge, Indigenous knowledge, traditional ecological knowledge and other forms of local knowledge) and how agencies are able to (or not able to) access knowledge when making management decisions (see Appendix A for complete list of questions). In addition, we focused on how the BHB in particular used available forms of knowledge (e.g., natural, social, local and Indigenous) to create a biosphere reserve supported by the knowledge mobilization efforts of its partners and how being a biosphere reserve allows for the ongoing engagement in knowledge mobilization amongst partners.

2.1. Sampling

This study followed purposeful sampling as described by Creswell and Poth [55] in which the researchers select individuals and sites as they can purposefully inform understanding of the research problem and central phenomenon of the study. Within purposeful sampling, Creswell and Poth describe various types of strategies; this study followed maximum variation so as to document diverse variations of individuals and partners within the BHB. We attempted to interview leaders and influential members of partner agencies and organizations within the BHB who were familiar with the designation process and subsequent activities of the BHB, recognizing that there are no set criteria for sample size within qualitative research. Our goal was to understand the case in rich detail, and with continuity across designation through operation phases of the BHB, and have representation from the various organizations. Criteria for the sample included all BHB partner organizations who have had or currently have influence over and expertise in land management within the BHB, and were familiar with the designation process and transition into the BHB.

The BHB Board includes representatives from local municipalities (Beaver County, Lamont County, Strathcona County, Leduc County), federal park staff working at Elk Island National Park, provincial park staff employed by Alberta Environment and Parks, researchers based at the University of Alberta, and NGO representatives from Alberta Fish and Game Association, Alberta Lake Management Society, Beaver Hills Dark Sky Preserve, Canadian Parks and Wilderness Society, Ducks Unlimited Canada, Edmonton and Area Land Trust, Friends of Elk Island Society, Land Stewardship Centre of Canada, Miistakis Institute, Nature Alberta, Nature Conservancy of Canada, North Saskatchewan Watershed Alliance, and the Royal Astronomical Society of Canada. Not all current representatives to the BHB Board have been involved over sufficient time to meet criteria for study participation. Indigenous groups and governments are not currently on the Board, but have worked with the BHI toward biosphere designation. They, and local landowner associations, were invited to participate but representatives were not available for engagement.

We invited 21 candidates to participate in the study. Fourteen participants agreed to participate; others declined for logistical and timing reasons. From January to September 2019, we conducted seven focus group discussions (five in person at the University of Alberta and Miquelon Lake Provincial Park and two by phone). Group size in the discussions ranged from one to four individuals. Focus group arrangements were based on location and availability of participants, and in some cases, were based on agency representation (i.e., municipalities in one focus group, provincial agencies in another). The two one-on-one interviews were conducted with academics who have been involved with the BHB for over 15 years and provided in-depth expertise to the UNESCO Biosphere application as well as many future land management documents and policies. The one-on-one format allowed for transparency and anonymity. The discussions ranged in length from 61 to 126 minutes.

2.2. Analysis

Guided by Braun and Clarke [56], this study followed a thematic analysis approach. Thematic analysis is a method for identifying, analyzing, and reporting patterns (themes) within data. It minimally organizes and describes the data set in rich detail. However, it goes further than this and interprets various aspects of the research topic [57]. This process follows an inductive approach to coding and development of themes, meaning that the themes identified are strongly linked to the data themselves [58]. This approach involved reducing the empirical material into categories guided by the participants' narratives without losing sight of the research aims, a process which allowed for the identification of emergent themes [59]. Thematic analysis follows a six-step approach as described by Braun and Clarke, the process followed by the research team is outlined in Figure 1 [56]. Phase one begins with familiarizing yourself with the data; in this phase, all audio recording of focus groups and interviews were transcribed, and each author read and re-read the transcripts. Phase two involved the authors generating initial codes using NVivo 12; the ideas captured in the focus group discussions were coded in an iterative process. During the third phase the research team began discussing and searching for themes by re-focusing the analysis at the broader level of themes, rather than codes. This involved sorting the different codes into potential themes and collating all the relevant coded data extracts within the identified themes. Phase four allowed for the authors to review themes, remove, and combine as necessary, and reflect on the inductive process by considering why the data were within the theme. Phase five allowed the research team to define and name themes, while keeping the perspective that themes do not have to be what is talked about the most, but rather should be a reflection of what is important and interesting in relation to the research questions and the data themselves. Phase six of the thematic analysis process focused on crafting this manuscript and selecting quotes to support the themes. After triangulating our respective individual interpretations from this process, further joint discussion facilitated the development of the interpretations that follow.

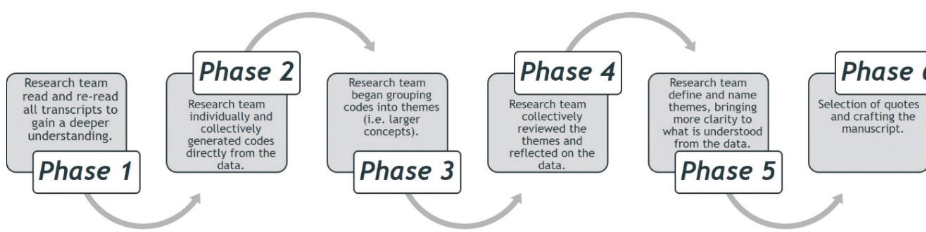

Figure 1. Phases of data analysis.

3. Results

In this section, we present how knowledge was described, understood, and used in the creation of the Beaver Hills Biosphere (BHB) and the ongoing partnerships within the BHB. Overwhelmingly participants acknowledged the contribution of scientific studies to planning and management activities in the BHB, whilst also recognizing the plurality and tensions within the various conservation agencies and the field more broadly when it comes to the creation, application, curation, and storage of knowledge.

3.1. All Knowledge Is Not Equally Valued or Understood

While many, if not all conservation agencies, including those who represent the BHB, noted the use of evidence-based decision-making practices, our findings reveal that evidence utilization is subject to availability, accessibility, and preference in most instances. Rather than utilize the most appropriate, holistic or robust knowledge, partners in the BHB still appear to turn to knowledge that they are most familiar with and avoid or undervalue other forms of knowledge. For example: *"Both with the BHI and with environmental planning in Strathcona [County] we don't really focus on social science; we rely more on natural science. Like if we are talking about the interactions with people and the environment there is no study that we are basing it off of, to me it's just common sense" (Municipality #1).*

One respondent described the interplay between land use planners and ecologists in the creation of the BHB's Land Management Framework, a foundational document to the BHB's designation. During development of the framework, the value of social science compared to natural science was questioned: *"the recognition of the value of [social science] in the land management framework, which was very* *much seen as being a tool to facilitate more informed decision making by the five counties is very strongly by physically base. And the marine report, which is very comprehensive in terms of the biophysical and I use that term in the broader sense of the term, and what is covered in the socio economic [social sciences] is dare I say pretty rudimentary. a lot of my experience has been in the land use planning side of things . . . " (Academic 1).* The value of social science is downplayed as "common sense" rather than considered a scientific discipline with training, expertise, and merit in management scenarios.

Even when social science is conducted within the BHB, the application of findings and the ability to effectively mobilize social science knowledge is not realized; for example, "*Now there were people like you who have done studies dealing with some of the [human] behavioural elements and stuff like that. But it hasn't been incorporated at this point in time in terms of major decision making and the future the biosphere reserve" (Academic #2).*

The idea that knowledge is supported by science or evidence is not untrue; it appears, however, that science typically refers to natural science. The use of social science is largely underutilized, misunderstood, and seen as costly or time consuming within the BHB. Many actors within the BHB struggle to identify what social science is, identifying visitor satisfaction surveys or public consultation as examples of social science, but unable to elaborate. For example: *"I think a lot of natural scientists look at that and go, it's pretty easy to catch a fish, measure it, release it, etc. But getting into peoples' behaviours and why they love fishing, holy moly, that's hard, I'm going to leave that alone!" (Park Agency # 4).* However, natural science appears to be highly valued, relatively easy to access, and support: *"I think natural science can definitely be worked in [to park/land management practices] easier. We claim we are science-based decision making so I guess it's easier, but I think natural science [is easier], I mean people expect that when they come to a park." (Park Agency #5).* Natural science is better understood and is communicated to politicians and decision-makers more often as it is considered more tangible and quantifiable: "*I'd say the physical sort of biological sciences are easier for us, most of us have a background and they're easier in some way to measure."* (NGO#3)

This bias is not just driven by individual preferences or training, but also agency traditions; focus group participants acknowledged it would take a major incident to inspire use of 'other' knowledge:

- Interviewer: *So what would it take for social science and local or indigenous knowledge to be fully integrated [into management practices]?*
- ParkAgency 5: *maybe a crisis, unfortunately.*
- Interviewer: *Like injury or death?*
- ParkAgency 6: *Yeah or something that is a game changer.*
- ParkAgency 5: *A hunting accident, or a nice dog walker being shot by a hunter, now we get the money and attention to deal with it. It's a horrible way to do business but . . .*
- ParkAgency 6: *Well yeah it's reacting again, we could spend days and months and years talking and no one is going to listen until something happens.*

Furthermore, as Canada searches for meaningful reconciliation between colonial settlers and Indigenous peoples, the value of traditional and Indigenous knowledge is beginning to be considered in BHB management and practices. However, that same knowledge was critically missed in the BHI's first attempt to be designated a biosphere reserve: "*The first time the BHI nomination went in for designation as a biosphere reserve, it was totally silent on Indigenous use of this landscape except in a historical context" (Academic #1).* While this realization led to many months of research and extensive historical exploration to ensure accurate and authentic representation was made in the subsequent application document, it does not appear to be understood and used in the same manner as other forms of science and knowledge. In part, this may stem from a lack of understanding among decision-makers of how Indigenous knowledge is shared, compared to Western science, and a need to rebuilt trust with potential Indigenous partners. One park agency described:

"You can spend an awful lot of time with Indigenous people in the field and get invited to sweat but you've really got nothing to show for it – there is no widgets at the end to say I produced this thing, you may reap the benefits in 5 years time and that's sometimes hard for managers and directors to say we poured $150,000 into this, what did we get out of it? Well I went on a sweat and I went to the pow wow and we're friends now and that's hard to justify to the public, but we well know there are benefits. So 3, 4, 5 times meetings would go beyond the hours of what they had costed out. You just have to appreciate that it is different, and you need to understand that. It takes time and you may not have a widget within the first year or the second, but five years down the road you are getting something out of it and the appreciation of that and little things" (Park Agency 4).

The BHB and partner agencies also recognize the challenge of integrating traditional and Indigenous knowledge into management decision making and knowledge mobilization. Canada is still grappling with the effects of colonialism on Indigenous societies and cultures. *"The Truth and Reconciliation committee is really a big challenge, Strathcona [County] doesn't have an overall policy or advisory statement and neither does the BHI at this point, although that's a target with some funding attached, so work has been done." (NGO #2).* A park agency employee summed up current practices with the following statement: *"Honestly, with Indigenous knowledge, I don't have much experience because that is usually not really accessible, I get more from historical resources and books." (Park Agency #6)* Accessing Indigenous knowledge related to the Beaver Hills is a challenge, in part due to the historical displacement of Indigenous peoples from the moraine. However, this may also indicate a lower value attributed to lay knowledge, relative to natural or social science. Focus group participants rarely spoke to other sources of Indigenous or local knowledge, such as landowners' or long-time recreational users' insights.

3.2. The Potential Value of Partnerships

Knowledge can be informed by various sources, including non-traditional sources. Partnerships allow access to these information sources. Participants reflected on how integral partnerships and "outside" sources (i.e., outside their own agency) were to accessing and generating information, highlighting the value of the BHB and the relationships developed through the creation and ongoing work as a biosphere reserve. Many BHB agencies commented on how participating in the biosphere reserve development process improved their ability to access knowledge even within their own organization:

". . . to mobilize knowledge internally, I seek those opportunities out [when] training seasonal employees, the firearms instruction crews, [mixing] fisheries researchers with bios, getting into Cooking Lake Blackfoot and actually meeting the people there now I know if I need to mobilize knowledge from these people they're not just someone with an Outlook email address, I can actually reach out to [Joe So-and-so] or whoever and I can ask them, [I need a solution for] enforcement challenges in X, and they know who I am. It's like hey how are you doing? I'll share this information rather than here's some dude who works for the division but he is in Edmonton and 'I don't know with your esoteric questions.' So they are more likely to relate to that, so I think that in terms of mobilizing knowledge works better within an organization." (Park Agency 4)

External agency relationships within the BHB partners are also a direct result of the biosphere reserve designation process. ". . . and then externally, meeting Parks Canada people, working with the Land Stewardship Centre, or Nature Alberta, or ECA—those personal relationships are invaluable in actually mobilizing good knowledge sometimes." (Park Agency #4). External partnerships allow for easier access to knowledge, which in theory makes it easier to mobilize, and for some partners in the BHB (mainly the smaller organizations), this seems to be a tremendous benefit, "I found the open sharing within the Biosphere in the initiative has been really nice and I know that that data report that was done in 2015 is really good for getting a general sense of data within the region, especially very locally." (NGO #4). Reading through focus group transcripts, we wonder, however, if the external partnership benefits are strong and meaningful or if they are perhaps more surface level. It appears to be mainly agency staff and politicians with experience of working with the BHB who embrace the partnerships rather than their fellow colleagues and organizations. It is for this reason we feel that partnerships have the potential to be incredibly valuable but do not appear to be fully capitalized.

3.3. The Reality of Partnerships

Partnerships and collaboration only work when all parties are engaged and participate; whilst external partnerships are the strength and purpose of forming the BHB they do not always come to fruition nor are they welcomed by all. For example: *"With the FireSmart plan, we said as the BHI we are paying for this work, do you want to be included? We thought it was like a no brainer, but we had one county who refused, we couldn't get them on board." (Municipality #1)* The information developed in this project [FireSmart Plan] provided an understanding of fire risk and prevention measures in the moraine, but it may not have been equally valued by, or immediately useful for all partners. Yet if shared with all regional land managers and owners, it could have reduced risk of wildfires increasingly prevalent with climate change. The need to show the utility of information to encourage use by partners was highlighted by another participant, who said: *"We just got a bunch of information sitting around, and we are not talking to each other, right. And then I think at some point it'd be good to have projects that utilize that information that you have somebody that goes in there and pulls information down and does some kind of meta-analysis or something uh even for some of the indicators that we had in the Beaver Hills report maybe a reason for that." (NGO #3)*

Furthermore, the struggle to create meaningful partnerships was a factor right from the beginning. As discussions commenced regarding the establishment of the biosphere reserve, control was an imposing barrier. Some agencies were worried about giving up control while others were clearly seeking to share management responsibilities and strategies. For example: *"I think a lot of the stumbling blocks and time wasted, I think there was always, particularly from the elected officials' side, concerns that the BHI would become a decision making body as opposed to a facilitator, providing a range of tools, and being able to implement and use those tools to the betterment of the broader interest. So that was one of the biggest problems um I think uh depending on the people around the table the effectiveness of them and the agency or interest they represented depended very much on those people." (Academic #2).*

Regional partners did not want another decision-making body, telling them what to do, and feared the BHI and later the BHB would assume that role, adding another layer of bureaucracy to the region, and reducing the autonomy of smaller municipalities and organizations. This is well represented in the narrative below which details a small municipality's reticence to become a formal partner in the biosphere reserve: *"I remember going to Camrose Council and a counselor that was pretty resistant to the whole BHI idea. Initially, someone had said the words biosphere reserve and it triggered a whole negative response and backlash really. He spent a whole council meeting in that part of the BHI presentation trying to barter [his region out of the project]." (Academic #1)*

Knowledge mobilization to advance conservation, sustainability and social benefits is retarded when not all regional partners are willing to engage in the process. The BHB and its predecessor, the BHI, struggle, like all biosphere reserves, to cultivate and secure partner engagement on a long-term basis.

3.4. Knowledge Mobilization and Decision Making Is Layered and Complex

Participants described a complex and dynamic system of knowledge creation and use. Many decisions that are made for parks and conservation management were described as reactionary or based on previous experiences, therefore creating layers to the use of various forms of knowledge. Even when the BHB consciously plans to use knowledge to inform their planning and facilitation efforts there are a host of factors that affect their ability to do so. These include such things as time, finances, and training required to "do" science, fears of what research will find and how to apply and communicate those findings, various government and bureaucratic policies, and challenges associated with collaborations and partnerships.

Time is one of the most frequent barriers; time to lobby organizations and governments to invest in a knowledge creation project, time to circulate new knowledge to co-workers and superiors, time to engage the public in meaningful outreach were frequently cited time scarcity examples provided by study participants. Participants felt pressure to react to problems or management decisions rather than prepare and conduct future planning and relevant research:

"Yeah, because you know you are dealing with the day-to-day, which is the problem you do some research, but you don't always have the time to get the data sorted, so you need to find some students or something and look around at different sources. It's the name of the game you see the problem, try to put out the fire and then try to put the research knowledge out there so you have it for the future and a better understanding of the problems and issues. You are reacting big time." (Park Agency #6).

Efforts to promote new ideas within regional organizations, which takes time but also influence and ability to push information "up-" and "down-stream" in an organization is reflected in this comment: *"The real difficulty I think, and this applies not just to the government only, but also to NGOs and so forth, is how do you get that information back up the line to make the people who basically decide policy and allocate resources that is the important issue." (Academic #2)*

Biospheres are areas where people live and work close to and within a natural landscape, which poses unique questions and management strategies that require pooled knowledge and expertise. However, fear appears to be holding the BHB back from realizing some of the potentials of their partnerships and pooled expertise. While some are afraid of admitting a mistake and thus not allowing others and themselves to learn from that mistake, others are afraid of not having the expertise required to engage in research. Instead of relying on partners within the BHB (i.e., academic or NGO institutions with specific research skills) they simply avoid certain opportunities: *"so it's that kind of thing about improving business and admitting we made a mistake and to learn from it but there's this, whoa we can't admit fault, error, we can't talk to people." (Park Agency #1).* A second quotation supports this issue:

"So I think having a go back to our comfort level of you know if we see X species that we know it's there that is something we can be sure about whereas if you have to disseminate that information socially for the social sciences in a way that is effective and also representative I think it's something that I struggle with. How do we know that we're talking to the right people or have a good representation of the data from the area and it's not just the opinion of one person that may or may not be accurate." (NGO #5)

A biosphere reserve also poses a unique challenge in regards to knowledge creation, as they often encompass peri-urban areas and developed lived-in landscapes. This urbanization and development are accompanied by layers of government, and biosphere reserves must continually adapt to municipal, provincial and federal election cycles and competing political agendas. This timing creates additional pressure for BHB agencies and partners to react, and hinders their ability to conduct in-depth or longitudinal research projects: *"Yeah it completely forces us into short term projects." (Park Agency #5).* *"Council only has four years and they need to make their mark in that short amount of time. Research, we know goes year and years and that's the trick with municipal government and decision making, you may have a decision for four years." (Municipality #2)*

Capacity and training appear to be lacking in certain areas; however, it is unclear why the BHB and its partnership is not being called upon in more significant ways to address the capacity gaps between one organization and another. Specifically, an interest in but lack of capacity to conduct social science research, access and understand social science findings, and engaging with local and Indigenous knowledge is articulated well in these quotations:

"The challenge right now is to demonstrate enough capacity to the leadership that they'll trust in me that I'm taking them on a path forward right, because no disrespect to the past but the path might not have been as straight as we needed it to be. So, I think about it now as how can we [accomplish this] as a biosphere, the evaluation of effort of the social science effort. So, we talk about the extension of programming if I had tools and resources that could demonstrate the effectives than that would resonate with partners even more so." (NGO #1)

"Probably more resources or more a better understanding amongst the rest of us that don't do it typically about how that could be utilized or how that would feedback to the work that we do. So um with the Friends [of Elk Island National Park] for instance if I could figure out what drives people to go out in the park or to get involved in citizen science or to want to learn about those kinds of things. In fact, that kind of information would be useful for us in terms of shaping our programs for our offering so that we could engage more people." (NGO #3)

Similar sentiments relating to capacity and training were noted for engaging with Canada's Indigenous peoples and the knowledge exchange and co-creation that would arise from that effort.

In short, the knowledge created, used, and mobilized within the BHB is a representation of the efforts of many years of dedicated and passionate individuals and agencies. However, long-entrenched traditions of how "things are done", limitations in terms of time, capacity and finances, and complexities of the landscape and actors involved (i.e., political process, relations, influence, trust and control) have shaped decision making throughout the biosphere's lifespan and may continue to do so.

4. Discussion

Study interviewees struggled to provide specific examples of knowledge used for the biosphere reserve application or ongoing landscape management collaboration efforts that were sourced outside of traditional natural science fields of study. Park visitor statistics, information gathered at public consultation campaigns, and economic impact studies were consistently and solely identified as 'social science,' when interviewees were pressed to provide non-natural science examples of knowledge that could be used for management and planning within the BHB or that had been used to support the BHB's application for biosphere reserve status. This trend corroborates findings from other studies [21,22,31] that highlight the need for more social science research and application of its findings in biodiversity and environmental management efforts. Two examples of this include Head's [60] study of the use of human dimensions research in addressing invasive species and Harris, McGee, and McFarlane's [61] examination of local municipalities' emergency preparedness for wildfire, including the use of social science. Invasive species and wildfires are two challenges that are increasingly prevalent for the peri-urban context of the BHB. Wildfire has long been of interest to the BHB and generated substantial research and management action, based entirely in natural sciences (fire history and risk prediction). Such studies do not readily translate to management action though, and as some participants noted, this information has not been embraced by partner agencies as quickly as expected. In other regions, social aspects of management such as perception of risk have been well studied, and used to communicate risk in community education and awareness programming, e.g., [62]. A broader understanding of the applications and benefits of social science would be helpful to the BHB, and other similar initiatives.

When asked about the potential of Indigenous knowledge, traditional ecological knowledge or local, land-based knowledge for achieving BHB management objectives, replies were more apologetic in tone or interviewees had no examples to share. Engagement with the diverse Indigenous peoples who have historic and cultural ties to the Beaver Hills region has been limited, and, as articulated in the Findings section, led to, in addition to lack of public outreach in general, the failure of the first application for biosphere reserve status. This lack of engagement with 'others' and alternative ways of knowing is not uncommon. Lemieux et al. [63] in a survey of 121 Canadian conservation professionals found that while traditional (including local and Indigenous) knowledge was valued to a moderate degree (i.e., 2.9 out of 4, where 1=Not valued at all and 4=Very Valuable)), it was used much less often, scoring 2.2 out of 4 on a similarly framed "Use" scale. Lemieux and colleagues also noted that Indigenous knowledge was significantly less valued by professionals who were male or had longer professional service records. Calls for Indigenous knowledge, characterized by some researchers as traditional ecological knowledge have been made for at least two decades now [15–17], however the shift to embrace this knowledge as an equally valued tool for supporting conservation and sustainability objectives has been slow. Based on findings from a study of the potential for traditional and local ecological knowledge to contribute to biodiversity conservation in the US Pacific Northwest Coast, Charnley et al. [19] suggest knowledge holders must be directly engaged as active participants in conservation efforts. However, social, economic and policy constraints must be addressed to facilitate this involvement. In Canada, the capacity of Indigenous governments and communities to collaborate is oversubscribed at present—this is a real constraint of which the BHB is mindful. The BHB also recognized the need for its network partners to increase their capacities to engage with Indigenous actors. Efforts to promote cross-cultural awareness and communications challenges, adoption of a more holistic socio-ecological systems thinking, and identification of common goals are a few of the overarching recommendations for addressing the pluralistic and dynamic perspectives that characterize the efforts to manage large scale landscapes [64–67].

Unexpectedly, very few of the focus group participants cited examples of local knowledge being employed to advance the development of the BHB, its application package, or its current collaborative activities. Undoubtedly, within a wide-ranging landscape such as the Beaver Hills, the agencies and partners involved in the BHB collect and utilize local knowledge in their daily and annual efforts (e.g., in land use planning), but these forms of knowledge failed to surface as common sources of information amongst interviewees. In comparison, appreciation of and use of local knowledge in Lemieux et al.'s [63] survey of Canadian conservation professionals, identified patterns of valuation (3.2 out of 4) and use (2.6 out of 4) of local knowledge for the evidence-based management of Canada's protected areas; this was slightly higher than scores relating to Indigenous knowledge from the same survey. The study also documented experiential expertise of managers was more valued and frequently used by conservation practitioners. The subordinate role that lay or local knowledge plays in comparison to technical or scientific knowledge has been documented in other contexts, including van Tol Smit, de Loë, and Plumber's [68] examination of collaborative environmental governance in New Brunswick, Canada, and may explain why, even when prompted, local knowledge was rarely discussed as a source of knowledge from decision making by BHB actors during our focus groups. Hockings et al. [3] call for greater integration of science and local knowledge to strengthen biosphere reserves, suggesting they are excellent laboratories for testing integration of scientific, local and Indigenous forms of knowledge. Raymond et al.'s [6] comparison of three projects that attempted integration of local knowledge into environmental management efforts noted there is no single optimum approach for integrating local and scientific knowledge and observed the need for future efforts to be systemic, reflexive and cyclic.

Study participants noted the partnerships and network afforded by the BHB and its establishing board, the BHI, were invaluable for improving their access to knowledge. Study participants suggested knowledge was created and exchanged more often between organizations because of their involvement in the BHB. The BHB and its predecessor, the BHI, could be labelled as a boundary organization, bridging the divide between knowledge creators and keepers, and knowledge users [69]. Boundary organizations, often NGOs, have traditionally bridged the gap between science organization and knowledge users [69]. The BHB, on a monthly basis at its board and advisory committee meetings, through its newsletters and related communications tools, and via initiatives such as the biosphere reserve application process or FireSmart preparations facilitate communications and knowledge exchange [2]. However, the BHB and its predecessor the BHI, have tread a fine line, working to maintain neutrality and autonomy, and not appearing to align with one partner agency vs another. The perceived influence of one of its main funders, the largest of five municipal partners, has at times, slowed the buy-in of other neighbouring municipalities. This was exemplified in the FireSmart program and a municipality's refusal to get involved, gaining access to and exchange information that would have helped it prepare for wildfires. To be a successful boundary organization, the BHB must strive to represent all sides in efforts to facilitate the exchange of information between knowledge users and producers, maintaining its independence. As an example, finding ways to better solicit and integrate local knowledge, would help to remove perceptions of bias. Similarly, working with Indigenous partners to explore areas of potential collaboration, in ways respectful of capacity constraints, and the need to develop shared cultural understandings would help to build trust, an essential starting point.

Study participants also claimed their participation in the BHB, as board members or advisers, improved their ability to bring knowledge from other organizations into their own agencies, but also move information within their agencies more effectively. BHB leadership (i.e., board members and advisory committee members) appear to be performing knowledge brokering within their respective agencies, especially when it comes to the sharing and curation of Beaver Hills environmental data. Knowledge brokers facilitate the exchange of knowledge among policy makers, practitioners, and knowledge creators and keepers [2]. Amongst study participants, numerous examples of sharing and generating natural systems knowledge was alluded to, however, while the importance of acquiring and applying cultural and social knowledge was acknowledged, many of the participants interviewed noted the lack of training and easy access to this knowledge.

Co-creation of knowledge that advances biosphere reserve objectives such as sustainability, biodiversity conservation, cultural heritage conservation and social benefits also needs to be adopted by the BHB and regional actors. Our understanding of co-creation of knowledge is that it entails people exchanging perceptions of a particular phenomena and collaborating to learn more about that phenomena together. The objective of these efforts is the co-creation of knowledge, which will inform action, leading to biosphere reserve-relevant goals such as social, cultural and environmental benefits [70]. A few focus group participants noted partnerships between agencies and individual staff were productive in advancing a shared understanding of a complex problem, such as ungulate management (i.e., moose (*Alces alces)* and elk (*Cervus canadensis*)) in the Beaver Hills. They also mentioned citizen science activities, whereby residents and visitors helped to collect data, particularly in the region. It was unclear if the latter project was co-creation or co-production of knowledge.

We acknowledge the terms co-creation and co-production are often used interchangeably by some environment and knowledge mobilization experts, i.e., [2,71,72]. However, we understand co-production of knowledge to be an activity that does not include all actors in the planning process (e.g., debating what data collection method to use or what research question is most salient). Despite these subtleties in definition, the intent is the same—knowledge mobilization for conservation through collaboration. The importance and efficacy of co-creation and co-production processes were documented by Nel et al. [71] in their study of a 4-year conservation planning project in South Africa. They found that knowledge co-creation stimulated dialogue and negotiation and built capacity for multi-scale implementation beyond the original project—in short, it led to conservation action. Though not explicitly carried out as a co-creation project, the effort to document and share information (primarily about biological resources) between BHB conservation and land management agencies, with an aim to enhance landscape management and the creation of the biosphere reserve, shared many of the characteristics of the study detailed by Nel et al. [71]. However, diversity of voices (i.e., the public at large, Indigenous communities) and subject matter (e.g., social, cultural, economic) were less richly debated and documented during the BHI's efforts to obtain biosphere reserve status for the region. The effort appears to have been more focused on finding common cause, and support to drive the biosphere reserve forward toward designation. Acknowledging differences then may have defeated the main goal of designation.

Study participants unanimously agreed the BHB, and its predecessor the BHI were effective catalysts and facilitators of knowledge mobilization in the Beaver Hills region. However, knowledge mobilization collaborations were not always easily formed, needed time to develop, and key organizations were not consistently involved due to political and economic forces or the pull and push of power personalities. As a result, knowledge mobilization efforts have been stymied at times. As noted earlier, focus group participants noted that some potential partners were difficult to bring to the collaboration because of a fear of losing control. They did not want to support a biosphere reserve that could, in their minds, add another decision-making organization to the region with whom they would have to negotiate. Over time, with the right mix of personalities, the patient building of trust, and the recognition of common goals and values were used to reinforce nascent relationships and the forging of new partnerships. The development of strong personal relationships has been observed as an essential ingredient in successful partnerships [73]. Trust emerges from these personal relationships as does social capital. In her study of the factors that lead to the success of the BHI, Patriquin [45] observed these phenomena were essential ingredients to its success. She also observed that trust was built more often between people than agencies, which corroborates our speculation that the bonds that bind the BHB and facilitate its success as a knowledge mobilization organization, are driven more by individuals than agencies.

Stronger personal relationships bring higher levels of social capital, which can be utilized for more effective problem-solving and result in an expectation of reciprocity, resulting in long-term obligations between people [74]. Brown [75] suggests this can help bridge the gaps created by different levels of power and knowledge [73]. Patriquin [45] observed in her study of the BHI that trust and social capital were essential in advancing new knowledge and evidence-based management initiatives. These included data sharing, funding raising, and effort to seek biosphere reserve allocation. Shared cultural understandings, specifically a long-term history of conservation value of the moraine, also played a role. The value of the natural environment was a rallying factor for the nomination, more so than its cultural history, a factor that may contribute to the challenges in engaging local and Indigenous understandings in the BHB's management initiatives.

Gavin et al. [64] note that conservation is often called a crisis discipline, as much of its research output is focused on declining species and landscapes, and ineffectual debates about the best path forward to address these declines. Crisis is often used as a springboard inspire action, but actors are not certain if it is the right action at the right time. This sentiment was articulated by many of the BHB focus group participants who lamented that much of their work was reactive, lacking long term resourcing or leadership support. Many of their projects were short term due to political electoral cycles and related ability to access funding and permissions to engage in data collection or evidence-based policy and management recommendations. Efforts to engage in long-term knowledge creation and curation is perceived as a central challenge to the BHB and similar collaborative efforts. Straka et al.'s [66] study of muskrat populations in Canada's Peace-Athabasca Delta, illustrates the efficacy of long-term ecological monitoring that includes partners such as Indigenous communities.

To facilitate these collaborations, constraints and deficiencies such as time and financial resources, as well as the capacity of individuals (i.e., conflict resolution, cultural awareness and appreciation of diverse world views and disciplinary approaches) and organizations need to be addressed. The environmental management knowledge mobilization literature provides insights on how to address some of these challenges (see [37,47,64,66] for examples).

5. Conclusions

5.1. Study Limitations

The story of Indigenous knowledge mobilization as it relates to the formation of the BHB and its ongoing administration, governance, and collaborative activities is not fully understood from the interviews conducted for this study, as Indigenous representatives did not participate in the focus groups. However, focus group participants who work closely with different Indigenous communities who have historic and cultural ties with the Beaver Hills, did reflect on some of the challenges and opportunities relating to Indigenous knowledge mobilization. We also did not ask interviewees about their use and valuation of professional knowledge or the experiential knowledge accumulated and employed by managers [3,8,76]. Probing for information about this type of knowledge from practitioner participants may have contributed a more fulsome and realistic understanding of management and planning decision making in the BHB, and should be included as a focus in related studies.

Our sample size could be critiqued as being small, given the scale of the Beaver Hills region, and number of BHB partners and organization staff involved. However, our desire to assess knowledge mobilization over the timeframe leading to designation of the BHB, from the perspective of its various partner organizations, constrained selection of potential participants. Most current BHB leadership (i.e., board and advisory committee members who work for government, academic, and NGOs) were interviewed, as well as a number of previous participants who also served with the BHI. Finally, we suspect the longitudinal focus of our study made it difficult for participants to name and describe their perceptions of knowledge and knowledge use over such a long-time frame; the study could have benefited from a narrowed temporal focus.

5.2. Future Research

In addition to social science, the contributions of humanities and the arts research traditions to advancing the effective management of protected areas and landscapes such as biosphere reserves should be explored. These disciplines can also be used to critique and suggest alternative ways forward to advancing conservation and sustainability [77]. The arts and humanities articulate and inspire diverse ways of knowing in unique and challenging ways, often helping regional actors reflect on relationships with nature and each other. In the near future, examining the efficacy of the application of the arts in the BHB, in knowledge translation and negotiation may prove to be a fruitful avenue for the BHB to engage new constituencies with. As an example, profiles of the current and past residents of the moraine, in a manner similar to that used to document its natural heritage, could help build connections with local and Indigenous communities, and engagement with the BHB.

To engage in knowledge mobilization relating to Indigenous knowledge, deeper relationships are needed with individual Indigenous persons, groups, and governments. Relationship building will develop trust and advance reconciliation efforts, which are ongoing throughout Canada. Understanding of epistemological perspectives and ethical protocols will be needed to pursue joint research initiatives, but firstly, a deeper understanding of the colonial history that has influenced Indigenous connections to this landscape is needed to facilitate reconciliation and then encourage partnerships. This process will need to include skills and knowledge development of BHB leadership and staff within the biosphere reserve, but also key partners of the reserve. This is already occurring at protected areas located in the BHB such as Elk Island National Park, Cooking Lake Blackfoot Provincial Recreation Area, and Strathcona Wilderness Area. These parks are co-creating programs and policies with Indigenous communities. Research activities must involve "more collaborative and empowering forms of participation, and the use of Indigenous epistemologies and methods" [78,79]. This effort will have to be facilitated by the increased capacity of Indigenous communities to co-create and co-produce knowledge (e.g., financial and technical assistance, Indigenous controlled research infrastructure) and respectful dialogue to gauge interest in such activities. Traditional institutions (e.g., universities and their funders) must also recognize the complexities of ethics and financing that are needed to develop research relationships, co-production of knowledge, and secure knowledge asset management [67,79].

Our focus group interviews did not allow us to delve deeply into past and potential BHB co-creation and co-production of knowledge activities. Noting Cvitanovic et al.'s [2], Onaindia et al.'s [70] and other's [78,80] identification of the potential for these approaches to engage regional actors, build relationships and produce knowledge that is more supportive of biosphere reserve goals, we recommend a more expanded inquiry into how knowledge co-creation and co-production occurs in complex lived-in landscapes such as the Beaver Hills. Follow up studies of citizen science, public history curation, and wildlife preparedness planning are topics the BHB is pursuing that may provide further lessons that will enhance knowledge mobilization efficacy and efficiencies.

5.3. Concluding Thoughts

Returning to our original objectives, we asked how park, conservation, and other land management agencies associated with the BHB are able to access knowledge when making management decisions. In short, access depends on the type of knowledge, level of collaboration, and potential for application. In addition, we asked how the BHB allows for the ongoing use of knowledge mobilization amongst partners. Similarly, effective knowledge mobilization requires patience, long-term collaboration, equality among partners (perception and reality), and an appreciation of how complex knowledge really is.

As the BHB moves into its first decade of operating as a biosphere reserve, building on an additional decade of foundation building by the BHI, the organization and partnership must be mindful of several challenges. This is particularly salient for addressing calls by international experts who suggest biosphere reserve success will be contingent upon efforts to "engage with and support diverse knowledge holders and knowledge systems" [81]. First, the diversity of knowledge sources is important, namely a broader incorporation of social science, humanities, and arts generated disciplinary outputs are essential to advancing sustainability and related biosphere reserve goals. Equally important in achieving these goals will be Indigenous engagement and knowledge exchange, as well as partnerships and information sharing with local communities, landowners, and traditional users. The BHB is taking steps toward this through applied research projects in partnership with local universities. One example of this is a humanities-informed project in which historians are interviewing local residents and collecting archival materials for a public history project [82] to deepen and empower public connection with the BH's past. Additional capacity development within the BHB, with respect to Indigenous history and culture will be necessary to ensure respectful, and equitable collaboration.

Second, as the BHB formalizes its governance, stabilizes its revenues, expands staffing, and establishes strategic priorities, it must work hard to maintain a commitment to being an "open system —philosophically and operationally" [83] ensuring access to diverse perspectives, skills, and resources of individuals and organizations. Through interviews with leaders associated with the Yellowstone to Yukon (Y2Y) initiative, Mattson et al. [83] noted that as large-scale conservation organizations mature, consolidation of power around a long-standing formula reduced the effectiveness of Y2Y. As a biosphere reserve, and based on the BHI's previous successes of partnership building, this openness and dialogue must be maintained (this has been the case with most conservation agencies and municipalities) and expanded to other groups such as the public at large and specific actors (e.g., Indigenous governments and individuals, landowners, recreation users, and industry). These efforts will build trust and exchange of ideas, and relatedly for this article, the mobilization of knowledge that can be used to advance the broad array of park management objectives including biodiversity and cultural heritage conservation, and social benefits. To foster successful governance of the BHB and biosphere reserves like it, Vasser [84] recommends the pace of governance and management must consider "spatial and temporal scales of ecological processes within a socio-ecological system" (p. 309) and in particular consider different cultures' approaches to time, process and procedures. He cites Canada's Indigenous Circle of Experts (ICE) process to generate recommendations to achieve Canada's commitment to its Aichi Target 1 biodiversity protection goals, as one example [85].

Third, partners and especially leadership within the BHB must work hard to be conscious of the inherent economic and discursive power that coalitions within the Beaver Hills wield in the prioritization of biosphere reserve activities, based on narratives that are exchanged and promoted. These narratives are rooted both in local experience and knowledge as well as scientific data and the professional 'know-how' and influence of politicians and practitioners. One of the most contentious challenges of the region, the management of beaver populations, especially during years with high levels of precipitation, shares many parallels with observations made by Robbins [86] in his review of ecological knowledge relating to wildlife management and ranching in Northern Yellowstone and Maderson and Wynn-Jones' [87] examination of beekeepers' knowledge and participation in pollinator conservation and tensions with agricultural production. In short, efforts to listen to silent and silenced constituencies need to be a long-term commitment of the BHB as it moves towards its biosphere reserve objectives.

Finally, we would like to acknowledge that Canada has a history of land management that devalues community integration and consultation and rather imposes parks based on ecological and conservation science [88–90]. As such, in this paper, we assert that social science research, characterized by distinct disciplinary theories and methods but focused on advancing social knowledge, has not received the same recognition as natural science within North America and Western conservation contexts [21]. Globally, there may be different understandings of and valuations of social science as a practice; within the BHB, understandings of what social science is and what it may contribute to conservation management is still very much at an early stage of development. We believe that all forms of knowledge are essential to effective conservation and land management and therefore are advocating for interdisciplinary approaches in park and land management.

Author Contributions: Conceptualization, C.-J.B., E.A.H., G.T.H. and D.P.; Methodology, C.-J.B., E.A.H. and G.T.H.; Validation, C.-J.B.; Formal Analysis, C.-J.B.; Investigation, G.T.H., E.A.H., C.-J.B. and D.P.; Resources, E.A.H. and C.-J.B.; Data Curation, C.-J.B.; Writing—Original Draft Preparation, C.-J.B., E.A.H., G.T.H., and D.P.; Writing—Review and Editing, C.-J.B., E.A.H., G.T.H., and D.P.; Supervision, E.A.H.; Project Administration, E.A.H.; Funding Acquisition, E.A.H. All authors have read and agreed to the published version of the manuscript.

Funding: The authors would like to thank all funding partners, specifically Canada's Social Sciences and Humanities Research Council, Alberta Environment and Parks Innovation Fund, and The University of Alberta.

Acknowledgments: The authors would like to thank all BHB partner organizations and research assistant Carolyn Cook.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Research Interview Questions

Opening Section (Participant Background)

1. Could you please describe your professional background (eg. education, job experience) relative to [case study location]?
2. How has knowledge (and what kind of knowledge) has typically been integrated in planning and management for the Beaver Hills Biosphere [and/or its predecessor, the Beaver Hills Initiative]? Note: some time period may be useful (e.g., over the past 2 to 5 years)?
3. Can you describe your professional role in conservation/environmental management in the Beaver Hills Biosphere [and/or its predecessor, the Beaver Hills Initiative]? What are the key management issues that you have been involved in recently? How well has your background educational or work background prepared you for that role?

Knowledge Mobilization Section

Case-specific Management Decision-making Processes:

1. Can you describe (one to three) important management decisions that you helped make will working within the Beaver Hills Biosphere [and/or its predecessor, the Beaver Hills Initiative]?
   a. For each decision, would you please describe how the decision was made (open ended start to discussion)?
   b. Now would you outline what kinds of information were used to assist in making each decision (probe for possible types of information, e.g., colleagues, government documents)?
2. Can you describe a decision where **social science** (e.g., psychology, sociology, political science) was used to help with the decision making relative to each management issue (may need to probe to explain what is meant by social science)? Why was social science integrated into management of this particular issue?
   a. Can you describe any difficulties or barriers in accessing or applying appropriate social science information in making decisions such as this, at this case study location? (Relate this back to theoretical context, and known barriers/enabling factors.)
3. Can you describe a decision where **natural science** was used to help with decision making (may need to probe to explain what is meant by natural science)? Why was natural science integrated into management of this particular issue? Was it easier to incorporate natural science, relative to social science in this example situation?

a. Can you describe any difficulties or barriers in accessing appropriate natural science information in making decisions? Any enabling conditions that helped access scientific information useful for decision-making? (Relate this back to theoretical context, and known barriers/enabling factors.)

4. Can you describe a situation where **traditional ecological knowledge, Indigenous knowledge, or other forms of local knowledge** were used to help making a decision (may need to probe to explain what is meant by traditional ecological knowledge or local knowledge.)

    a. Can you describe any difficulties or barriers in accessing appropriate traditional ecological knowledge, Indigenous knowledge or other forms of local knowledge in making decisions? Any enabling conditions that helped access scientific information useful for decision-making? (Relate this back to theoretical context, and known barriers/enabling factors.)

General Process of Knowledge Application:

1. Do you think some forms of knowledge can be integrated into biosphere-related planning and management easier than others? Why do you think that?
2. What do you think are/were the main opportunities and barriers to integrating scientific knowledge into biosphere/BHI planning and management? Do you think these barriers could be minimized in any way?
3. What do you think are/were the main barriers and opportunities are for integrating Indigenous knowledge into biosphere/BHI planning and management? Do you think these barriers could be minimized in any way?
4. Many researchers suggest that conservation decisions have traditionally used primarily natural sciences to help them plan and manage protected areas/ecosystems/landscapes.

    a. Would you agree with this assessment, and why or why not?
    b. What would it take for either social science or Indigenous knowledge to be more fully integrated into Beaver Hills Biosphere planning and management?

5. What kind of knowledge is typically used to deal with any social science-related issues in the Beaver Hills Biosphere (e.g., overuse issues or problems dealing with recreational conflicts between users)?
6. What trends do you see in accessing and using various types of knowledge in management and planning decisions in the Beaver Hills Biosphere?

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Mobilizing Indigenous Knowledge through the Caribou Hunter Success Working Group

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Received: 30 September 2020; Accepted: 28 October 2020; Published: 31 October 2020

Abstract: The caribou stewardship practices of the Iñupiat have persisted through cycles of abundance and decline for the Western Arctic Caribou Herd (WACH). This research seeks to address the challenges and opportunities faced when mobilizing Indigenous Knowledge in the National Park Service (NPS) management of the herd. Motivated by Indigenous stewardship concerns, NPS staff facilitate and participate in an informal working group focused on caribou hunter success. Using Indigenous Knowledge methods, this study examined the outcomes of the working group and the use of "rules of thumb" to identify and share stewardship practices. In the two cases, the Caribou Hunter Success Working Group created space for subsistence hunters to develop educational materials based on Indigenous Knowledge to address specific hunter success issues. Subsistence users participate in the federal subsistence programs and related subsistence forums, and it is the work of the NPS to mobilize the knowledge they contribute to improve subsistence management for both the users and the resource. There are two additional benefits for the NPS: (1) a better understanding of the use of the resource, and (2) when regulations are informed by Indigenous Knowledge, there is a greater likelihood of adherence. The mobilization of Indigenous Knowledge leads to more effective management.

Keywords: Indigenous Knowledge; traditional knowledge; traditional ecological knowledge; subsistence, caribou; Iñupiat, Alaska; national parks; co-management

1. Introduction

The Iñupiat of northwest Alaska have an intimate relationship with caribou going back millennia, as both a primary food and material resource, and as a feature of their collective identity. The 1980 Alaska National Interest Lands Conservation Act (ANILCA) established National Parklands encompassing much of the range of the Western Arctic Caribou Herd (WACH). Kobuk Valley National Park (NP) and Cape Krusenstern National Monument (NM) are specifically directed at protecting the viability of subsistence resources and subsistence uses.

In carrying out ANILCA National Park Service (NPS), managers work alongside neighboring state and federal land management agencies, and rural subsistence users who depend on the parks. NPS managers for Kobuk Valley NP and Cape Krusenstern NM work in Kotzebue, located in northwest Alaska. The majority of subsistence users are of Iñupiaq heritage and rely on Indigenous Knowledge (IK) to steward resources for the next generation [1,2]. IK is the "cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" [3] (p. 1252). The use of the term Indigenous Knowledge recognizes that the Iñupiat have generations of knowledge related to the WACH, as well as adaptive relationship to the resource. The knowledge used to harvest and manage is evolving.

To integrate IK into the ANILCA framework of subsistence management, the Caribou Hunter Success Working Group (CHSWG) has formed to address specific concerns about the stewardship of caribou. This study will explore the IK shared through the CHSWG, as well as the challenges to and opportunities for mobilizing that knowledge in NPS management.

The WACH is the largest caribou herd in Alaska. The herd migrates across northwest Alaska, with a range estimated at 157,000 square miles, the route taken varying year to year. Generally, the fall migration takes them from Alaska's North Slope southward through the Noatak, Kobuk, and Selawik river drainages, and along the coast of the Chukchi Sea. The range spans lands owned and managed by the State of Alaska, Native Corporations, and Federal Lands (Bureau of Land Management, Fish and Wildlife Service, and NPS). With virtually no roads in the region, subsistence hunters' best access to the fall season's prime bull caribou is to intercept migration by boat along waterways near their communities. Roughly 40 villages harvest from the WACH for an estimated annual harvest of 10,000–15,000 caribou. This study focuses on two of those communities in the Northwest Arctic Borough: Kiana, on the Kobuk River, and Kotzebue, located on the coast of Kotzebue Sound [4].

The size of the herd fluctuates following natural trends of abundance and decline. The past century included scarcity in the early 1900s, an increase in the 1930s–1950s, and another decline of the herd in 1975 when the population was estimated at the lowest on record, 75,000 caribou. The herd again increased until 2003, reaching a population of 490,000 caribou. Since 2003, the herd's size has been reduced by half. The recent decline has charged regulatory discussion, as subsistence users and managers have heightened concerns about sustaining the herd [4].

For the Iñupiat of northwest Alaska, caribou is a cultural keystone species [5–8]. That is, the WACH "play a unique role in shaping and characterizing the identity of the people who rely on them ... that become embedded in a people's cultural traditions and narratives, their ceremonies, dances, songs, and discourse" [9] (p. 1). Traditionally, caribou were hunted through a community-wide effort to herd the caribou into locations that would make for easy harvest. This includes but is not limited to rivers, lakes, and constructed corrals and snares [10]. The relationship to the herd was understood to be one of interdependence. The Iñupiat way of life, including seasonal settlement patterns, were determined by the caribou movements and hunter behavior could alter the migration of the herd. [5].

In the modern management context, the caribou herd is the shared interest that brings both NPS staff and Iñupiaq subsistence hunters to the same table with other land management agencies. As the NPS aims to mobilize IK in subsistence management, they are working against the NPS legacy of erasing Indigenous people and use from the land [11]. The erasure began with removal of Indigenous people from their homelands for the establishment of parks, as was the case for Yellowstone National Park, Yosemite National Park, and Grand Canyon National Park [12]. For many tribes, the disruption of traditional use of plants, fish, and wildlife accompanied removal [13].

In Alaska, ANILCA and the Alaska Native Claims Settlement Act (ANCSA) that preceded it in 1971, define almost all aspects of federal land management and federal relationships with native peoples. ANCSA was the settlement of land claims from the Alaskan natives, opening the gate for federal conservation units to be established through ANILCA. In ANCSA, legislators also promised to uphold Alaska Native subsistence land use on federal lands. In practice, ANILCA provides a subsistence priority for all rural residents, Alaska Natives among them, and establishes a framework for subsistence users to give input to federal managers on subsistence uses [14,15].

The enabling legislation for Cape Krusenstern NM and Kobuk Valley NP in ANILCA directs managers to "protect the viability of subsistence resources" as well as to work with Alaska Natives to preserve and interpret resources [16] (Title II, Sec 201). Title VIII, setting the framework for subsistence management in national parks, establishes Subsistence Resource Commissions (SRCs) [16] (Sec. 808). The commissions have a direct channel to the Secretary of the Interior and the Governor of Alaska, inform NPS management, and feed into the Federal Subsistence program. Also enabled by ANILCA, the Regional Advisory Councils (RACs) are formed of rural subsistence users and advise on subsistence management across federal lands [16] (Sec. 805). In addition to the SRCs and RACs formed through ANILCA, NPS participates in the Western Arctic Caribou Herd Working Group (WACHWG). Formed in 1997, this group evaluates herd status based on the most current herd demographics, then chooses a management level centered on population size, growth rate trend, and harvest rate. This management level comes with regulatory recommendations, and the management plan is used to inform regulatory proposal reviews [4].

SRC and RAC meetings are typically held in Kotzebue twice a year. Subsistence users appointed to the commissions and councils who come from IK systems of knowing are motivated to volunteer by the desire to improve management through sharing their IK [15]. They become skilled at working in two vastly different management systems and asserting IK, despite several obstacles presented by the SRC program. Because the meetings are held in Kotzebue, participation from outlying communities is not common, functionally limiting participation to the appointed representatives and removing the discussion of specific resources from the context of seasonal harvest. In a study that sought to understand the relationship between the Qikiqtaġruŋmiut, Kotzebue tribal members, and the NPS, the majority of respondents spoke of "restrictions in general" as a concern; and the number of tribal members who want to know more about regulations suggests the SRCs are falling short of broad public engagement [17] (p. 30). The fact that the meeting follows a standard agenda and Roberts Rules of Order presents another barrier. These parameters can limit the conversation necessary to discuss the nuances of IK. In the end, the management integration of IK shared at these meetings is the responsibility of Park Service managers; however, vacant positions and staff turnover have made such integration difficult in the past and have caused frustration for Kotzebue tribal members [17].

These SRC limitations affect the managers' ability to understand and mobilize IK. Subsistence management is only as effective as the framework established by ANILCA allows it to be [15]. In addressing effective management, this study builds on a 2003 report completed through a Cooperative Agreement with Cape Krusenstern NM and Kobuk Valley NP management titled "The Western Arctic Caribou Herd Barriers and Bridges to Cooperative Management" [18]. In the report, co-management opportunities and levels of control were identified in different functions of management. The authors argued that co-management groups have proximate authority, meaning co-management groups are created by and bought into by the agencies, so there is a social expectation that they will be listened to [18]. Risks involved in co-management, such as conflicting understandings among managers, can be mitigated by increasing the number of actors in the co-management network, such as by the formation of a working group [19]. Mobilizing IK is identified as one of the central strategies and opportunities in the co-management of the WACH [18]. The CHSWG, created by the SRCs and facilitated by NPS staff, has the potential to mitigate some of the risks involved with co-management by engaging more participants in management and increasing the understanding of IK for both managers and subsistence users for the more effective management of the WACH.

Effective management is the ability to respond to resource decline with measures that protect subsistence use and conserve the resource [20]. The recent decline of the WACH has necessitated increased collaboration between the NPS, partner organizations, and subsistence users. In 2015 and 2016, biologists reported that hunting would soon impact the population if the decline continued. Regulatory boards and commissions responded with conservative regulation changes [21]. At the same time, disagreement within subsistence hunting communities over the traditional stewardship of the herd climaxed.

The setting of this disagreement was the Kobuk River, as subsistence hunters, following traditional patterns of use, boated upriver to harvest fall caribou where their migration crosses reliably each year [5]. One such reliable crossing, a small channel of the Kobuk River to the east of Kiana, attracts hunters from neighboring communities, including Kotzebue, the region's population center. Because the fall caribou migration has taken place considerably later in recent years, subsistence hunters' access to the prized bulls has become increasingly uncertain. Competition among subsistence hunters has increased. Issues with hunting on the Kobuk River have included overcrowding, the unsafe use of firearms, not sharing, non-traditional hunting practices, and waste [22]. For the people of Kiana, the small channel of the Kobuk River that was the focal point of disagreements over use, has been identified by the Elders as their traditional hunting grounds. In 2015, the Kiana Elders Council addressed the hunter issues by putting out a list of guidelines based on traditions of their ancestors:

- Always camp and hunt on the south side of the river;
- When caribou start crossing the river, wait until they are half-way across, and approach from the north side to keep the migration moving south;
- If you already have caribou, let the next boat in line have a chance;
- Use smaller caliber rifles, for the safety of others;
- Respect the cabins that you stop at and replace any source you borrowed, keep allotments clean;
- Keep the land and the water clean of trash "we live on this land and drink from this river".

They requested compliance from all hunters using the area [22] but were presented with the challenge of communicating with hunters from the seven villages that harvest from the Kobuk River [21].

At the fall 2016 meeting of the Kobuk Valley and Cape Krusenstern SRCs, members talked at length about hunting issues on the Kobuk River. Members agreed that hunter congestion in the river was putting others in danger and turning the herd back from their crossing. In discussion, members first suggested regulatory change to address the issues. However, SRC member and Kiana Elder Larry Westlake explained the IK behind hunting on the river: "that's our traditional way of hunting ever since they start crossing, and we learned it from our Elders. It worked out for everybody, everybody got what they wanted. It's common sense, you can't get in front of a herd and chase it back and get your catch. You have to continue the migration. You can get your catch and the migration continues" [21]. The Commission dropped the regulatory proposal in favor of an educational initiative and formed the CHSWG to support the Kiana Elders Council efforts.

The CHSWG formed in order for subsistence hunters to work with managers to utilize and develop educational materials based on IK. The IK-based conflict speaks to the complexity of managing subsistence use. The issue is not just maintaining the herd population needed for harvest, it is also about equitable access to the resource, the traditional and cultural practices surrounding harvest, and preserving the way of life for future generations. This study analyzed the records from the CHSWG to determine the effectiveness of identifying IK and opportunities to mobilize the knowledge. The outcome of this model has implications for co-management. With the recent decline of the WACH, the NPS is motivated to gain a better understanding of the use of resources and to integrate formal regulations and Indigenous Knowledge, for a greater likelihood of adherence. In the analysis we will look for new IK presented through the working group and for an increase in the number of people engaged in the management system as indicators of IK being mobilized. By deepening understanding of subsistence and engaging more users in the subsistence management systems, the mobilization of IK leads to more effective management.

2. Materials and Methods

The current effort to document caribou hunting IK began with the CHSWG meetings. The CHSWG formed to address "Hunter Success" issues from an IK perspective, with a focus on public outreach. "Hunter Success" comes from the "Iñupiat Ilitqusiat", a program created by northwest Arctic leaders and Elders to define the values of the Iñupiat. Hunter Success is one of seventeen values aimed at passing on knowledge to the next generation. The definition of "Hunter Success" is getting meat for your family. It is tied to traditions and knowledge passed down from Elders [23]. When addressing the subsistence hunting issues on the Kobuk River, the Kiana Elders Council chose to frame their IK as Hunter Success [22].

At the direction of the SRCs, NPS staff facilitated the group made up of federal and state managers, along with subsistence users. Participants are self-selecting and because of the informal nature of the group, attendance varies. The contact list notified of CHSWG meetings is comprised of 24 participants. Of the 24, seven participants are Elders or hunters with IK about caribou hunting. Because these participants have or are currently serving on the SRCs, they can be described as key informants with established relationships of information sharing. The agencies, along with the NPS, involved in the working group include: the State of Alaska Department of Fish and Game, the Alaska State Wildlife Trooper, Selawik Fish and Wildlife Refuge, NANA Regional Corporation (the ANCSA Native Corporation for northwest Alaska), The Native Village of Kotzebue (Kotzebue's tribal organization), northwest Arctic Borough, Maniilaq Association (the Native non-profit for the northwest Arctic), and Teck Alaska (a mining and development corporation). The agencies involved are also self-selecting. Participants include biologists, educators, and managers—all with interest in the management of the hunt from the WACH. Since 2017, seventeen working group meetings have been held. The meetings served as "analytical workshops". Huntington described the benefit of this approach: "a workshop that brings together scientists and the holders of TEK can allow both groups to better understand the other's perspective, and to offer fresh insights. By cooperating in the analysis of data, the two groups may also find common understanding and jointly develop priorities" [24] (p. 1271).

The CHSWG was designed to be informal by not making decisions and providing a space to discuss IK and public outreach efforts. Each meeting is held at the NPS office and through teleconference. Rather than setting a formal agenda, the facilitator moves through discussion items, and the group is consensus-driven, with hunters and Elders holding the authority on IK, the main topic of discussion. Elders and hunters often ask managers for information on state and federal regulations and the WACH status. Outcomes of the working group are reported to the RACs and the SRCs at their biannual meetings.

The primary goal of the CHSWG is to support the transmission of IK. While the subsistence hunters in the group were primarily motivated by lax adherence to traditional hunting values, they also acknowledged a lack of awareness of current hunting regulations and the health of the herd, as this information changes from year to year. To increase communication in the villages, tribes hosted interagency informational meetings in the villages prior to the fall caribou hunting season. Since 2017, fifteen meetings were hosted in seven villages [22]. The community hunter success meetings were "analytical workshops" considering localized IK; for example, the discussion in Kiana was focused on IK specific to the small channel of the Kobuk River, their traditional hunting grounds.

Community meetings were designed with several considerations for the cultural context of IK transmission. Firstly, meetings are held in the village right before the hunting season. This encourages the sharing of location-specific knowledge during the time of year when it is most relevant. The meetings are hosted in partnership with the local tribal government and are organized with local recommendations for a successful meeting. For example, a prayer is said at the beginning of the meeting if that is customary in the community. Secondly, participation in the community meetings is self-selecting. A raffle for all attendees may be offered as an incentive. Thirdly, as with the CHSWG meetings, Hunter Success community meetings are driven by consensus and Elders hold the authority on IK. Finally, agencies provide information in a question and answer style discussion. Village hunters who do not regularly meet with agency staff take the opportunity to ask questions about regulations that they do not understand.

For this study, the meeting records for subsistence meetings during the period 2016–2019 were analyzed using qualitative methods to determine if the CHSWG has created opportunities to mobilize IK. SRC and RAC meetings are recorded and transcribed. Working group meetings and community meetings are documented in a summary of discussion generated by the NPS. The records from the meetings were analyzed by the author to identify the "rules of thumb" in use for Iñupiaq caribou stewardship. The term "rules of thumb" is defined as "simple prescriptions based on a historical and cultural understanding of the environment". They are often backed up by religious belief, ritual, taboos, and social conventions [25] (p. 194). Rules of thumb can be expressed in a sentence, though the historical and cultural understanding of the environment make up a deep body of knowledge that the short form is meant to reference. In some settings, IK is transmitted in long form, for example, through an elder telling a story. Short-form rules of thumb are often engaged in co-management settings [26].

Literature on IK has identified an issue with the way that it is mobilized in management in that IK is only partially understood by managers and removed from its context [25]. IK is multifaceted, but the most commonly utilized part of IK is factual observations about the environment [27]. The CHSWG aims to share IK in a holistic sense. The success can be measured, in part, by the analysis of materials for new facets of IK identified. Mobilizing IK in the existing structure of management will only serve to remove it from its context, however, mobilizing IK can affect management if it is integrated in a system that engages Indigenous people. One measure of integration is the number of people involved in the management structure. This method acknowledges IK as dynamic and responding to social context, rather than a static data source removed from the system of Indigenous management that it is derived from [28].

3. Results

The CHSWG identified IK related to hunting issues brought up by Elders and hunters. The outcome of the CHSWG and the community meetings was the identification of IK rules of thumb. In two cases, the identification of IK happened through discussion at community meetings, semi-formal interviewing, and educational publications in the form of flyers, radio announcements, and social media campaigns. In each case, the CHSWG relied on publications that attempted to transmit IK in the form of rules of thumb. "Iñupiat Ilitqusiat Aŋunialgułik: Hunter Success for Caribou Hunting" (Figure 1) was developed by the Kiana Elders Council and "Iñupiat Ilitqusiat Guidelines on Winter Caribou Hunting" (Figure 2) was developed by the Native Village of Kotzebue with assistance from the CHSWG.

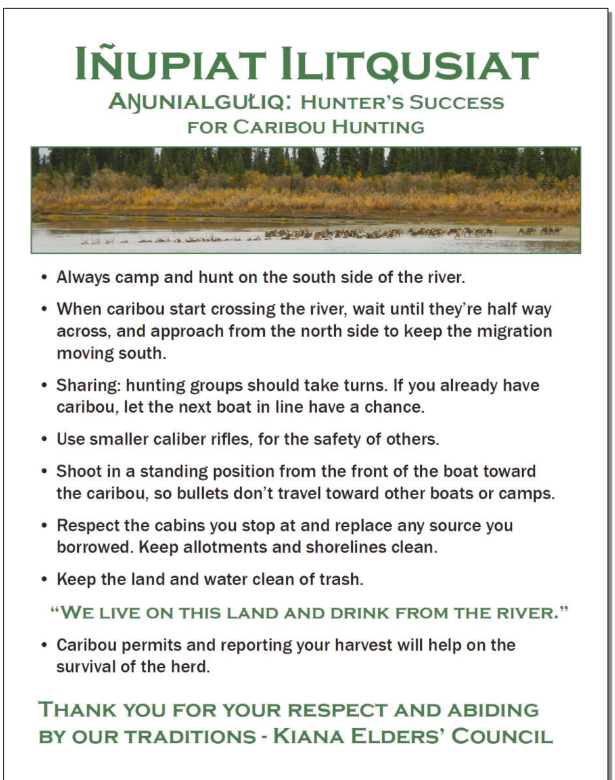

Figure 1. "Iñupiat Ilitqusiat Aŋunialgułik: Hunter Success for Caribou Hunting" flyer published by Kiana Elders Council first in 2015 and updated in 2017.

Iñupiat Iḷitqusiat Guidelines on Winter Caribou Hunting
from the Native Village of Kotzebue

Caribou should be treated with respect. Tuttu are integral to our culture. We want to have these animals come back every year. We need to have respectful, responsible hunting.

- Consider hunting with a partner or a group. You can work together and make a plan of how to get close to the caribou or move them toward another hunter's position. Through sharing and cooperation everyone will get a portion of the harvest.
- Take your time. Observe caribou groups before you approach.
- Pick out the animals you want to harvest.
  - *-Look for animals that are fat and in good shape before you shoot. The shape of the back, the color/quality of the hide, and the upward curve of the tail can be clues to look for.*
  - *-When mature bulls are in rut, younger bulls and barren cows can still provide good meat.*
  - *-Do not shoot cows with calves. If you want to take a cow, wait to see if it has a calf with it.*
  - *-Avoid pregnant cows when possible, they are the breeding stock of the herd.*
- Don't shoot into a bunched up group of caribou. Wait until they separate & target specific animals.
- Chasing caribou and running them too much is bad for the health of the animals and results in poor quality meat. If you must chase, pick out one animal and move it away from the rest of the group.
- Use the terrain: look for high ground, hills or cover, or deep snow. Caribou will often go to high ground if they are being approached. You can make a plan to take advantage of this. Or, you can try to move caribou toward deep snow, which will allow you to get closer to them.
- Show respect for the caribou after it's harvested. You're responsible for the caribou you shoot. Take good care of the meat & all the parts. This is how we give thanks to the animal that gives itself to us.
- Not only is waste of caribou disrespectful, it is illegal.
- In the wintertime, an effective way to tenderize the meat is not to butcher the animal too soon. You may gut the animal out in the country, but keep the skin on and don't take the animal apart. Then, bury it in the snow for a few days. The hide will keep the meat from freezing, and the retained heat will tenderize your meat.

NATIVE VILLAGE OF KOTZEBUE
KOTZEBUE IRA

Developed by NVOK & The Caribou Hunter Success Working Group
Spring 2018

Figure 2. "Iñupiat Ilitqusiat Guidelines on Winter Caribou Hunting" flyer published by Native Village of Kotzebue in 2018.

The CHSWG resulted in further definition of the Hunter Success issues on the Kobuk River. Larry Westlake, participating in the CHSWG to follow up on his work on the Kiana Elders Council and SRC, explained his motivation for educating his community:

> "It is close to 60 years since caribou crossed near Kiana. When caribou came through the narrows, hunters in Kiana would wait two days after the caribou started crossing. After the first had crossed and established the migration, the Elders say, we would have caribou all our lifetime. Now-a-days there are more hunters and less caribou, all in a six-mile area on the Kobuk River. There are too many hunters. That's why we brought Hunter Success back. They are not regulations but guidelines for a more successful hunt, for example, keep heads and horns out of the river side. Take care of the river" [22] (p. 4).

In order to address the issues with hunting on the Kobuk River, community meetings were held in the villages that hunt from the Kobuk River. The first part of the community meetings was dedicated to discussing traditional Iñupiaq values around hunting. "Iñupiat Ilitqusiat Aŋunialgułik: Hunter Success for Caribou Hunting" (Figure 1) was shared and used to start a discussion of differences and similarities between the values in neighboring communities. Then, agency staff provided information about the health of the herd and the changes in hunting regulations for the year. The information was presented in a two-way conversation with attendees; and throughout the communities, residents were consistent in questions about land ownership, jurisdiction, and enforcement [22].

Table 1 shows the number of community meetings held during the period 2017–2019 and the attendance at the meetings relative to the population of the community. The attendance of community meetings shows the increase in the number of subsistence hunters participating in the co-management of the herd. This is in contrast to the representatives from those communities that serve on the SRCs, RACs, or WACHWG. There are four representatives from Kiana that serve on either the SRCs, RACs, or WACHWG, so it can be concluded that holding a meeting in Kiana increases the number of Kiana participants in the co-management of the WACH.

Table 1. Table of results from the Caribou Hunter Success Working Group community meetings showing the population of the village and attendance for 2017, 2018, and 2019.

		Attendance		
Village	**Population**	**2017**	**2018**	**2019**
Kiana	421	20	29	40
Noorvik	629	48	30	40
Ambler	287	46	-	26
Kotzebue	3121	4	-	-
Selawik	629	62	-	-
Noatak	581	46	43	34
Buckland	511	10	-	32

3.1. Caribou Hunting on the Kobuk River

In the case of the Kobuk River Hunter Success issues, community meetings provided space for IK rules of thumb to be further defined to address the issues identified. The community had defined the IK rules of thumb in their 2015 flyer "Iñupiat Ilitqusiat: Hunter Success for Caribou Hunting". In 2017, the Kiana Elders Council along with the CHSWG revisited their 2015 document, and edits were made to the flyer to include a recent change in enforcement of caribou registration permits (Figure 1). Following hunting regulations and Iñupiaq values were both considered a part of a successful hunt [22]. In 2018 and 2019, the Kiana Hunter Success meeting started with the rules of thumb expressed in short form, then with Elders and hunters explaining the experience of hunting informed by IK, thus rules of thumb were thereby reshaped [22].

This process included forming a committee of Kiana residents to shape the rules of thumb and to transmit the rules to their community [22]. The Kiana committee worked to put together a call to hunters to wait twenty-four hours after the first migration of the herd before hunting, and to avoid the little channel of the Kobuk River. This guidance was based on the IK shared by the Kiana Elder Larry Westlake concerning how the caribou hunt was managed by his ancestors. The twenty-four hours after migration timeline falls under protecting the lead caribou rules of thumb. The request to avoid the little channel was directly tied to positioning of the hunter rules of thumb. The Hunter Success meeting gave space for the deep IK context of these rules of thumb to be explained, and for multiple Elders to explain their experiences with it. The flyer communicated IK in short form. Some members of the Kiana committee also hope to codify the rules of thumb in state hunting regulations [22].

Before the hunting season, agency partners in the CHSWG shared the IK-based guidance created by the Kiana Committee. In the working group meetings that followed, Kiana community members reported less boats on the river, though effectiveness of their efforts was difficult to measure as the migration of the caribou did not include the crossing near Kiana in 2018. Boats were not there because the caribou were not there [22].

3.2. Caribou Hunting by Snowmachine

The next case we will discuss was brought to the CHSWG after formation and the Kobuk River case served as a model to address the issue through the identification of IK. To give some background, we will first start by saying the migration pattern of the WACH is highly variable. However, a relatively new pattern of movement brings the herd along the coast of the Chukchi Sea and across Kotzebue Sound in November, after ice has formed, to surround Kotzebue while snow is on the ground [29]. Subsistence hunters from Kotzebue and nearby areas hunt these migrating caribou from snowmachines. This method, combined with the herd's proximity to the large community of Kotzebue, provides greater access than fall hunting by boat in the rivers. As Cyrus Harris, an Iñupiaq subsistence hunter from Kotzebue, Alaska, explained during a Working Group meeting: "The migration around Kotzebue after freeze-up is, for some people, their first time seeing caribou. People likely have the tools to harvest a caribou for the first time. All you need is a snowmachine and a gun. It is an educational wake-up call" [22].

The needed education included more detailed IK rules of thumb on how and when to hunt caribou by snowmachine. The issue involved both formal regulation and the IK management system enforced by community standards [22]. Snowmachines allow hunters to position themselves and the animals, herding caribou so they are easier to harvest. Snowmachines have been utilized since the mid-1960s when they replaced dog teams as the main form of winter transportation. In general, the use of the machines for hunting developed out of traditional methods of intercept hunting [5]. On NPS and other federal lands in northwest Alaska, federal subsistence regulations set the parameters for hunters, such that: "a snowmachine may be used to position a hunter to select individual caribou for harvest provided that the animals are not shot from a moving snowmachine". Under general statewide "Subsistence Restrictions" on federal lands, hunters are prohibited from using snowmachines to "drive, herd, or molest" caribou [30] (p. 16–20).

Subsistence users maintain that the appropriate use of snowmachines to hunt and harvest can be negotiated through IK management systems. IK management systems allow hunters the most agency to apply IK to specific hunt situations [26,31]. The CHSWG, using the Kobuk River case as a model, set out to work with the Native Village of Kotzebue to identify IK rules of thumb in this case [22]. The rules of thumb identified were approved by the Tribal Council and published in a document titled "Iñupiat Ilitqusiat Guidelines on Winter Caribou Hunting" (Figure 2). However, in this case, it was determined by the CHSWG that community meetings would not be effective, given the low turn out of one community meeting held in Kotzebue (Table 1).

Agency staff from the CHSWG used semi-formal interviewing to guide the discussion of IK. Questions were informed by the rules of thumb that surfaced each time the working group discussed traditional caribou harvest, including: protection of the lead caribou, rules positioning the hunter, rules for selecting and positioning the animal, salvage practices to use all parts of an animal, knowing the land/respecting the land, sharing, hunter safety, and following regulations [22].

The resulting conversation covered knowledge passed down over generations focusing on the rules of thumb for hunter positioning and the positioning of animals. The following quote from Robert Schaeffer, an Iñupiaq hunter from Kotzebue, provides an example of a story used to transmit IK in long form.

> "I remember when I first came back from school dad took us out and we needed to get a couple [of caribou], that we needed really bad, so we went over to the Noatak Flats toward the Hatchery area. It was colder than hell that day . . . and anyway we got there, we saw the

> herd down there, and he didn't want to chase because he was more concerned about the health of the animals, he don't want to chase in the cold because it will freeze their lungs and will affect them. So he said 'what we'll do is, I'll sit up here, and you'll go down and around them to the river. And you'll come up at them slowly, and almost come to the top side. I'll just wait here ... all we need is four.' And, sure enough, they headed to the top side. He picked out his four, got his four ... Working together is really important. I think when we went out there with our younger folks afterwards, and ran into a caribou herd, we'd plan out what we are going to do before we even take off. We don't just go out and go dashing into the herd, hoping like heck we can get something. Planning something like that is really important" [32].

In the conversation surrounding this story, the hunters discussed landscape features that help in a hunt, such as the tendency of animals to run to high ground when they are threatened and the use of deep snow to slow a fleeing animal. Elders' stories were transmitted through short-form assertions meant to be easily remembered, though they referenced a larger system of knowledge surrounding the assertions [26].

The short form that was included in the hunter flyer reads, "Use the terrain: look for high ground, hills or cover, or deep snow. Caribou will often go to high ground if they are being approached. You can make a plan or take advantage of this. Or you can try to move caribou toward deep snow, which will allow you to get closer to them" (Figure 2). The risk of sharing this information without the original conversation involves removing short-form information from a context of generational knowledge. Other methods of sharing information were suggested, such as school programs and hunter mentorships [22]. While this was discussed at the working group, it would require the expansion of the program, including funding and possibly more staff.

It is challenging to measure the success of this educational initiative. Because community meetings were not used to spread the information, we do not have attendance numbers to gauge participation. The flyer was shared at the Native Village of Kotzebue Annual Meeting as well as at the 2018 RAC meeting. In early winter 2018, after a full year of circulating the "Iñupiat Ilitqusiat Guidelines on Winter Caribou Hunting" flyer (Figure 2), parts of the caribou herd again migrated in November through the ice-covered Kotzebue Sound, bringing caribou right through town. Two young hunters killed a caribou by hitting it with their snowmachine. The Iñupiaq community was outraged at the lack of respect for nature [33]. While the information shared by the CHSWG had not prevented the incident, the working group provided a space for hunters to communicate with the Alaska Wildlife Trooper on how the case was being handled, to discuss the disconnect between the traditional ways of hunting and the youth, and to recommend educational and service-oriented sentencing when the case went to court [22].

4. Discussion

For managers of Kobuk Valley NP and Cape Krusenstern NM, mobilizing IK is the next step towards cooperative management. Subsistence hunters participating in formal subsistence management groups bring their IK perspective into NPS management, and the CHSWG has succeeded in creating opportunities to mobilize IK. In both Kiana and Kotzebue, IK rules of thumb were identified in order to address hunter success issues. In this work, there is the opportunity to make NPS management more effective through a deeper understanding of caribou harvest and by integrating IK into regulation, legitimizing NPS management [18]. We can learn about similar challenges and inform our recommendations by looking at two studies on IK mobilized in the management of the Porcupine Caribou Herd on Alaska's northern border with Canada [26,34]. Wray analyzed the Porcupine Caribou Management Board (PCMB) educational materials for rules of thumb and compared them to government regulations for caribou hunting [26]. The PCMB also worked with government officials to establish formal regulations to protect the lead caribou migrating around the Dempster Highway in Canada's Yukon and northwest territories [34]. Finally, our discussion includes limitations of the current efforts to document IK through the CHSWG and recommendations for expanding the program.

The community meetings held by the Working Group in villages prior to the hunting season are an educational effort where IK rules of thumb are identified alongside Federal and State regulation. Spaeder et al. called the educational programs "the primary strategy in which resource agencies attempt to address resource conflicts and the gulf that exists between law and customary practice" [18] (p. 88). At the 2018 Hunter Success Meeting in Kiana, community members discussed who has the power to make change in local hunting practices: the tribe, the federal government, or community members [22]. This discussion of who holds the power of change is integral in landscapes split by jurisdiction and layered with multiple management systems. The hunter's experience is shaped by the regulatory system as well as the management systems associated with the IK of the local people. Some Kiana community members called for change in the state regulations to reflect rules of thumb around the protection of the lead caribou [22].

Kiana community members, over the course of three years of Hunter Success Community meetings, were able to identify and refine IK rules of thumb to address issues in the river channel east of town. Each meeting ended in consensus, but the consensus did not extend to the community members not in attendance [22]. The study of the PCMB in Canada is helpful in the discussion of the challenges associated with reaching consensus on IK rules of thumb. Padilla and Kofinas found that "intercommunity conflict and intergenerational divide" in first nations groups created resistance to the formal regulations enforced by the Canadian government that were based on IK rules of thumb. The meaning of the "lead caribou", when defined by the Indigenous Elders, is "highly context-dependent" [34] (p. 212). The regulations to protect the lead caribou focused on closing portions of the road for weeks at a time. This method took the agency away from individual hunters to exercise IK as it fit the situation [34]. In the case of the "Iñupiat Ilitqusiat Aŋunialgułik: Hunter Success for Caribou Hunting" (Figure 1), consensus over IK rules of thumb is challenged by intercommunity conflict. The Kiana Elders Council wants to have hunters across the region comply with their values, but there is some variation in the IK shared in different traditional groups. In Noorvik, the community closest to Kiana, the IK was affirmed by a local Elder at a 2017 Hunter Success Meeting as he told stories based on his own experience of hunting on the Kobuk River. However, in Kotzebue, further from the hunting grounds where this IK was developed, hunters may be less educated in IK specific to the Kobuk River [22].

In the case of caribou hunting by snowmachine near Kotzebue, there are similar aspects of intergenerational divide and the agency granted to the hunter to apply the guidance to specific hunting situations. When rules of thumb are shared through stories, such as the hunting story shared by the Iñupiaq hunter from Kotzebue, Robert Schaeffer [32], the application of the rule of thumb to the specific hunting situation is communicated in ways hunters can learn and model. In Wray's observation of the PCMB, shorthand versions of rules that are also communicated through stories and shared experiences serve an important function. "The use of such shorthand may be the only means of ensuring compliance with particular norms without the necessity of communicating all meaning in all instances" [26] (p. 177).

However, sharing rules in shorthand assumes young hunters have the deeper understandings it is supposed to recall [26]. In the Padilla and Kofinas case study, the interviewees expressed concern about youth in their community understanding traditional knowledge [34]. In the case of caribou hunting by snowmachine around Kotzebue, the effectiveness of the educational efforts is limited by the youth's lack of knowledge about the use of landscape, caribou physiology, and herding techniques. Because of gaps in the experiential learning required to be a successful hunter, all of the knowledge needed to have a successful hunt is not being communicated well through the short-hand IK rules of thumb that can be shared through a flyer.

Efforts to address subsistence issues surrounding Kotzebue winter caribou hunting will likely require a combination of hunting regulation enforcement and education through IK. In the development of the "Iñupiat Ilitqusiat Guidelines on Winter Caribou Hunting from the Native Village of Kotzebue" (Figure 2), hunters were encouraged to develop IK rules of thumb to respond to the evolving hunting issue. Rules of thumb have the potential to hold hunters to values and ethics that will sustain the herd, while also allowing agency to the hunter [26]. Some subsistence users have asked for agencies to enforce IK rules of thumb, and at times have gone through the regulatory process to codify the unwritten law of the land [18]. The outcome for the PCMB is a caution that without consensus, the NPS enforcement of IK may be perceived as further infringement on the individual hunter's subsistence rights and as a result, could delegitimize both systems of management [34]. In the informal discussion around IK rules of thumb, the Kotzebue hunters flowed between regulatory changes and IK allowing all of the management tools to be explored—the alignment between hunter actions and IK ethics and values being the ultimate goal.

The CHSWG is expanding on the framework laid out in ANILCA. This follows recommendations, from Spaeder et al., to establish space for NPS and subsistence users to discuss issues outside the formal management structure and to facilitate collaborative efforts to solve issues [18]. Looking at the way the conversation about Kobuk River hunting developed, we can see that when it was brought up at the 2016 SRC meetings, managers and subsistence users were unable to fully understand and address the issue. By forming this working group with a special focus on IK, federal and state managers and subsistence users worked together to identify IK rules of thumb. Participating in the working group meetings and community meetings as "Analytical Workshops" [24] (p. 1271), the NPS has gained a deeper understanding of what is meant by "the lead caribou" and traditional methods of harvesting caribou by snowmachine [22]. This knowledge can be mobilized in NPS interactions with subsistence users such as community meetings, subsistence commissions, and enforcement interactions. The informal setting allows Elders and hunters to discuss the intergenerational and intercommunity disconnect, and the agency staff are able to ask questions and generate solutions.

In the discussion of whether this working group approach leads to the effective management of the WACH, it is important to note that the impact on the WACH population and harvest numbers is outside of the scope of this study. Future research directions may include the impact of co-management initiatives on the WACH population and would need to be monitored over the course of decades. While a qualitative analysis of materials from the CHSWG shows that new information was gained, it is difficult to measure the reach of the educational materials used by the working group. Participation at the community meetings hosted by the working group give us some idea of the expansion of the co-management network, but it does not capture the reach of the message and does not directly correlate to the success of the educational effort. Because of the interpretive aspect of IK, it is also hard to measure success in terms of compliance. In both cases, the local conflicts around subsistence hunting continue. It is not the role of the NPS to fix this conflict, but it is clear that the NPS has an important role in management and that management of the herd should involve IK. This study shows that the collaborative relationships between the NPS and local entities is a step towards effective management.

Limitations to the organization and the reach of the CHSWG do exist. Because the aim is to bring subsistence users and agencies together to work informally, participants have loose obligations to attend. The working group reports back to the Kobuk Valley and Cape Krusenstern SRC; the decision-making power is with the NPS and other land management agencies. With an educational focus, the CHSWG operates within these limitations. Expansion of the efforts of the working group would require commitment from the NPS or other resource management agencies [22].

This study has used three years of data gained through participation and observation. Further analysis could result in a better understanding of where IK originates and the outcomes of sharing that IK. Regardless of the limitations of the working group and research, this should be looked at as part of a broader management effort. The NPS is working to recognize, document, and mobilize IK through multiple efforts. IK is shared with the NPS at SRC meetings and through tribal consultation. Baseline documentation such as Traditional Use Studies are in progress in Noatak National Preserve and Kobuk Valley National Park [7,8]; and IK is integrated into Natural Resource and Cultural Resource projects.

The NPS managers for Cape Krusenstern NM and Kobuk Valley NP can further efforts to mobilize IK following several recommendations that come from our analysis of the CHSWG. First, intercommunity dialogue should be supported. As is customary in IK management systems, decision making is driven by consensus. It may take multiple conversations across different communities to reach a consensus. However, to mobilize IK based on just one source could result in the defiance of the guidelines and/or regulations by the hunters excluded from that by an incomplete consensus [34]. Efforts to bolster IK must focus on long-term discussion, as IK is constantly forming and adapting to new situations. Rules of thumb should not be shared in short form without access to the deeper context [26]. Mentorship programs have been suggested as a solution [32]. Elders hold the authority on IK, and agency staff must be cautious to maintain that dynamic. IK-informed regulations enforced by government agencies threaten to delegitimize both the agency and IK. Lastly, the formation of a working group to focus on specific topics has proven to be a successful informal environment in which to discuss IK.

Funding: This research was undertaken as a part of the Western Arctic National Parklands Subsistence Program and funded by the National Park Service.

Acknowledgments: This study would not have been possible without the work of the Caribou Hunter Success Working Group. Larry Westlake has contributed greatly to this effort. Cyrus Harris has also provided consistent insight. Thank you to Alex Whiting, Susan Georgette, Raime Fronstin, and Justin Junge for the time spent reviewing and commenting on this manuscript. Thank you to Douglas Deur for insightful discussion that shaped parts of this paper and well-timed advice.

Conflicts of Interest: The author declares no conflict of interest.

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Article

Informing Protected Area Decision Making through Academic-Practitioner Collaborations

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Received: 31 July 2020; Accepted: 2 October 2020; Published: 7 October 2020

Abstract: This study examined knowledge mobilization and collaboration practices of practitioners in a Canadian provincial park agency, BC Parks. Data was collected through four focus groups, an on line survey (N = 125), and a follow up workshop. Results showed that the most important information sources used by the agency were "internal" (e.g., policy and management guidelines), while "external sources" such as academic researchers or journals were rated lower. However, those who collaborated with outside groups, including academics, and those working in a science capacity within the agency, rated external information sources more positively. Barriers and enabling conditions for effective knowledge mobilization were identified.

Keywords: knowledge mobilization; protected areas; evidence-based decision making

1. Introduction

For at least the last two decades, there has been a growth in the literature that describes the need for, but suggests a lack of, evidence-based decision-making among conservation practitioners [1–6]. Somewhat more recently, a number of contributions have sought to explain the persistent gaps between science and decision-making by conservation practitioners, and to offer solutions for bridging those gaps [7–10]. Despite this growth in the literature, however, relatively few contributions examine these gaps [10,11], and this has been noted for decision making within protected areas (PAs) [3,11]. Accordingly, this article provides a specific, empirical focus on the relationships between academic researchers, and practitioners within British Columbia (BC) Parks, North America's third largest parks system.

The specific questions of this study were: (1) What is the overall perceived importance of research to BC Parks practitioners in fulfilling their job responsibilities? (2) What levels of importance do BC Parks practitioners assign to different information sources in guiding decision-making? (3) With whom do BC Parks practitioners interact or collaborate with to gather information to guide decision-making? (4) What are the perceived advantages and disadvantages of collaboration with university-based researchers? These questions have been elaborated into hypotheses, described later in the paper. This paper describes the relevant literature (next section), methods used to conduct the study, research findings, discussion, and conclusion.

2. Literature Review

Several authors have charged that conservation practitioners, for a variety of reasons, tend not to rely on scientific evidence in decision-making, but rather adopt ad hoc processes, relying on experience, anecdote, and informal relationships to make decisions [1,5,9]. Descriptions of, and suggested solutions to, the gaps between science and practitioner decision-making tend to fall into two overlapping general perspectives. The first, sometimes described as the 'engineering', 'linear', or 'science push' model frames scientists and practitioners as being in somewhat different domains, and essentially posits that 'good' science produced by scientists will be valued and used by decision-making practitioners [8,10,12]. The characteristics that make for 'good science' vary in the literature, though there are some common themes. For example, authors have pointed to the importance of asking better/different questions, including adopting interdisciplinary approaches, bringing in the social sciences, attacking 'real-world' and/or 'relevant' problems, and producing results within time-frames that more closely match the needs of practitioners [7,10,13,14]. In addition to this attention to the nature of science produced, others have focused on the importance of science communication. Authors in this vein have emphasized factors such as the lack of access to scientific sources (e.g., subscription journals), prohibitively complex language, inadequate 'translation' and the absence of explicit connections to decision-making, and the tendency of some scientists to simply avoid policy/decision-making arenas [7,10,15–17]. This engineering model has implications for the present study, as the model suggests that those conservation practitioners employed in a science capacity may be more supportive of the use of science in decision making, and attach more importance to the use of information sources external to the agency.

The engineering model has also been criticized for being overly simplified. In contrast, the social or 'two-way' model focuses on the interactive social aspects of knowledge utilization. For example, researchers have pointed to (a lack of) opportunities for direct interactions between scientists and practitioners such as informal personal contacts, participation in committees, and other mechanisms [10,18]. Some authors have suggested that cultural, organizational, or ideological differences between scientists and practitioners can lead to difficult communication and barriers [10,14,19], while others have suggested that developing more participatory and inclusive processes of research objective setting and knowledge production (including the useful roles that intermediary 'knowledge brokers' and/or boundary spanners can play) will lead to better understanding and uptake [8,9,20]. This social model has implications for the present study, as the model suggests that those conservation practitioners who have collaborated with other groups external to the agency may be more supportive of the use of science in decision making, and attach more importance to the use of information sources external to the agency.

Despite the elaboration of these conceptual models, and the wide range of barriers and solutions identified, there has been relatively little empirical investigation of how these apply in practice [2,9,21]. There are important exceptions, however, some of which are useful to mention here. For example, in a study of Australian protected area managers' use of evidence-based knowledge (derived from research, monitoring, and/or formal assessment), Cook et al. [3] found that 2% to 20% of conservation managers used evidence-based knowledge exclusively to support their management decisions. Managers tended to use multiple sources of evidence, including general and specific management plans (termed "intermediate evidence"); and observational and anecdotal data ("experience-based evidence") in addition to evidence-based knowledge. Further, the type of evidence used varied substantially depending on the management issue at hand. For example, 57% of managers used experience-based evidence when addressing visitor impacts, whereas approximately 20% of managers reported using evidence-based sources to address management of cultural heritage use [2,3]. Findings also indicated that although managers valued empirical evidence, they reported insufficient access to empirical evidence to support decision-making [2]. Similarly, Sutherland et al. [1] found that practitioners (wetland managers) in the UK overwhelmingly favored 'common sense', personal experience and talking to other managers over the primary scientific literature. Likewise, Pullin et al. [15] surveyed compilers of management plans within UK conservation organizations and found that existing management plans, opinions from outside experts, reference to previous management plans and public reviews were accessed much more frequently than published science.

Although the gaps between science and decision-making in conservation are well documented, recent evidence suggests there appears to be much consensus regarding the barriers and solutions. For example, a recent global survey involving 758 respondents, selected to represent the fields of policy, practice, and research in 68 countries were asked to describe barriers to knowledge mobilization, and possible solutions [22]. The top 10 barriers reported in this study were: (1) lack of policy relevant science; (2) lack of a political priority for conservation; (3) mismatch of time scales; (4) complex uncertain problems; (5) little understanding of science by policy-makers; (6) lack of funding for conservation science; (7) priority of the private sector agenda over conservation; (8) insufficient consideration of stakeholders; (9) lack of understanding by scientists about how policy is made; and, (10) bad communication between scientists and policy makers. Five solutions emerged from the study: (1) provide incentives for scientists to work on policy issues; (2) translate key findings in journals into different languages; (3) create more collaborations between scientists and policy makers (meetings, projects, etc.); (4) provide more knowledge brokers and; (5) tailor evidence to audience (blogs, open access, policy briefs, etc.). These listings of barriers and solutions to knowledge mobilization can be linked to the present study, in that they suggest, in part, that those conservation practitioners who are based at BC Parks headquarters in Victoria will have better access to academic researchers (that is, near to 5 universities) and may be more supportive of the use of science in decision making, and attach more importance to the use of information sources external to the agency.

Further insights into social processes involved in knowledge mobilization are provided by Reed et al. [23]. Moving beyond describing the barriers to knowledge mobilization, the authors suggest that the social learning model of knowledge mobilization can be improved through the application of five principles, developed from interviews conducted with 32 researchers and stakeholders involved in 13 environmental projects in the UK: (1) incorporate knowledge mobilization as part of research processes from the outset of a project, to develop trust and shared ownership; (2) understand the needs of all stakeholders in a project; (3) build long term, trusting relationships; (4) deliver tangible results as soon as possible; and (5) consider how to sustain stakeholder relationships beyond the life of a project.

Of course, 'science/scientist' and 'practitioner' are general (and overlapping) categories and science-practice gaps can occur across a wide range of contexts. Further, we recognize that there are different types of knowledge that are pertinent to decision making in the context of conservation and PAs [24,25], and this would include: academic knowledge (natural sciences and social sciences); local knowledge; indigenous knowledge; and expert professional knowledge (e.g., knowledge gained from experience by PA managers). In this article, we are particularly interested in the relationships between academic (university-based) research related to decision-making by BC Parks, a government agency that administers Provincial Parks in British Columbia, Canada. Parks and protected areas have long been the sites of academic research, and Canadian PAs are no exception. For example, a ProQuest dissertation search revealed a listing of 734 theses and dissertations completed at 98 Canadian universities, but we have no sense of the impact of this research on decision making in PAs. Further, we have little knowledge of the needs of practitioners (such as government park agencies), how they perceive the advantages and limitations of working with academic science/scientists in relationship to other sources, and how they utilize it in decision-making information (see also [4,26,27]). Accordingly, this paper explores the usefulness of academic research as perceived by practitioners within a conservation agency, BC Parks, and examines three possible explanatory factors identified in this literature review, leading to the following hypotheses:

Hypothesis 1 (H1). *External information sources of information (outside of BC Parks) will be perceived to be more important by those practitioners who have collaborated with "external sources" (such as academics); are employed in a science capacity; or are employed in Victoria headquarters.*

Hypothesis 2 (H2). *Overall importance of research is perceived to be more important by those practitioners who have collaborated with "external sources" (such as academics); are employed in a science capacity; or who are employed in BC Parks headquarters in Victoria, BC.*

3. Methodology

3.1. Study Background: BC Parks

BC Parks, as part of the Provincial Ministry of Environment, is responsible for the designation, management and conservation of a system of protected areas located throughout the province. BC Park's mission is to protect representative and special natural places within the Province's Protected Areas System for world-class conservation, outdoor recreation, education, and scientific study. BC Parks' services and management are delivered through a headquarters office in Victoria and regional offices in five regions located throughout the province. As of 2019, the system managed by BC Parks included 1034 protected lands, covering approximately 14.4% of BC or approximately 14 million hectares [28]. British Columbia's protected areas system is the third largest in North America (after the Canadian and United States national parks systems) and the largest provincial/territorial system in Canada [28]. There are a number of employment categories within the organization, including natural science, visitor management, planning and protected area designation, and field operations.

3.2. Research Design

The research incorporated a phased design that was developed in close collaboration with two senior staff affiliated with BC Parks. Data collection consisted of two main stages: the first stage was a series of four focus groups, the primary purpose of which was to inform the development of an online survey comprising the second stage of the research. Results of these two stages were presented to attendees at a subsequent annual BC Parks employee conference. Though unstructured, this feedback process generated some useful insights, some of which are presented here. All of this work was conducted with the approval of the relevant University research ethics boards.

Focus groups were led by university-based researchers (authors on this study). Groups were designed to include a number of different types of BC Parks employees (working in different job types), and to include representatives from different parts of the Province. The first focus group was conducted by telephone with seven resource conservation officers employed by BC Parks, representing different administrative regions within the Province. The second focus group was conducted by telephone with six visitor service officers employed by BC Parks, also representing different administrative regions within the province. The third and fourth focus groups were undertaken in a face-to-face format at two provincial parks with two BC Parks employees at each venue. At each focus group, we asked questions relating to: (1) pressing management issues or challenges faced (these data are not presented here); (2) types of information used (or planned to use) in developing policy or decisions regarding those management issues; and (3) experience with university researchers, including professors and students, in helping to make management decisions.

3.3. Questionnaire Survey Design

Findings from these focus groups were incorporated into the design of an online questionnaire, used to collect data from all BC Parks employees located in Victoria, B.C. head office and regional offices located throughout the province.

Two dependent variables indicated in the hypotheses were included in the questionnaire. The first dependent variable was "overall importance of research", measured on a five-point Likert style scale from 1 'not too important' to 5 'extremely important'. The second dependent variable examined the importance of 16 information sources (identified during the focus groups as potentially being important) including external sources (such as university research) and internal sources (such as government reports and websites) to fulfilling their job responsibilities. Response categories to these items also were measured on a five-point Likert style scale from 1 'not too important' to 5 'extremely important'. This response scale is ordinal, but was analyzed as interval data in order to produce mean scores and to generate t test findings when comparing mean scores between groups, as indicated in the research hypotheses and tables of findings below. Treatment of ordinal data in this way is a common procedure in social sciences [29].

Three independent variables were indicated in the hypotheses as possibly influencing the responses to the dependent variables described above. The first independent variable is "collaboration with an external group", where respondents were asked to indicate how many times in the past 12-month period they had collaborated with external groups, through a partnership or short term research contract. A three-category response format was provided: 'never', '1 to 5 times' and 'more than 5 times'. For analysis, these responses were collapsed into two categories: (1) did collaborate; and (2) did not collaborate. It was reasoned that respondents who had collaborated with an external group would rate the use of science more highly, as well as the use of external sources of information.

The second independent variable was "type of employment", where respondents were provided with the following response categories: natural science, visitor management, planning, or field operations. BC Parks staff informed the researchers that the agency employed scientists in the natural science category but not in the other categories. Therefore, for analysis, type of employment was later recoded as (1) science (natural science) or (2) other (merging the other remaining categories). It was reasoned that respondents with a science type of employment in the agency would rate the use of science more highly, as well as the use of external sources of information.

The third independent variable was "location" where respondents were coded as (1) located in the park headquarters in Victoria; or (2) located in one of the regional offices located in more remote areas of the province. It was reasoned that respondents located in Victoria would have greater access to other external information sources, compared to respondents located in more remote locations, and would rate the use of science more highly, as well as the use of external sources of information.

Lastly, an open-ended response format was used to capture the perceived advantages and disadvantages of having university researchers undertake studies for BC Parks.

3.4. Pilot Studies and Survey Administration

In April, 2016, two pilot studies were undertaken prior to administering the questionnaire to assist with questionnaire development and field-testing. Questionnaires were then administered online in May, 2016, using Grapevine Online Survey Tool to 178 BC Parks employees located in Victoria, B.C. head office and regional offices located throughout the province.

These efforts resulted in 125 useable questionnaires and an overall response rate of 70%. Of the 125 respondents, 78% were located in regional offices throughout BC and 22% of respondents were located at BC Parks head office in Victoria. Data on attributes of respondents were not recorded. Quantitative data was exported from the online format and analyzed using SPSS software. Differences in mean responses between groups on Likert-style questions were tested using the student's *t*-test for independent samples. Effect sizes were measured with Cohen's d [29], which can be interpreted as "minimal" (d = 0.20), "typical" (d = 0.50), or "substantial" (d = 0.80). Qualitative data gathered from open-ended questions was analyzed for themes using an inductive approach within the range of responses to each open-ended question. In this paper, we focus on the findings obtained from the online survey, though we occasionally add insights from the focus groups and feedback workshop that inform the analysis of the results.

4. Results

In this section the results of the on-line survey are presented, focusing on the two dependent variables: (1) importance of specific information sources in making decisions; and (2) overall importance of science in decision making. Both of these independent variables are examined with three independent variables: (1) location; (2) type of employment; and (3) collaboration.

4.1. Importance of Specific Information Sources by BC Parks Employees

Respondents were asked to rate the importance of information sources to their work, using a 5-point scale ranging from 1 = not too important, to 5 = extremely important. Table 1 displays the mean responses, standard deviation, and rank order (based on mean scores). These results indicate that the five most important information sources used to make management decisions were internal to BC Parks and include, (1) advice from BC Parks staff; (2) advice from Ministry of Environment (MOE); (3) PA management plans; (4) BC Parks policy; and (5) in house workshops. External information sources ranked lower, including: (6) informal meetings with interest groups; (8) advice from consultants; (10) consultant reports; (11) advice from academic researchers; and (16) academic journal articles, which ranked the lowest of all information sources.

Table 1. Mean importance rankings of internal and external information sources.

Information Source	Mean Importance	s.d.	Rank
Internal sources			
Advice from BC Parks staff	4.4	0.63	1
Advice from Ministry of Environment staff	4.0	1.01	2
BC Parks management plans	3.9	1.05	3
BC Parks policy and guidelines	3.9	0.93	4
In house workshops	3.5	1.19	5
Advice from other parks agencies	3.3	1.04	7
BC Parks web-based tools	3.1	1.08	9
Other government web-based tools	3.0	1.17	12
Government data bases	2.8	1.04	14
Government research and technical reports	2.7	1.18	15
External sources			
Informal meetings with interest groups	3.4	0.95	6
Advice from consultants	3.3	1.11	8
Consultant reports	3.1	1.10	10
Advice from academic researchers	3.1	1.15	11
Professional conferences	2.8	1.05	13
Academic journals	2.3	1.09	16

4.2. The Effect of Type of Employment on Importance of External Information Sources

External sources of information are of particular interest in the present study, and were examined more closely in the next stage of analysis. The first comparison (Table 2) compares those BC Parks employees involved in "science", with those employed in "other" capacities. As described in the methods section, the "science" group consisted of natural scientists employed by the agency, and the "other" group consisted of those employees assigned to other positions, including visitor management, planning, or field operations. The independent samples *t*-test analysis indicates that those employed in science tend to have higher mean ratings for most external information sources, including: advice from consultants, consultant reports, advice from academic researchers, professional conferences, and academic journals. D values ranged from 0.49 to 1.63, suggesting typical to substantial effects [29].

Table 2. The effect of type of employment on importance of external information sources.

External Information Source	Mean Importance, by Type of Employment		t	df	*p*-Value	d
	Science	Other				
Informal meetings with interest groups	3.1 (n = 20)	3.5 (n = 100)	1.56	118	0.121	
Advice from consultants	3.7 (n = 20)	3.2 (n = 99)	2.01	117	0.047	0.49
Consultant reports	3.8 (n = 20)	3.0 (n = 99)	3.02	117	0.003	0.74
Advice from academic researchers	3.7 (n = 19)	3.0 (n = 101)	2.80	118	0.006	0.70
Professional conferences	3.7 (n = 19)	2.7 (n = 98)	4.09	115	0.001	1.03
Academic journals	2.6 (n = 20)	2.1 (n = 101)	6.64	119	0.001	1.63

4.3. The Effect of Location of Employment on Importance of External Information Sources

The analysis was repeated to compare mean importance scores for those working in Victoria with those working in other regions of the province. These comparisons indicated no significant differences between these two groups for any of the external information sources.

4.4. The Effect of Collaboration on Importance of External Information Sources

Respondents were asked to indicate how many times in the past 12 months they had collaborated with different groups to undertake research. The majority of respondents had collaborated with consultants (65.6%), local clubs or organizations (65.8%), and students (50.4%). Respondents collaborated the least with instructors or professors (39.2%). Each of these four types of collaboration were explored separately to determine possible relationship with each type of external information (Table 3).

The first column of Table 3 lists the four types of collaboration and the six types of external information sources. Columns 2 and 3 compare the mean importance scores between those respondents who collaborated with the mean importance scores of those who did not. For example, the first segment of the table examines the effect of collaborating with consultants. The first line examines the importance of academic journals, comparing the mean importance scores for those who did collaborate with consultants (mean = 2.3), with those who had not collaborated with consultants (mean = 2.2). This difference was not statistically significant, as indicated by the p value of 0.306. However, this part of the table indicates that those who collaborated with consultants rated three types of external information sources significantly higher than those who did not collaborate with consultants, as follows: advice from academic researchers, advice from consultants, and consultant reports.

The rest of Table 3 indicates a number of significant comparisons, with higher importance scores in all cases for those respondents who had collaborated. The second segment of the table examines the impact of those who had collaborated with local groups, and indicates just one significant finding, a higher mean importance score for informal meetings by those who had collaborated with local groups. The most consistent difference in importance ratings occur between those BC Park practitioners who collaborated with students or instructors/professors and those that did not. For those that had collaborated at least once with students, five of the six possible comparisons were significant, with effect sizes (d) between 0.29 and 0.57. Similarly, for those BC Parks' practitioners who had collaborated with instructors/professors, four out of six comparisons were significant, and effect sizes (d) varied between 0.25 and 0.66.

Table 3. The effect of collaboration (yes, no) with external groups on the perceived importance of external information.

Type of External Group, and Information Source	Mean Importance of External Information		t	df	*p*-Value	d
	No- Do Not Collaborate	Yes- Do Collaborate				
Collaboration with Consultants						
Academic journal articles	2.2 (n = 36)	2.3 (n = 83)	5.07	117	0.306	
Advice from academic researchers	2.6 (n = 35)	3.2 (n = 83)	2.43	116	0.008	0.48
Advice from consultants	2.8 (n = 36)	3.4 (n = 81)	2.76	115	0.003	0.53
Professional conferences	2.6 (n = 34)	2.8 (n = 81)	1.06	100	0.144	
Consultant reports	2.6 (n = 36)	3.3 (n = 81)	3.12	115	0.001	0.62
Informal mtgs w/interest groups	3.2 (n = 35)	3.4 (n = 83)	0.88	53	0.189	
Collaboration with local groups						
Academic journal articles	2.2 (n = 46)	2.3 (n = 71)	2.72	115	0.393	
Advice from academic researchers	2.8 (n = 45)	3.1 (n = 71)	1.61	114	0.054	
Advice from consultants	3.0 (n = 47)	3.3 (n = 69)	1.30	114	0.097	
Professional conferences	2.5 (n = 44)	2.9 (n = 69)	1.59	96	0.056	
Consultant reports	2.9 (n = 46)	3.1 (n = 69)	1.00	113	0.159	
Informal mtgs w/interest groups	3.1 (n = 45)	3.5 (n = 71)	2.11	74	0.019	0.20
Collaboration with students						
Academic journal articles	2.1 (n = 57)	2.4 (n = 63)	2.00	118	0.023	0.36
Advice from academic researchers	2.7 (n = 56)	3.3 (n = 63)	2.98	117	>0.001	0.54
Advice from consultants	3.0 (n = 58)	3.4 (n = 60)	1.82	116	0.035	0.32
Professional conferences	2.5 (n = 54)	3.1 (n = 62)	3.01	110	0.001	0.57
Consultant reports	2.7 (n = 56)	3.3 (n = 62)	3.32	97	>0.001	0.29
Meetings with interest groups	3.3 (n = 56)	3.4 (n = 63)	0.79	117	0.214	
Collaboration with academics						
Academic journal articles	2.0 (n = 69)	2.6 (n = 49)	2.74	86	0.003	0.25
Advice from academic researchers	2.9 (n = 68)	3.3 (n = 49)	1.83	115	0.035	0.34
Advice from consultants	3.1 (n = 70)	3.4 (n = 43)	1.32	115	0.093	
Professional conferences	2.5 (n = 66)	3.1 (n = 48)	2.83	110	0.003	0.54
Consultant reports	2.7 (n = 68)	3.4 (n = 48)	3.46	114	>0.001	0.66
Informal mtgs w/interest groups	3.3 (n = 68)	3.4 (n = 49)	0.81	115	0.235	

4.5. Overall Importance of Research to Their Work

When asked about the overall importance of availability of research to their work, the majority (54%) of respondents stated that research studies were extremely important (10%) or very important (44%) in decision-making. Less than half the respondents felt that research was moderately important (28%) or slightly or not important (18%). The average response for the importance of research was 3.39 on a five-point Likert-style scale. These findings suggest variability in perceptions of the overall importance of research, an observation that is taken up in the following sections that examine the effect of collaboration, type of work, and location of work.

4.6. The Effect of Collaboration on Overall Importance of Research to Their Work

Table 4 examines each type of collaboration and compares those who collaborated with those who had not collaborated. Those respondents who collaborated with consultants, local clubs, or with students indicated significantly higher overall importance of research compared to those who had not collaborated. For example, lines 1 and 2 compare those respondents who collaborated with consultants with those who had not collaborated with consultants. The mean importance score of those who had collaborated with consultants was 3.5, compared to 2.9 for those who had not collaborated with consultants, and this difference is statistically significant. Similar results are apparent for those who collaborated with local clubs, and with students. D values ranged from 0.32 to 0.57. However, this pattern did not extend to those who collaborated with instructors/professors, where observed differences were not significant.

Table 4. The effect of type of collaboration on the overall importance of research.

Type of Collaboration	MeanImportance of Research	T	df	Prob	d
Did collaborate with consultants	3.5 (n = 82)	3.01	119	0.001	0.57
Did not collaborate with consultants	2.9 (n = 39)				
Did collaborate with local clubs and organizations	3.5 (n = 71)	1.72	117	0.043	0.32
Did not collaborate with local clubs or organizations	3.1 (n = 48)				
Did collaborate with students	3.6 (n = 63)	2.70	120	0.003	0.49
Did not collaborate with students	3.1 (n = 59)				
Did collaborate with instructors or professors	3.5 (n = 49)	1.40	116	0.082	
Did not collaborate with instructors or professors	3.2 (n = 71)				

4.7. The Effect of Type of Work and Location of Work on Overall Importance of Research to Their Work

The "type of work" analysis involved a comparison of those who were employed in a science capacity with those employed in other areas. Those employees involved in science had a significantly higher mean rating for the overall importance of research to their work (mean = 4.0) compared to other BC Parks employees (mean = 3.3; df = 33.8, t = 3.54, p = 0.001, d = 0.86).

Analysis by "location of work" involved comparisons similar to those in Table 4, but in this case comparing mean responses of those respondents living in Victoria (near to park headquarters) in with those living in more remote regions of the province. These comparisons were not statistically significant.

4.8. Advantages and Disadvantages of Collaboration

Respondents were asked to provide open-ended responses about their perceived advantages and disadvantages of having university/college instructors or students undertake research studies for BC Parks. These findings are presented in Table 5. The most cited advantage was the low cost (for BC Parks) of university research (46%), followed by increased information (27%), and a cutting-edge perspective (23%). Disadvantages cited included more work for the respondents to supervise, manage and provide permits for outside research (27%), low quality of research (22%), and that the research was not useful

(17%). Fewer respondents reported lack of organizational understanding (of academic scientists of BC Parks), available time (of BC Parks employees for collaboration), and lack of access to findings as disadvantages.

Table 5. Perceived advantages and disadvantages of University- British Columbia (BC) Parks collaborative partnerships.

Advantages/Disadvantages	%
Advantages	
Low cost	46
Increased information	27
Cutting edge perspective	23
Networking and profile building	18
Eagerness and enthusiasm; fresh perspective	15
Unbiased perspective	08
Disadvantages	
More work	27
Low quality	22
Not useful	17
Lack of understanding of BC Parks	10
Time available	10
Lack of access to findings	03

Further analysis of this data was not carried out, due to concerns stemming from lower response rates to this question, and the subjective nature of qualitative data obtained in this question. Hence comparisons by location, type of work, or collaboration are not provided.

Findings from the focus groups and workshop shed additional light on impediments to collaboration between university researchers and BC Parks employees and/or the use of collaboratively generated research findings, including: time lag for academic researchers to complete the research, lack of contact with researchers, lack of confidence and trust in the information, and lack of communication of research findings.

Respondents were also asked whether the agency should give, more, less, or the same attention to developing academic partnerships (if funding could be secured for 'applied research projects in BC parks'). The majority (57%) felt that more attention, and 27% felt that 'much more' attention should be placed on this type of partnership.

5. Discussion

This study examined the types of information used by BC Parks in decision making, and specifically the role of external sources such as academic research. The main findings of this study can be summarized as follows: (1) internal sources of information are generally more important to BC Parks practitioners that are external sources of information; (2) those employed in science roles within the agency tend to attach greater importance to external sources of information than do those working in other capacities; (3) those respondents who had recently collaborated with external groups (including academics), tend to attach greater importance to external sources of information compared to those who had not collaborated recently; (4) respondents identified many advantages of collaborating with academics, including obtaining low cost, increased information, and cutting edge perspectives, and, (5) disadvantages of collaborating with academics included needing to do more work, low quality perspectives, and collaboration not always being useful. These findings are discussed in the following sections.

5.1. Relative Importance of Internal and External Information Sources

One of the interesting outcomes of this project lies in the relationship between the findings that suggest, on the one hand, BC Parks practitioners value research in decision-making and wish to see more university partnerships, but that on the other, 'typical' academic products (journal papers, conferences, interaction with academics) are seen as among the least important sources of information. These findings are consistent with many other studies [1,5,9,30,31]. Together, these findings demand attention towards other 'pathways' by which scientifically derived information can enter into decision-making, including the role of collaborations with different groups (including, but not limited to, scientists) and drawing on information sources other than typical academic products. There are several other findings that are worth highlighting in this vein.

For example, the results suggest that internal sources such as advice from BC Parks staff, MoE employees, BC Parks policy, and management documents are more important to respondents (as a whole) in fulfilling their work responsibilities than external sources, such as advice from academic researchers, conferences and academic journal articles. These results resonate with other studies that have found conservation managers tend to rely on informal sources, internal interactions, and 'experience' [1,3,5,15].

5.2. *The Effect of Type of Work and Location of Work*

The findings indicate that BC Parks practitioners vary somewhat in their opinions, with those employed within the science realm of the agency attaching greater importance to external sources of information, such as consultant reports, advice from academics and academic journals. In contrast to Landry et al. [7], who found no evidence that position predicts knowledge utilization across several policy domains, this study found that although BC Parks practitioners as a whole valued research highly, there were differences among these practitioners in terms of the importance assigned to different information sources. 'BC Park practitioners' are not a homogeneous group, but rather represent an amalgamation of employee 'types' with different responsibilities and information needs. Specifically, regarding overall importance of research, the mean importance reported by employees involved in 'science' was higher than for employees in other roles. Further, importance ratings for half of the external information sources, including advice from academic researchers, professional conferences, and academic journal articles, were significantly higher for those in science than those in other positions. On the other hand, employee work location (BC Parks headquarters or outside of headquarters) provided little or no explanatory power for variation in mean importance rankings for external information.

Further, just because a source is 'internal' (or what Cook et al. [3] might call 'intermediate') does not mean that the internal source is not itself built on, or informed by, other sources of information (including academic science). However, Cook et al. [3] express some concern towards some intermediate information sources that have not verified the information through monitoring or other reliability testing. This is an area warranting further research.

5.3. *The Effect of Collaboration*

The findings highlight the importance of collaboration, which often involves knowledge transmission. Up to two thirds of BC Parks' practitioners had engaged in some forms of collaboration but about 40% had not, a finding similar to Crona and Parker [20], who found that 44% of scientists and practitioners had no interaction with each other. However, while many BC Parks practitioners had collaborated at least once with other groups, this study did not explore the nature or meaningfulness of these collaborations. This is an area for future research.

Collaboration (with various groups) was correlated with BC Parks practitioners' overall perceptions of the importance of research (Table 4). BC Parks practitioners who have collaborated with instructors/professors and students tend to perceive academic journal articles, advice from researchers and professional conferences as more important than those who do not collaborate. The implication that university collaboration may enhance knowledge utilization has been supported in previous studies that found the number of direct contacts and intensity of links between policy makers/decision-makers and researchers to be good predictors of knowledge utilization [20,27,32,33]. Belkhodja et al. [32], for example, examined organizational determinants of research use in the Canadian health system and found that formal linkages between producers and users of research as the most important organizational determinant of research use. Overall, these studies identify the importance of personal interaction and linkages between producers and users of research [20,22,23], with calls for more empirical work examining collaboration processes as a means of improving knowledge utilization [17].

5.4. Perceived Advantages and Disadvantages of Collaborations

This study provided several insights about the perceived advantages and disadvantages of practitioner-academic collaborations (Table 5). Several advantages to University-BC Parks collaboration were directly identified in the results, including low cost, increased information and the provision of a cutting-edge perspective. At the same time, several disadvantages were also identified, including more work for BC Parks practitioners, low quality and usefulness of research, lack of contact with researchers, lack of confidence and trust in the information, and a lack of access to findings (though this last one was mentioned by a small number of respondents). Responses related to a lack of understanding of BC Parks and a lack of access to available research resonate with previous research that has identified similar barriers [2,7,10,15–17]. Many of these barriers may be related to instances of lower collaboration or ineffective collaboration, such that relationships of trust and mutual understanding are not developed leading to lost opportunities for mutual understanding of agency needs (see [22,23]). As McNie [4] states, simply providing more research is often inadequate if it does not correspond to the information needs of the decision makers. Participants in focus groups also noted that this mismatch can stem from the fact that BC Parks has a limited budget to initiate research and that collaboration between BC Parks and academics tends to occur when academic institutions choose to initiate collaboration with BC Parks.

On the other hand, both lack of access and a lack of fit with BC Parks needs were mentioned much less frequently than practical considerations related to the time/work demands of supporting university research, as well as concerns about the quality of work. These two disadvantages were frequently discussed in focus groups, and often centered on the role of students. Students were described as playing central roles in academic efforts in BC Parks and, on the one hand, were frequently described as providing fresh, timely perspectives at low cost. At the same time, however, they were often described as requiring a lot of work (mentorship, oversight, and guidance), and producing results of uneven quality. These finding suggest that effective collaborations may take time to initiate and sustain, to allow for academics to better understand the needs of a PA agency, and for a PA agency to realize the benefits that can accrue from investing some time and effort with an academic partner. In this vein, Reed et al. [23] describe how knowledge mobilization should be part of a research project, not just a component added once the research is completed, in order to create relevance, reliability, and accessibility to academic research.

The role of internal BC Parks scientists in bridging the academic knowledge/decision-making gap emerged from this study as an important area for additional research. For example, while many BC Parks practitioners tend not to utilize traditional academic outputs, those that identify as scientists appear more likely to do so. Additionally, by far the most important sources of information for decision-making are advice from BC Parks staff, as well as the 'codified knowledge' present in management plans (what Cook et al. [3] call 'intermediate knowledge'). Presumably, internal scientists play a role in providing this advice and developing these 'intermediate' forms of knowledge. The importance of another informal pathway created by internal scientists was highlighted in a description, offered in more than one focus group, of a former employee who took it upon himself to act as a 'boundary spanner' by providing, via email, a brief summary of current, relevant research findings to interested employees. Many participants noted how important this source of information was, and how disappointed they were when this employee stopped doing so. These findings point to the utility of adopting a perspective that looks at the complex ways, often based on personal interactions, by which science can move into decision-making [8,9,20,27,33]. Network analysis, as adopted by Crona and Parker [20], shows promise as a tool to investigate these types of interactions.

In considering these findings, it should be noted that they are case specific, and limited to the context of BC Parks and collaborations with academic scientists. Further, this study focused on the importance of research and specific information sources—findings cannot speak to the impact or influence of research on actual policy making. Future research could incorporate knowledge utilization measures, as adopted in other studies [20,27,34] to address levels of impact and influence of scientific knowledge on decision-making.

6. Conclusions

This study explored the use and relevance of research to BC Parks practitioners, the level of collaboration with university researchers and other external groups, and the influence of this collaboration on perceptions of the importance of research. We found that while BC Parks practitioners consider research to be important in their work, and would like to see more collaboration with academic scientists, they also rank traditional academic venues (journal articles, conferences, etc.) as among the least important sources of information. Rather, they tend to rely on personal interactions within their own agency, and on 'intermediate' forms of knowledge as embedded in policy guidelines and management plans [3]. These findings suggest that cultural and/or ideological differences do not play simple roles as barriers; nor do they suggest that producing 'more or better science' (as suggested by linear model ways of thinking) are likely to bridge the science–practice gap in isolation. Those in 'science' positions within the agency also appear to play an important role in processes by which academic types of knowledge are utilized. Moreover, collaboration levels positively influence perceptions of research and the perceived importance of information sources. Given the findings in this study and others [20,27], future research adopting a social interactions framework to examine social linkages between researchers and practitioners and the influence of those linkages on knowledge utilization is warranted. As described in Allen [24], this process involves moving beyond the engineering model described in this paper toward a multi stakeholder approach in which participants, including decision-makers, scientists, and other stakeholders are empowered to work collaboratively to develop the research project. This approach is more likely to create a shared understanding of the findings and contribute to on the ground decisions.

While this study has examined the barriers and enabling conditions for the mobilization of academic knowledge within the context of protected areas, future studies could expand this research to examine other types of knowledge thought to be relevant to the management of protected areas, including local community knowledge and indigenous knowledge, as outlined in Allen et al. [24].

Author Contributions: Conceptualization and methodology used in the project was undertaken by G.M. and R.R. Project funding and project management was undertaken by G.M. Data collection and storage was undertaken by R.R. and G.M. Data analysis and visualization (tables) was undertaken by C.R. Initial drafts of the paper were developed by C.R. and G.M. Review and editing of the paper was undertaken by R.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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Accessing and Mobilizing "New" Data to Evaluate Emerging Environmental Impacts on Semi-Aquatic Mammals

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Received: 1 August 2020; Accepted: 21 September 2020; Published: 23 September 2020

Abstract: This paper describes how knowledge mobilization evolved during a study that assessed a proposed increase in industrial water withdrawals from the Athabasca River in northern Alberta, Canada, and potential impacts on a suite of freshwater semi-aquatic mammals in the broader ecosystem. The oil sands region in northeastern Alberta faces various pressures that require rapid knowledge mobilization and decision making, while still acknowledging ecological sensitivities immediately downstream in the Peace-Athabasca Delta (PAD) in the Wood Buffalo National Park. Data were acquired using a multi-faceted approach, including literature reviews, acquisition and synthesis of raw data, and interviews with local knowledge holders. The final outcome of the study was then contextualized relative to elements of knowledge mobilization: (1) research, (2) dissemination, (3) uptake, (4) implementation, and (5) impact. Knowledge mobilization was easiest to quantify for the first two elements, yet was still present in varying forms in the latter stages. The cultural importance of beavers, muskrats, river otters, and mink for communities associated with the Athabasca River and the PAD allowed for increased engagement during all stages of the research process, which then facilitated the co-production of potential solutions among different organization and perspectives.

Keywords: data sources; Indigenous knowledge; industrial development; semi-aquatic mammals

1. Introduction

Understanding the potential impacts of temporal and spatial availability of fresh water is critical for the wise allocation and management of surface water at various scales. Many allocation schemes have a distinct focus on human needs [1], while over time there has been growing awareness of the obligation to meet ecological requirements as well [1,2]. The difficulty comes in balancing the two perspectives; it seems easier to quantify the average number of cubic meters of water required to run a household or an industry than to calculate required water depths, flow rates, and temperatures in the context of seasonal variability and ecological processes. Quantification of water storage, use, and renewal is difficult enough on just one major river system, especially when incorporating ecological considerations, but applying hydrological modeling and ecological predictions to areas where multiple major rivers and associated water bodies converge presents even greater challenges [3,4]. Various studies on the impacts that water allocation schemes have on fish highlight these challenges [5,6], while studies of other vertebrates (e.g., semi-aquatic mammals) are rare or non-existent for some species, and require multidisciplinary approaches for others, as seen with muskrats in northern Canada [7,8]. Despite the ability to access water-flow data from government agencies and peer-reviewed flow models and methods from the literature, synthesizing and translating those data into an ecological and land-based context requires more nuanced sources of original data and experiential knowledge. Hydrological modeling is just one tool in an overall assessment of how freshwater-dependent species might respond to environmental change; therefore, an integration of multiple data sources is needed to fully understand the ecological, cultural, and socio-economic implications of anthropogenic impacts on freshwater systems.

Globally, human demand for fresh water increased dramatically from 1900 to 2000 [9], which reflects concurrent population increases and associated water withdrawals for urbanization, industrialization and, in particular, irrigation [10]. According to the Government of Canada (www.canada.ca), Canada has 20% of the world's total freshwater resources, of which only 7% are considered renewable (i.e., returned back into the hydrological cycle in a usable form). In 2017, total withdrawals of fresh water were 35.6 billion m^3/year, with 78.9% used for industrial activities (2015 values; http://www.fao.org). As such, Canada is the 10th highest consumer of fresh water per capita in the world, despite having less than 0.5% of the world's population. The United States, at 444.3 billion m^3/year (47.2% of which is for industrial uses), is second only to China (598.1 billion m^3/year) in per capita water use (https://data.oecd.org). Rivers represent some of the most physiographically complex sources of fresh water because of their natural fluctuations in seasonal water flows and spatial extent. This complexity extends to freshwater habitats and the species they support.

As rivers flow through the landscape, they influence physical, chemical, and biological processes, thus creating a "shifting habitat mosaic" [11] that creates diverse riparian (river bank and shoreline) habitats well adapted to annual flood pulses and seasonal and cyclic changes in river flows [12,13]. In particular, aquatic connectivity and the interplay between the water body and adjacent riparian habitat is directly influenced by spatial and temporal variations in flow [11,13,14], which in turn can result in short-term availability of habitat for freshwater-dependent wildlife and plants [14–17]. Changes in availability can have immediate impacts on local communities that are dependent on these resources. Understanding the complexity of these systems requires a multi-disciplinary approach that can then be translated and mobilized in a meaningful way to all stakeholders throughout the watershed. This is no small challenge, given that most of the world's large river-floodplain ecosystems have been dramatically influenced by humans [13], and an increasingly warming climate [14,18]. The lower Athabasca River and its associated Peace-Athabasca Delta (PAD), present an excellent example of the complexity of data acquisition, its interpretation, and associated knowledge mobilization among the many residents and organizations living and operating within and adjacent to the area.

The Athabasca River flows from its glacial origins in the Canadian Rockies, then north across the province of Alberta, to the PAD in the Wood Buffalo National Park (WBNP), with the PAD being the largest inland freshwater delta in North America. Despite being the longest river (1231 km) in Alberta, there has been a disproportionate amount of research focused on the lower, more northerly, reaches of the river as it relates to Canada's bitumen extraction from the oil sands region [19]. In their systematic review of 386 publications focusing on the entirety of the Athabasca River over a 50-year period [19], Ana Lima and Frederick Wrona determined that the majority of studies concentrated primarily on a single stressor (68.4%), especially factors pertaining to pulp and paper manufacturing and oil sands projects. Much of the research investigated chemical pollutants, although water withdrawals were another stressor that received some attention. Water withdrawals from the lower Athabasca River from oil sands activities in 2017 were 37.9 million m^3 (0.56% to 2.5%) of the measured flow rate during winter, and from 0.17% to 1.15% of the measured flow rate during ice-free periods (www.environment.alberta.ca/apps/OSEM0). However, as with overall cumulative effects on the river, the total impact of oil sands mining on water availability is difficult to quantify. Associated removal of peatlands adjacent to the Athabasca River certainly impacts horizontal water flow from these wetlands into the river, but the volume of water lost to the river is unknown. Additionally, cumulative effects related to climate change and large hydro-electric projects (e.g., W.A.C. Bennett Dam in British Columbia on the Peace River) also play a major role in complex ecological relationships in the lower Athabasca River and its delta [14,18,20]. As Kevin Timoney and his colleagues note [4], the hydrological dynamics of the PAD are often oversimplified, given that the PAD is not a single delta, but rater three semi-independent sectors: the central main lakes, the delta of the Athabasca River, and the delta of the more northerly Peace River that flows northeast from British Columbia.

Adding to this complexity are the data gaps when assessing how current and future industrial water withdrawals might impact ecological needs within the lower Athabasca River and the PAD, especially as they relate to culturally and ecologically important species such as the American beaver (*Castor canadensis*), American mink (*Neovison vison*), muskrat (*Ondatra zibethicus*), and North American river otter (*Lontra canadensis*), all of which are semi-aquatic mammals. Applying computer simulations developed for one system and one industry (e.g., hydro-power production) [21], might not be appropriate for the assessment of the ecological balance of another system where species interactions are strongly influenced by climate, historical events, and unique habitats. These four species of semi-aquatic mammals perform important roles, ecologically, economically, and culturally in many of the communities along the lower Athabasca River and in the PAD within and adjacent to the Wood Buffalo National Park. Muskrats, in particular, have played a central role in many of the Indigenous communities within the PAD and along the lower Athabasca River for millennia [7,8,15,17,22]. Similarly, despite being a commonly trapped furbearer, beavers are highly valued for their ability to positively influence surface and groundwater storage [23–25] and enhance the habitat for other species [26]. In particular, river otters are strongly associated with beaver habitat [27–29], both because of enhanced fish habitat and aquatic connectivity provided by beaver impoundments, and the ability for beaver lodges, bank dens, and downed woody debris to serve as resting and rearing sites for otters [30]. In turn, river otters are an apex predator in freshwater systems, thereby aiding the ecological balance of the system. Similarly, mink are a key predator for muskrats, while also using muskrat huts and dens, and sometimes beaver lodges, as temporary resting cover instead of building their own structures [31,32]. The interdependence of these four species is well documented and highlights the multi-faceted nature of freshwater systems [33].

For all four species, seasonal water levels play a critical role in population dynamics. Areas of open water that are at least 1 m to 2 m deep are generally beneficial. Overly high water levels could present difficulties for muskrats where key forage species are inundated and unable to grow. In winter, if water withdrawals create low water levels under the ice (e.g., 1 m deep), beavers and muskrats can be "frozen out" and are unable to access food during the winter [23,34], and mink and otters would have difficulty accessing open water for travel and foraging [30]. Conversely, if water is discharged in winter, lodges, huts, and dens could be swamped, thereby resulting in the drowning of beavers and muskrats due to an inability to access air pockets under the ice. River otters also require air spaces to swim under the ice in winter to reduce energy loss on land [30]. As such, regulated rivers pose difficult challenges to semi-aquatic mammals in northern climates, whether it be from temporal changes in water flow produced by hydro-electric development, or reduction in water availability from industrial water extraction throughout the year. Predicting and accurately reporting the impacts of these changes provides similar challenges [35].

This paper presents a 2009 study (conducted by the author) that investigated how a proposed 15% increase in industrial water withdrawals from the lower Athabasca River for oil sands activities might influence beaver, muskrat, mink, and river otter populations in the downstream reaches of the river and the PAD within the WBNP. The study was done in the context of cumulative environmental effects and examined whether any models exist to quantify these effects [35]. Additionally, this paper details how various data sources, including original data records, traditional knowledge (TK), and published and grey literature were accessed and synthesized from multiple sources, and how knowledge derived from the research was mobilized to aid decision-makers and key constituents in the government, industry, local communities, other associated organizations in the study area specifically, and the broader community as a whole.

2. Materials and Methods

2.1. Study Area

At the request of the Instream Flow Needs Technical Task Group (IFNTTG) of the Cumulative Environmental Management Association (CEMA), the 2009 study focused on the portion of the lower Athabasca River from the city of Fort McMurray, Alberta downstream to, and including, the Peace-Athabasca Delta in the WBNP (Figure 1). CEMA is a multi-stakeholder group comprised of industry, government, non-governmental organizations, and Indigenous peoples, and was established to address and reduce long-term impacts of industrial development on the environment of the lower Athabasca River Watershed. The area is entirely within the Boreal Forest Natural Region (BFNR), which contains three Natural Subregions: the Central Mixedwood Natural Subregion, the Athabasca Plain Natural Subregion, and the Peace-Athabasca Delta Natural Subregion [36]. The Central Mixedwood Natural Subregion in the southern part of the study area is dominated by trembling aspen (*Populus tremuloides*) and white spruce (*Picea glauca*) forests, interspersed with Jack pine (*Pinus banksiana*). Peatlands (bogs and fens) are found throughout the area. Progressing northward to the Athabasca Plain Natural Subregion, just south of Lake Athabasca, the force of the river becomes more apparent with the representation of hummocky and rolling sandy and gravel-dominated uplands. These are rapidly draining soils, with sedge meadows, treed fens, and black spruce (*Picea mariana*) bogs in the lowlands, and Jackpine forest in the uplands. The Richardson, Old Fort, Harrison, Marguerite, and Firebag Rivers flow through this area into the Athabasca River. The Peace-Athabasca Delta Natural Subregion includes the area immediately south and to the west of Lake Athabasca. It is dominated by fluvial habitats, large open lakes, and perched basins [36]. The Athabasca River flows into the PAD in the southeast quadrant of the WBNP near Fort Chipewyan. The largest lakes include Lake Claire, and Mamawi, Baril, and Richardson lakes. Along with a number of perched basins, which fill during flood events, dominant wetlands are open water ponds, fens, and marshes. The PAD, much of which is protected within the WBNP, is a Ramsar site (designated by the Ramsar Convention as a wetland of international significance). The park itself was designated as a UNESCO World Heritage Site in 1983. Throughout the BFNR, the climate consists of long cold winters (average temperature −19 °C), and temperate summers (average July temperature 17 °C), although average temperatures have been recently increasing above the 30-year average [35].

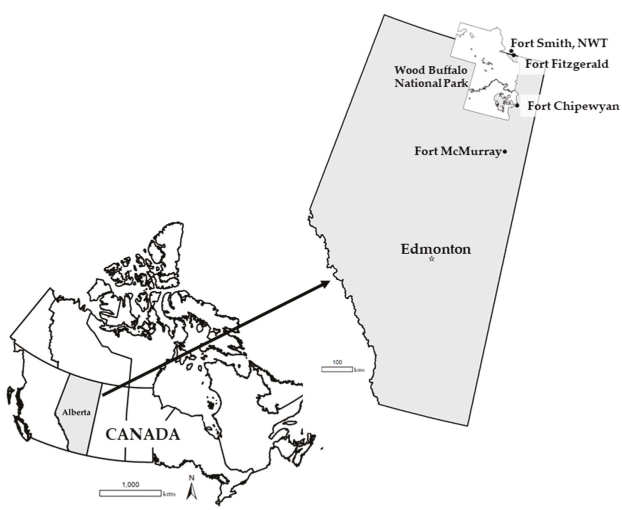

Figure 1. Study area including key communities involved in the project, and the Wood Buffalo National Park, Canada.

The region has supported Indigenous peoples for several thousand years, with the communities of Fort Chipewyan, Fort McKay, and Fort McMurray being important centers that formed during the colonial fur trade, peaking in the 18th to 19th centuries in what is now Alberta. Beaver, Cree, Chipewyan (Dene), Métis, and non-Indigenous trappers still live and work along the waterways throughout the area, although trapping as a primary profession is rare. Active trappers are most common in the PAD within the WBNP. Outside of trapping, the oil sands and associated service industries provide extensive employment in the region, while inside the WBNP, Parks Canada is the main employer.

2.2. Data Acquisition

This section provides an overview of how data were gathered during the 2009 study. Data within that context are defined as original numerical tallies, aerial imagery, interview responses, and modeling pertaining to how anthropogenic fluctuations in water levels in riverine, lacustrine, and wetland environments might influence population-level responses of semi-aquatic mammals. CEMA set an eight month timeline for the study, beginning from the start of the study in May 2009 to report delivery and presentation in December 2009. In part, the accelerated search and acquisition of these data was facilitated by an existing relationship of the principal investigator (G.A. Hood) with various organizations and community members, following a 19-year career with Parks Canada's Warden Service (including a posting in the WBNP).

2.2.1. Trapping Records

There were two main sources of trapping records: (1) photocopies of original fur tallies from the Hudson Bay Company (HBC) Archives, which were stored in the Parks Canada library in Fort Chipewyan, AB and, (2) original Parks Canada fur returns and notes on trapping activities within the WBNP, stored in the filing cabinets in the basement of the WBNP Parks Canada office in Fort Smith, NT. As identified in the *Wood Buffalo National Park Game Regulations*, trapping is legal within the park for designated trappers (named on a certificate of registration under the Regulations) from surrounding communities. In 1946, the Canadian federal government initiated the establishment of set trapping areas in the WBNP, which were formally established in 1947. This change meant that trappers who were once allowed to trap throughout the Peace-Athabasca Delta were no longer able to trap outside their assigned trapping areas. Those trappers were represented by the WBNP data, while trappers prior to the establishment of the park were represented by the HBC.

Once all records were located, I entered all trapping data into a Microsoft Excel spreadsheet and then tallied all fur returns by species to assess trends over time. For the WBNP fur returns, the number of trappers was included. Fur returns were used as a proxy for population dynamics of the four species of semi-aquatic mammals over time, while the number of trappers by year represented trapping effort.

2.2.2. Aerial Photograph Database

To catalog existing imagery for future hydrological modeling, my research team and I documented the availability of aerial photographs by searching the Alberta Sustainable Resource Development Air Photo Record System (APRS). Photographic coverage included all photographs beginning from the earliest available aerial photographs (1949) up to and including those available at the time of the study (2009). The search area included all images that included the Athabasca River from Fort McMurray to Fort Chipewyan and the PAD. We also documented all images one township width (~1.6 km) away from the main river course and the main lakes of the PAD to ensure side tributaries and perched basins were represented. Data entered into the Excel spreadsheet for each aerial photograph were categorized by: government project number, government project name, year, month, day, roll number, flight line, photo number, elevation (asl), scale, map sheet, township, range, meridian, origin, company flying the survey, the organization requesting the survey, color, calibration report, camera, lens, focal length, film, filter, duplicates, coverage (partial/complete), and comments. Due to time constraints, we did not construct a similar database for satellite imagery but instead provided references for obtaining these data.

2.3. Trapper, Community Member, and Biologist Interviews

Prior to beginning interviews, the Education, Extension, Augustana, and Campus Saint Jean (EEASJ) Research Ethics Board at the University of Alberta reviewed all questions (Appendix A) and methodologies. This review ensured that the project met all ethical guidelines prior to approval (project number Pro00007196). Using a semi-structured interview format, interviews focused mainly on active trappers, long-standing community members, and a biologist with extensive experience in the study area. I developed an initial list of participants using professional relationships developed while working in the WBNP, which was then augmented through snowball sampling. Questions focused around three central themes: (1) trapping experience and recent activity, (2) observed changes in the hydrology of the Athabasca River and the PAD, and (3) knowledge of the relationship between semi-aquatic mammals and water levels. Following the interviews, responses for each question were typed and organized by question to ensure anonymity. Then, I analyzed responses by categorizing them by central theme and identifying common trends in the content of responses [37]. To qualify species-specific responses to changes in water levels, I further summarized responses specific to whether they described beaver, muskrat, river otter, or mink.

2.4. Literature Review

Literature, in the context of this study, included all printed material (excluding ledgers of fur returns as noted in Section 2.2.1 above). My research team and I used the University of Alberta's library databases, along with Web of Science and Google Scholar, to locate all peer-reviewed literature pertaining to the study area, hydrological modeling, and species-specific ecology relative to changing water levels. We accessed much of the unpublished "grey" literature in the Parks Canada libraries and filing cabinets at the park offices in Fort Smith, NT, and Fort Chipewyan, AB after obtaining access permissions from the WBNP. Additional documents, in particular, environmental impact assessments and consultant's reports for numerous oil sands projects, were housed at the public library in Fort McMurray, AB. CEMA also provided various hydrological modeling studies it had commissioned over the years. We then summarized key points from each document in a common annotated bibliography. I then synthesized results from the literature review with the fur return data, aerial photograph database, and interview transcripts to provide a comprehensive report that assessed the potential effects of water withdrawals on semi-aquatic mammals, and identified any existing models applicable to the study area.

2.5. Knowledge Translation and Mobilization

The elements of knowledge mobilization proposed by David Phipps and his colleagues [38,39] set the framework to assess the extent of knowledge translation and mobilization of this study. Following the research phase, these elements include: (1) **dissemination** of research beyond traditional academic venues; (2) **uptake**, community access, and engagement of the research beyond academia; (3) **implementation** to inform organizational decisions; and (4) **impact** through the utilization of the research to effect meaningful change within the community [39]. Through an assessment of the research process, final report, and associated presentations, I assessed project conceptualization, design, implementation, dissemination, uptake, and impact through within the context of this framework.

3. Results

The original research question for the 2009 study remained true to the original request by CEMA: How might an increase in industrial water withdrawals from the lower Athabasca River impact semi-aquatic mammals, and do models exist that could quantify any impacts? My research team and I determined that there were no existing models that could be applied to the impact of increased water withdrawals on the semi-aquatic mammals in the lower Athabasca River and the PAD. Some research was available for the effects of water levels on muskrats in the PAD, but much of it was relative to population declines associated with the W.A.C. Bennett Dam on the Peace River, which feeds into the PAD from northern tributaries [15]. Despite some research on muskrats, any existing studies were more retrospective in nature. Nothing similar existed for beavers, river otters, or mink. The synthesis of the data and literature that we found, combined with in-person interviews (some at trapper cabins on the PAD), presented a single reference source to aid future model development if desired. The original 2009 report [35] provides detailed summaries, transcripts, and databases; however, a more detailed account of the data itself and the breadth of materials allows for an assessment of how information was mobilized within and beyond the research process.

3.1. Data Acquisition

My research team and I were able to acquire an extensive amount of data and information in all the categories specified in the original study design (i.e., original trapping records, aerial imagery, in-person interviews, and a review of the published and unpublished literature).

3.1.1. Trapping Records

Hudson Bay Company fur returns were available from 1821 to 1883. Although the records found in the Fort Chipewyan library were incomplete between the dates of 1821 to 1857, within the returns that were available in the library for this time period (1821 to 1883), there were 228,703 fur returns for muskrats, 31,728 for beavers, 1658 for mink, and 3127 for river otters recorded for the Athabasca District and Fort Chipewyan. It is important to note, however, that some of the beaver returns included coats, bonnets, cuttings, etc., thus making whole animal contributions difficult to quantify. There were more accurate tallies for two distinct periods ranging from 1858 to 1870, and 1871 to 1883 (Table 1). It is of note that, given the central role of Fort Chipewyan trading posts in the northwestern fur trade, furs could have come from other locations and then brought to the forts to trade, thereby inflating the fur returns associated with the lower Athabasca River and the PAD.

Table 1. Fur returns for muskrat, beaver, mink, and river otter in the Athabasca District, Canada from 1858 to 1883. Source: Hudson's Bay Archives.

Years	Muskrat	Beaver	Mink	River Otter
1858 to 1870	54,078	173,627	5364	2511
1871 to 1883	60,009	258,932	19,023	4159

The WBNP trapping records extended from 1934 to 1988. Muskrats represented the largest number of fur returns during that time, with a peak of 145,713 furs reported in the 1965/1966 trapping season and a minimum in the 1982/1983 trapping season (Figure 2a). Beaver fur returns reached their peak in 1940 (2520 furs), and a low of zero in the 1950/1951 trapping season (Figure 2a), when beavers were thought to be extirpated from the park [40]. Mink fur returns were lowest in the 1966/1967 trapping season and highest at 3169 in 1944/1945 (Figure 2a). Otters were consistently found in lower numbers, with the largest number of otter fur returns (65 pelts) in 1940, and only one otter fur registered in both 1955/1956, and 1974/1975 (Figure 2b). The number of trappers listed on the fur returns was 324 in 1951/1952, with the lowest number of trappers (n = 64) in 1971/1972 (Figure 2c), immediately after the filling of the Williston Lake reservoir associated with the W.A.C. Bennett Dam on the Peace River in 1971.

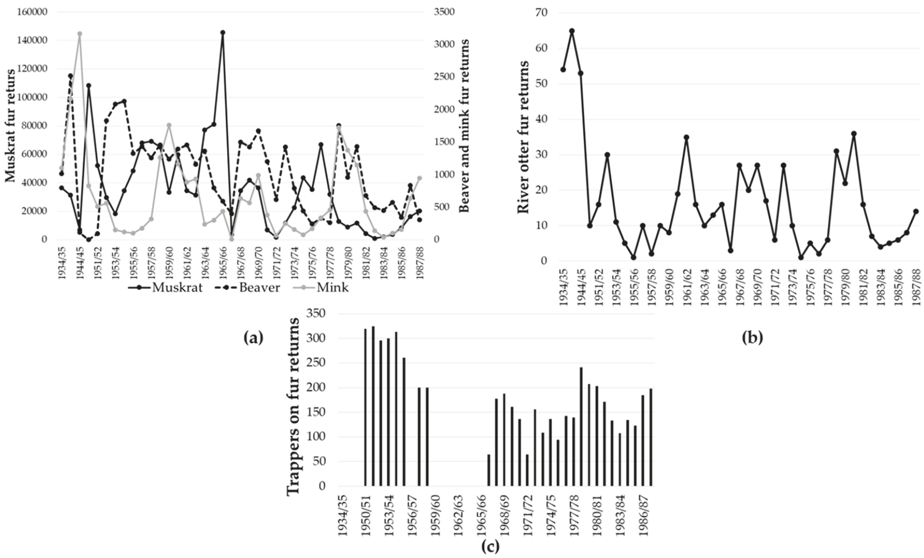

Figure 2. Fur returns muskrat, beaver, mink (**a**), and river otter (**b**), and number of trappers (**c**) for the Wood Buffalo National Park from 1934 to 1988. Source: Wood Buffalo National Park trapping records.

3.1.2. Aerial Photograph Database

We documented 1484 aerial photographs dating from 1949 to 2008; including 384 duplicates, (without duplicates = 1100 images). Images ranged from black and white to panchromatic, true color, false color, and infrared (Table 2; see Appendix B for a link to the full database). Despite the source agency, when evaluating the identified purpose of the images, the majority (35.8%) of the photographs were taken for forestry interests. The second highest identified application for the aerial photographs was for transportation planning (27.2%). Energy projects accounted for just under 10% of the images, although the use of the images in all categories likely would be interconnected. This data set represents the first tally for all images within a township width along the lower Athabasca River and the PAD over a 50-year period and allowed for a clear assessment of changes in surface water extent over time.

Table 2. Aerial photographs by source from 1949 to 2008 for the lower Athabasca River from Fort McMurray, AB to Fort Chipewyan, AB, including the Peace-Athabasca Delta (n = 1100 images).

Source	Number of Images	Percent of Total
Air Photo Coverage Map	22	2.0%
Air Photo Index	14	1.3%
Alberta Energy and Natural Resources	615	56.3%
Alberta Environment	59	5.4%
Alberta Environmental Protection	25	2.3%
Alberta Forestry, Lands and Wildlife	187	17.0%
Alberta Lands and Forests	78	7.1%
Alberta Sustainable Resource Development	96	8.7%

3.2. Trapper, Community Member, and Biologist Interviews

Of the people interviewed, 11 were trappers, 2 were long-term community members with close ties to local trapping history and its role in their community, and 1 was a wildlife biologist with over 20 years of experience in the region. Of the trappers, nine identified themselves as active trappers, despite having to work to supplement their income, which was not the case in earlier years. Within this group, four to five trappers lived on their traplines for >4 months of the year, with two trappers working their traplines for up to 9 months per year. Ages of the trappers ranged from their early 40s to their early 90 s, with a median age of 70 years old (*IQR* = 24). All trappers were from families who had trapped, sometimes over multiple generations, with six trappers living in Fort Chipewyan, two in Fort Smith, one in Fort Fitzgerald, and two in Fort McMurray (one of whom had formerly trapped along the Peace River and into the Peace-Athabasca Delta, and the other trapped near the mouth of the Athabasca River near Richardson Lake). Two trappers in the WBNP had formerly trapped along the Peace River (Trapping Area 1201) and had previously trapped in the PAD prior to the establishment of set trapping areas in 1947.

A notable decline in trapping over the past 30 to 40 years, either as a lifestyle or recreational pursuit, was a common theme in all of the interviews. During the interviews, there was some link to the impact of the residential school system on Indigenous trappers, but declining fur prices, declines in muskrat numbers after the opening of the W.A.C. Bennett Dam, and increased gas prices were consistently associated with the decline in trapping over time. With the decline in trapping as a whole, several trappers mentioned the lack of interest from younger generations (<30 years of age) to go out on the land. Trappers from Fort Chipewyan estimated that there were only five full-time trappers in the community at the time of the interviews (2009). Some community members still trapped recreationally. Trapping in Fort Smith (population ~2500) was even lower, with one trapper noting that only two trappers from that community were actively trapping for the past few years. Conversely, there were five to six active trappers (Indigenous and non-Indigenous) trapping full-time along the Athabasca River, with several others trapping as a "hobby".

Of the trappers in the WBNP, all but three trapped beavers, muskrats (when available) almost exclusively, and fine furs (e.g., lynx, wolf, marten, fox, and fisher) when available. One trapper from Fort McMurray noted that river otters were commonly trapped, but when population imbalances were noted by trappers (e.g., only catching adults), the trapping community would stop trapping them altogether until population structures were restored. The older trappers (>60 years old) noted that their best years of trapping were in the 1960s, prior to the construction of the W.A.C. Bennett Dam on the Peace River near Hudson's Hope, BC. In the 1960s, trapping returns for a single trapper in the PAD could range from 3000 to 4000 muskrats per year. Now muskrats are too difficult to find to warrant any concentrated trapping. A full account of trapper comments is in Appendix A of Hood, Bromley, and Tiitmamer Kur's 2009 report [35]. All comments are anonymous to meet ethics requirements.

3.3. Literature Review

Over the course of the study, we obtained and synthesized over 206 publications, of which 101 were formally cited in the final 2009 report [35]. Of the full suite of articles/reports (n = 206), 35% (n = 72) were peer-reviewed articles pertaining to species biology, hydrological modelling, and ecological processes in the study area, 56.3% (n = 116) were "grey literature" (unpublished reports and similar documents), 5.3% (n = 11) were books (mainly book chapters), and 3.4% were graduate theses (n = 7). Of the peer-reviewed articles, approximately half (51%, n = 37) addressed species ecology, while a third (33.3%, n = 24) addressed various aspects of riverine hydrology (e.g., flooding, ice jams, modeling water management). Within the grey literature, we obtained and synthesized 105 unpublished/technical reports, of which 35 documents (30.2%) were cited in the 2009 report, with an additional 13 documents not directly cited in the report (11.2%), but still providing raw data for the tabulation of fur returns for the WBNP. As a whole, all of the documents provided important context for wildlife ecology (n = 67, 57.8%), and hydrology (n = 46, 40%), including water quantity and quality.

Two reports within the grey literature tabulated and referenced data from several inaccessible consultant reports that contained species-specific survey data and inventories from 1970 to 2007 in the oil sands region [41,42] All but one [43] of the 53 consultant reports cited were specific to environmental impact assessments/reviews (ER) for oil sands projects. Of the ERs, 73.6% (n = 39) were written by environmental consultants who had conducted the wildlife surveys for various oil companies (n = 21 companies), while 24.5% (n = 13 reports) were ERs submitted to the government by industry as part of the formal project approval process. Wildlife surveys included in the ERs submitted by industry, however, were conducted by environmental consultants as supporting data for the final ER. Suncor Energy (n = 12 reports, 23.5%) and Syncrude Canada Ltd. (n = 11 reports, 21.6%) hired the majority of consultants who then wrote the reports for individual wildlife surveys. Most reports documented more than one species of semi-aquatic mammal. In Appendix B in the 2009 study [35], I further categorized these surveys into species-specific tables, along with their original source references.

From 1970 to 2006, there were 30 beaver surveys, all but one [35] conducted as part of proposals for oil sands projects. The one survey not associated with oil sands projects was a provincial analysis of fur production records from 1970 to 1975 [43], which included all four semi-aquatic furbearer species. From 1970 to 2006, there were 27 muskrat surveys, all but one connected to major oil sands projects, and the other being the previously mentioned trapline survey [35]. River otter surveys were quantified in 35 studies and, as with beavers and muskrats, all but one was associated with oil sands projects. Lastly, 35 studies quantified mink surveys in the study area, with all but one [35] associated with oil sands development.

The documents pertaining to beaver, muskrat, river otter, and mink that were specific to the lower Athabasca River, the PAD, or the WBNP (with park-wide data that included the PAD) comprised 17.4% (n = 36) of the documents surveyed for the study. Of these, only one was peer-reviewed (a river otter study) [30], while the rest were from the grey literature found in the two Parks Canada libraries. Of the grey literature, 42.9% (n = 15) of the reports were about muskrats (13 of which focused exclusively on the PAD). Six reports (17.1%) focused exclusively on beavers (with two of those reports specific to the PAD and four specific to the WBNP as a whole), and only two reports were specific to mink, one for the lower Athabasca River and one for the PAD. There was no grey literature pertaining exclusively to river otters, although there were 12 reports (34.3%) that included all four species together (one specific to the lower Athabasca River, five for the PAD, and six for the WBNP as a whole).

3.4. Knowledge Translation and Mobilization

3.4.1. Dissemination of Research beyond Traditional Academic Venues

The formal requirements from the funding agency (CEMA) for the 2009 research were a comprehensive technical report [35] and presentation of the final results to their board, to whom I submitted three printed copies and an electronic version of the final 91-page report on December 13, 2009. The oral presentation of the research was on December 4, 2009. As late as 2014, the report remained in CEMA's print library, but was later on CEMA's online library, although it was originally only accessible through a public login process. By 2018, it was openly available without login requirements (http://library.cemaonline.ca/ckan/dataset/2009-0017). I also provided two printed reports, one for the Fort Smith and one for the Fort Chipewyan Parks Canada libraries, and a digital copy to the park ecologist in the Wood Buffalo National Park (an ex-officio member of CEMA). At the time, the aerial photograph database (Appendix B) was provided on a computer disk, as well as through email. Rather than receiving individual copies, people interviewed during the project preferred that the report go directly to their affiliated community councils/organizations. As such, I also mailed printed reports to the Mikisew Cree First Nation, Athabasca Chipewyan First Nation, Smith's Landing First Nation, and the Metis Nation of Alberta Local #125, all of whom represented individual Indigenous trappers who had participated in the study. Sending these reports was not in the research contract agreement, but we considered it to be one of the more important aspects of initial research dissemination. Between 2010 and 2013, several environmental consultants requested digital copies of the report to use as a reference for their research and monitoring work in the lower Athabasca River and the PAD.

From 2008 to 2014, I presented the research beyond academia at eight different venues that ranged from public talks and multi-stakeholder forums to traditional academic conferences (Table 3).

The Unwrap the Research Conference in Fort McMurray, AB in 2010 was purposefully designed by Dr. Brenda Parlee of the University of Alberta to share research conducted in lower Athabasca and the PAD directly with affected parties in or nearby their home communities. The one talk that brought the research directly to the community that was most engaged in my 2009 research (Fort Chipewyan, Alberta) was the Peace Athabasca Delta Environmental Monitoring Program Forum in 2014. This talk served as the keynote address to open the Forum, in which community members, research scientists, Parks Canada staff, federal and provincial employees, and the general public, shared research and then worked collaboratively in break-out groups to address key issues of concern for the PAD and the lower Athabasca River. The results of the Forum were later provided to all participants by the WBNP in a summary report [44]. The report, combined with these presentations, helped increase public awareness of the ecological, economic, and cultural context of the area, past and present.

Table 3. Presentation of research beyond academia (2010 to 2012).

Date	Venue	Title	Audience
4 December 2009	Cumulative Environmental Management Association from Camrose, AB via web link	A review of existing models and potential effects of water withdrawals on semi-aquatic mammals in the lower Athabasca river	members of CEMA and ecologists from the WBNP
10 October 2010	Nordicity in Thought and Practice Conference, Camrose, AB	Bridging the gap: Indigenous knowledge of a northern ecology	visiting researchers from Norway, academics, and the public
23 October 2010	Unwrap the Research Conference, Fort McMurray, AB	Water, wildlife and change: How local knowledge helps answer big questions	local community members within the oil sands and the PAD region
29 November 2010	Augustana Faculty Colloquium Series, Camrose, AB	Potential effects of industrial water withdrawals on semi-aquatic mammals of the lower Athabasca River	alumni, academics, general public
12 March 2011	Alberta Chapter of the Wildlife Society, Camrose, AB	Potential effects of water withdrawals on semi-aquatic mammals in the lower Athabasca River	government biologists, environmental consultants, academics, university students, non-governmental organizations, wildlife professionals
24 January 2012	University of Alberta Calgary Centre, Alumni Education Series, Calgary, AB	Managing the oil sands environmental footprint	University of Alberta alumni and associates
24 September 2012	Augustana Faculty Colloquium Series, Camrose, AB	South Sudan and Canada: Water, culture and a marriage of ideas. [1]	Augustana alumni, academics, general public
18 February 2014	Peace Athabasca Delta Environmental Monitoring Program Forum. Fort Chipewyan, AB.	What can aquatic mammals tell us about healthy ecosystems? [2]	Indigenous groups, local citizens, trappers, Parks Canada staff, research scientists, government employees

[1] Co-presented with N. Tiitmamer Kur, co-author of 2009 report [35]. [2] Keynote address.

3.4.2. Uptake, Community Access, and Engagement of the Research beyond Academia

Relative to the uptake of the 2009 research by local communities and non-academic parties living and working within the study area, there were several reports generated by government staff and consultants that drew on data sets and information within our final 2009 report [35], which then helped inform future policy and practice. For example, in 2016, Parks Canada conducted an operational review of its ecological integrity monitoring program within the WBNP [45]. In particular, the synthesis of muskrat data, and water level predictions helped inform future research directions within the PAD, which is [7,8] a topic that remains of great concern for the community of Fort Chipewyan. One of the two academic studies within the WBNP [8] requested the use of the muskrat database that my team and I created for the 2009 research.

Our 2009 research was also noted in the 2011 *Athabasca Watershed Council State of the Watershed Report: Phase 1* [46]. Additional information for the report was presented on an associated CD. Our CEMA research helped inform contracted research on the potential impacts of beavers on the success of oil sands reclamation for CEMA in 2013 [47]. In this case, given my past experience with the 2009 research and additional studies specifically on beavers, the authors also asked that I peer-review their report prior to its final submission to CEMA, thus aiding the contextualization of the research relative to new research questions [38].

3.4.3. Implementation to Inform Organizational Decisions

As per Section 12 (2) of the Canada National Parks Act [48], "At least every two years, the Minister shall cause to be tabled in each House of Parliament a report on the state of the parks and on progress made towards the establishment of new parks". As noted in the previous sections, Parks Canada incorporated the 2009 research into its 2016 operational review of ecological integrity monitoring for the WBNP, and further highlighted the semi-aquatic mammal research at their 2014 Peace Athabasca Delta Environmental Monitoring Program Forum in Fort Chipewyan, AB. The opening remarks and presentations at the Forum set the stage for its key objectives: (1) identify the efficacy of current monitoring activities relative to ecological vulnerabilities in the PAD, (2) identify additional monitoring required to address these vulnerabilities, and (3) identify possible (and improved) collaborations, communication approaches, and ways to share and incorporate Traditional Knowledge [44]. During the rotating break-out group sessions during the two-day forum, participants focused on three specific themes: (1) contaminants, (2) water quantity and hydrology, and (3) "bringing Western Science and Traditional Knowledge together" [44], (p. 6). The results of this forum then helped inform policies within the WBNP, provided a venue to expand perspectives and provided a training opportunity to new park staff, and potentially leveraged new program funding, each of which is a metric defined in the co-produced pathway to impact framework outlined by David Phipps and his colleagues [38].

3.4.4. Impact Through Utilization of the Research to Effect Meaningful Change within the Community

The long-term impact of the research was more difficult to identify, although the final 2009 report was noted in the Mikisew Cree First Nation's submission of their petition to the World Heritage Committee (WHC) to request that the WBNP be placed on the *List of World Heritage in Danger* [49]. Rather than just address the decline of muskrats, as is often done to highlight declining water levels in the park, their petition noted our findings for all four species of semi-aquatic mammals that would be impacted by ongoing declines in water levels. The WHC did not include the WNBP on this list when the petition was submitted in 2017; however, ongoing consideration of its inclusion continues to be highlighted in the Canadian media.

4. Discussion

Rapid industrial change creates challenges in accurately assessing associated environmental and cultural impacts in an equally timely manner, particularly relative to the energy sector, where almost 140,000 million ha of boreal forest have been impacted through the mining of bitumen in northern Alberta, Canada over the past few decades [50,51]. The interaction of resource development projects with diverse and dynamic river systems creates added complexity, especially in areas where even basic ecological studies are rare or completely lacking. Such is the case with the lower Athabasca River and the PAD in northeastern Alberta, where semi-aquatic mammals have played important ecological and cultural roles for millennia, yet have faced population declines due to overharvesting and habitat alteration. Yet published literature for key species of semi-aquatic mammals in this area was almost non-existent [30], although two additional peer-reviewed studies on muskrat and based in the PAD have been published since 2018 [7,8]. Much of the research and monitoring of semi-aquatic mammals remains in the grey literature, with most of these documents housed in the Parks Canada libraries and filing cabinets in Fort Smith and Fort Chipewyan, which are generally inaccessible to the public. Of these unpublished documents, the majority were specific to muskrat populations in the PAD, especially following the establishment of the W.A.C. Bennett Dam and subsequent changes in flood pulses and water levels in the Peace River. Of note is that finding these documents within the WBNP libraries required my research team and I to physically examine the relevance of every single document on the shelves and tables in the two libraries because of a lack of up-to-date paper-based or electronic library database. A similar process occurred with documents housed in filing cabinets in storage areas.

In Parks Canada, and many other provincial and federal departments and agencies, it is very unusual to have a dedicated librarian and, although each park has a library, its organization and maintenance is either done as an additional secondary duty by an administrative assistant or becomes a side project for someone with an interest in library resources. Very seldom is there distinct library funding, often due to budget and staffing constraints. However, the documents in these libraries provided major contributions to the final 2009 report for CEMA [35] and allowed once forgotten data to resurface. Although we found no existing models directly applicable to the impact of increased water withdrawals on semi-aquatic mammals in the oil sands region, the variables required to develop a model were compiled in our final report, in no small part due to research, monitoring, and raw data contained within the grey literature and other unpublished documents (e.g., fur records, aerial photograph databases).

Although some scholars suggest that a solution to the increased use of the grey literature would be "to integrate access to grey literature within the databases that scholars regularly consult" [52] (p. 4), much of the grey literature we found that was applicable to the question of potential impacts of water withdrawals on semi-aquatic mammals in the lower Athabasca River and the PAD was not readily available to academic scholars. Indeed, without the author's previous knowledge and experience as a former Parks Canada employee, the lack of awareness of these libraries and associated archived files would have been an immediate barrier to knowledge mobilization in its initial stages ("Research") as defined by David Phipps and his colleagues [38]. The reduction and elimination of various government libraries and many of their holdings between 2014 and 2015 by Canada's federal government further limited the mobilization of invaluable knowledge stored within these libraries [53,54]. With many of the older reports used in our study that were produced with typewriters rather than computers, the loss of the historical ecology of the area would be permanent. Handwritten documents, including fur tallies, also would face the same fate. Projects, such as the creation of the *Antarctic Bibliography* in 1963, where data and publications (primarily grey literature) were copied to microfiche for preservation, provide a powerful example of foresight relative to knowledge mobilization for current and future scientists [55]. Now that microfiche is difficult to access and read, the National Science Foundation has created the *Polar Digitization* project to make the full-text grey literature materials from the *Antarctic Bibliography* (including rare government reports) openly available electronically [55]. Knowledge is impossible to mobilize if key reports and the historical context they document are not accessible; open electronic access ensures broad availability within and external to academia.

Much like the grey literature, peer-reviewed literature and academic books provided critical ecological information about the four species of interest: beaver, muskrat, river otter, and mink. However, as with hydrological models, the peer-reviewed literature, in particular, was often specific to a particular study area that was very different from boreal rivers and deltas of northern Alberta. Information with the greatest applicability to the lower Athabasca and the PAD, not surprisingly, came from the local trappers, residents, parks staff, and biologists. Fikret Berkes [56] notes that the complexity of socio-ecological systems, similar to those found in the lower Athabasca River and the PAD, results in knowledge that is dispersed among a varied hierarchy of groups and individuals, which then allows for management decisions to be assessed and mobilized at different temporal and spatial scales. In the WBNP and the surrounding communities, the Peace Athabasca Delta Environmental Monitoring Program (PADEMP) brings together traditional knowledge holders, scientists, and government personnel (including participants from Indigenous governments) to collaboratively achieve long-term monitoring and reporting on the ecological health of the PAD in particular, and the park more generally. Along with integrating Western Science and Traditional Knowledge, the PADEMP aims to provide open communication within and beyond the core group of participants. Its members include six First Nations, four Métis Associations, Parks Canada (WBNP), three additional federal departments, the governments of the Northwest Territories and Alberta, and two non-governmental organizations. Within this group, there is a broad age range, which helps expand the mobilization of knowledge across generations. As noted previously, the average age of the trappers interviewed in our study was 70 years old, and a common theme was the lack of youth engagement in land-based activities, trapping in particular. The opportunity to share perspectives within the PADEMP forum provides a means to foster a culture of co-management among groups, as well as intergenerational connections within groups.

When examining the movement of knowledge over a broad sociological landscape, decision-making is less impacted by scientific studies than expected [57]. Vivian Nguyen and her colleagues also note that it can take long periods of time before one really knows the true impact of knowledge on policy development or similar societal changes [57]. The length of time from the initiation of a scientific study to peer-review and publication can take years, which tends to provide important knowledge and possible solutions long after immediate needs for that research have passed (e.g., annual water allocation decisions without a current understanding of hydrological changes and impacts of past decisions). In the case of the 2009 study described in this paper [35], there was an eight-month turn around to assess how increasing industrial water withdrawals from the Athabasca River by an additional 15% would impact a suite of semi-aquatic mammals, all of which have different ecological requirements and niches. It required a multi-faceted approach to provide diverse pieces of the puzzle that might one day evolve into a workable model. Although an empirical model was not readily available in either the academic or grey literature, traditional knowledge, historical data, and varied literature sources provided a strong indication that further declines in water levels, especially timed outside of ecological norms, would add to the myriad of cumulative effects already experienced by these species and the people who depend on them. Over time, the impact of the study has slowly revealed itself within the local communities, consultancies, and academia. One example occurred after a presentation at the PADEMP Forum in Fort Chipewyan when people from the community, many of whom had participated or assisted with the interviews, expressed distinct appreciation that their lived experiences were included in the presentation in a manner that brought the cumulative body of knowledge back to the communities where solutions must be co-produced among different organization and perspectives for real change to take place.

Knowledge mobilization can only happen when those creating or translating it are able to speak. Academics possess the ability to retain intellectual property rights, and academic freedoms that provide a safe and open forum to present research findings through broad avenues. In the case of the semi-aquatic mammal study, these privileges allowed me to distribute the final CEMA report when it was not otherwise available. However, the manner in which knowledge is shared must be accessible beyond academic norms in presentation style and discourse. It must translate to the audience. Dissemination of the findings was the most robust aspect of knowledge mobilization in the case of this study. Uptake, implementation, and impact were much harder to quantify, yet are arguably more important for change. Therein lies the challenge for effective knowledge mobilization, how to assess and measure the true impact of research over different temporal and spatial scales, especially when rapid solutions are required for complex problems.

5. Conclusions

Rapid land-use changes challenge our ability to collect, synthesize, and report data in a timely and succinct manner. In the complex and dynamic riverine system of the lower Athabasca River and the Peace-Athabasca Delta in northern Alberta, Canada, the delicate balance between oil extraction and ecological integrity (particularly as required by law in the Wood Buffalo National Park) necessitates rapid knowledge mobilization and uptake. Unfortunately, access to data, documents, and relevant models can be difficult due to proprietary, political, and logistic realities. The study described in this paper presents a detailed assessment of the many sources of knowledge and the need to integrate these resources in a more open and accessible manner. Beyond these resources is the necessity of key actors within various organizations to be able to speak freely to the public without political interference. One cannot mobilize knowledge easily in the context of an anti-science agenda. For successful knowledge mobilization within policy development and its broader impact, multi-stakeholder involvement provides diverse venues through which knowledge can flow.

Funding: This research was funded by the Cumulative Environmental Management Association's Surface Water Working Group and conducted under the University of Alberta Research Ethics Board project number Pro00007196.

Acknowledgments: The author thanks summer research assistants Chantal Bromley and Nhial Tiitmamer Kur, the many people from Fort Chipewyan, Fort Fitzgerald, Fort Smith, Fort Resolution, and Fort McMurray who shared their knowledge of the land and its wildlife. The author is also indebted to the staff of the Wood Buffalo National Park who shared their time, knowledge, and access to the park's library and files. Finally, the author thanks members of the Instream Flow Needs Technical Task Group (IFNTTG) and the Cumulative Environmental Management Association (CEMA) who provided financial support and guidance for this project.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Interview questions used in the study following approval by the Education, Extension, Augustana, and Campus Saint Jean (EEASJ) Research Ethics Board at the University of Alberta (project number Pro00007196).

1. Are you still an active hunter/trapper? Why not anymore? How often do you trap/hunt? Do you make a living trapping?
2. What area do you trap/hunt in?
3. How much trapping and hunting is still being done in your area?
4. Where are the hot spots for trapping beavers, muskrat, mink, and river otters?
5. How are beavers and muskrats important in your community?
6. What changes have you noticed in the number of muskrats and beavers? What are the reasons for the change?
7. What kind of short term or long term changes have noticed in the habitats of muskrats and beavers?
8. How do beavers react to changes in water levels in the river?
9. How do muskrats react to changes in water levels in the river?
10. What do they eat during droughts/floods/during different seasons?
11. Where are they normally found during droughts/floods/during different seasons?
12. Do beavers living in rivers act differently than beavers in the ponds and snyes? (Note: a snye is a backwater or side-channel of a main river or stream.)
13. Do muskrats living in rivers act differently than muskrats in the ponds and snyes?
14. How do mink react to changes in water levels? (high or low water levels)
15. How do river otters react to changes in water levels? (high or low water levels)
16. If you could study just one thing about lowering of water levels in the Athabasca River and these animals, what would it be?
17. Is the water level now what it used to be like in the river/Delta (does it flood like it used to)?
18. Have there been many times that the water level changed before or since the Bennett Dam was constructed?
19. Do you recall your parent's experiences with changes in the water level and these animals?
20. Are there other areas that fill with water that might replace the dry areas? Do they stay filled?
21. Do you know of someone else we should talk with?

Appendix B

Aerial photograph inventory from 1949 to 2008 for the lower Athabasca River from Fort McMurray AB up to and including the Peace Athabasca Delta, and Fort Chipewyan, AB. Coverage extends to within one township (~1.6 km) adjacent to the river and the delta. The database is available at: http://library.cemaonline.ca/ckan/dataset/2009-0017/resource/3299160c-24e6-40be-9702-0454689c7122.

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Article

Reframing Native Knowledge, Co-Managing Native Landscapes: Ethnographic Data and Tribal Engagement at Yosemite National Park

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Received: 25 August 2020; Accepted: 18 September 2020; Published: 22 September 2020

Abstract: Several Native American communities assert traditional ties to Yosemite Valley, and special connections to the exceptional landmarks and natural resources of Yosemite National Park. However, tribal claims relating to this highly visible park with its many competing constituencies—such as tribal assertions of traditional ties to particular landscapes or requests for access to certain plant gathering areas—often require supporting documentation from the written record. Addressing this need, academic researchers, the National Park Service and park-associated tribes collaborated in a multi-year effort to assemble a comprehensive ethnographic database containing most available written accounts of Native American land and resource use in Yosemite National Park. To date, the database includes over 13,000 searchable and georeferenced entries from historical accounts, archived ethnographic notebooks, tribal oral history transcripts and more. The Yosemite National Park Ethnographic Database represents a progressive tool for identifying culturally significant places and resources in Yosemite—a tool already being used by both cultural and natural resource managers within the National Park Service as well as tribal communities considering opportunities for future collaborative management of their traditional homelands within Yosemite National Park. We conclude that the organization of such data, including inherent ambiguities and contradictions, periodically updated with data provided by contemporary Tribal members, offers a rich, multivocal and dynamic representation of cultural traditions linked to specific park lands and resources. Indeed, some Yosemite tribal members celebrate the outcomes as revelatory, and as a partial antidote to their textual erasure from dispossessed lands. In practice however, as with any database, we find that this approach still risks ossifying data and reinforcing hegemonic discourses relating to cultural stasis, ethnographic objectivity and administrative power. By critically engaging these contradictions, we argue that one can still navigate pathways forward—bringing Native voices more meaningfully into the management of parks and other protected spaces, and providing a template useful at other parks for collaboration toward shared conservation goals.

Keywords: Yosemite National Park; ethnographic databases; ethnography; National Park Service; cultural resource management; tribal co-management; Southern Sierra Miwuk; Mono Lake Paiute

1. Introduction

Since the advent of national park creation, United States national parks have provided a globally influential template for the preservation of preeminent natural landscapes. Simultaneously, the U.S. experience with parks underscores fundamental inequities and contradictions that animated these early conservation efforts. Initially, park-boosters such as John D. Rockefeller, Jr. and Theodore Roosevelt supported early park development to set aside lands for their sublime scenic values and recreational potentials for America's leisure class—shaping the priorities and the policies of the early National Park Service [1]. Guided by a historically inaccurate concept of "wilderness" and treating large swathes of the American landscape as terra nullius, the U.S. set aside keystone parks such as Yellowstone, Yosemite, Grand Canyon and Crater Lake—places long inhabited by Native peoples. Abruptly, these landscapes came to be managed by non-Native peoples like they were uninhabited wild spaces. These were "imagined wildernesses" [2], for they were "inhabited wildernesses" [3]. Nonetheless, federal policy shaped by this colonizing logic contributed to Native displacement, and in turn, Euro-American concepts of wilderness came, over time, to be manifest on the land.

While Native American archaeological sites might be treated as objects of touristic interest in the young National Park Service, as at Mesa Verde, the presence of living Native people was often perceived as an obstacle to national park goals. Indeed, some have suggested that the creation of U.S. national parks was an act of "ethnic cleansing"—a national project that removed people from the landscape, all the while eradicating the memory of their history within these unique places [4]. This phenomenon of physical and textual displacement has been documented among national parks globally [3,5] as well as in specific U.S. parks, with Yosemite National Park being an oft-cited example [2,6,7]. Such displacement of Native peoples from park lands has been said to disrupt human lives and longstanding anthropogenic ecologies within park lands, and to undermine the cultures of Native communities and the heritage of the American nation writ large [8,9]. In response, Native American tribes, as well as academic and administrative writers, have called for an effort to "restore a presence"—not only restoring a material presence of Native peoples and their traditional practices to park lands, but also restoring the knowledge, power and textual representation of Native peoples relating to dispossessed park lands [10]. Through the late 20th and early 21st centuries, this call has reflected not only broad ideological shifts in US public thought and governance, but increasingly practical necessities as well. For in recent decades, the U.S. National Park Service (NPS) has been transformed, becoming the lead agency legally responsible for implementation of several cornerstone federal laws protecting Indigenous cultural sites and the rights of Native people—from the protection of Native American graves, to the protection of "Traditional Cultural Properties" such as sacred sites as part of the National Register of Historic Places. With a retooled mission and a new sense of urgency, the agency has grappled with the meaning of this responsibility and has sought mechanisms to meet it.

Turning to Yosemite National Park, the written record makes it clear: despite 130 years of park management and the gradual removal of all Native residents, Native presence and Native imprints on the landscape endure at Yosemite [11–13]. Several Native American communities—descendants of the park's resident peoples—still assert traditional ties to Yosemite Valley and particular connections to its landmarks and natural resources. Traditional activities such as plant gathering continued in the park for generations after park creation, sometimes openly, but often clandestinely. In recent decades, park managers have demonstrated increasing interest in and recognition of the role that native peoples have had in shaping the landscape. This has been reflected in changing park interpretation, consultation and management efforts. Throughout the late 20th and early 21st centuries, Native American tribes have gained political leverage and attained important roles in influencing park policy. In this period, the NPS has hired a greater number of Native American staff, increased consultation with tribal governments, and explored opportunities for the collaborative management of certain parklands and resources with tribal partners [2] (pp. 16–17). Resource managers have begun incorporating Indigenous perspectives into research, recognizing connections to plants and landscape, and often seeking ways to achieve positive outcomes that achieve both scientific and cultural purposes.

While the tribes possess rich oral traditions of Yosemite, the written record of human activity has been understandably diffuse. Ironically, the written record is now in high demand. In this internationally visible park with its many mandates and constituencies, tribal claims to particular sacred places or plant gathering areas, for example, require substantiation from a written historical record to meet the terms for access set by federal laws and policies. The National Park Service has found itself with an awkward mandate to "restore a presence", including a textual presence, of peoples displaced by the park's creation.

Addressing the need to assemble a written record of Native presence, the authors, in collaboration with the National Park Service and park-associated tribes, directed a multi-year project to assemble a comprehensive ethnographic database containing available written accounts of Native American land and resource use in Yosemite National Park. This tool is already being used by cultural and natural resource managers within the National Park Service, as well as tribal communities, as they consider collaborative management of their traditional homelands within Yosemite National Park and the sharing of Native history with park visitors.

Initially, the NPS approved the development of the Yosemite Ethnographic Database to facilitate basic ethnographic research for park planning, and to identify significant cultural features and culturally significant natural resources that might be legally protected in the course of park planning. In time, however, park managers found less conventional applications for its use. The specific design of the database and the way the data has been organized makes it particularly appealing to natural resource managers who can readily access cultural information in a format familiar to them. The ease of access and newfound perception of cultural data as being approachable and "functional" has supported multidisciplinary research and collaboration and introduced natural resource staff to new perspectives on resources. While the database has proven useful, there are inherent dangers in forcing cultural data into a positivist framework. The database was originally designed as a tool for cultural resource employees with a background that would allow them to comprehend the data, in context; significant challenges arise when this database is used without regard to its context or complexity, and when subjective interpretations are accepted as objective truth.

Databases are at once powerful and increasingly popular tools to support the integration of Native voices, values and knowledge into park management, while being a significant threat to such efforts if used unadvisedly. Therefore, we offer our experiences developing, managing and sharing the Yosemite database as a potentially instructive reference point for other parks and protected lands —at once providing the database as a model, while also seeking to problematize the concept of database production generally. We do so recognizing that natural scientists increasingly seek to adopt ethnographic data in innovative ways, and that other national parks in the United States and beyond now seek to develop their own databases. In these efforts, Yosemite's experiences with both the opportunities and pitfalls of incorporating ethnographic data into park land and resource management prove informative.

Though the quantification of cultural data makes it more accessible to natural resource managers, promoting multidisciplinary studies and facilitating identification of sites for compliance projects, this approach risks ossifying data and reinforcing hegemonic discourses related to cultural stasis, ethnographic objectivity and administrative power. We conclude that contextualizing the data, including its inherent ambiguities and contradictions, by periodically updating it with data from contemporary Tribal members, offers a richer, more multivocal and dynamic representation of cultural traditions linked to specific park lands and resources. Indeed, we recommend employing the database only in conjunction with such a hermeneutic approach—especially in consideration of the weaknesses of other databases and issues within the specific cultural and historical context of Yosemite National Park. A more culturally relativistic and historically contextualized representation of cultural data serves as a partial antidote to the textual erasure of tribal communities from dispossessed lands. Herein, we will discuss both the general issues confronting the use of a positivist framework for using and interpreting cultural information, and will analyze specific issues inherent in such a methodology as it pertains to Yosemite National Park. By critically engaging these contradictions, one can navigate the complex path of bringing Native voices more meaningfully into the management of parks and other protected spaces while simultaneously enhancing opportunities for collaboration toward shared conservation goals. Specifically, the following discussion summarizes pitfalls inherent in adoption of cultural data without attention to nuance, as well as opportunities to incorporate data in useful and meaningful ways both to perform innovative conservation work and to build and foster relationships between resource managers and tribal communities.

2. Materials and Methods

Without a clear written record of their connections, however, tribes and tribal organizations often struggle to meet the legal standards to develop plant-gathering agreements, recover human remains unearthed by park development, and the like—not only at Yosemite, but at other national parks across the nation. Additionally, in the absence of clear mandates and funding sources, U.S. national parks have highly variegated systems for documenting information regarding Native American uses of lands and resources within parks. Most have maintained paper files in various stages of development, often scattered somewhat unpredictably between multiple offices relating to different aspects of Native-park relations; in more recent times, GIS databases and electronic files have taken shape.

In initial efforts to create databases, the NPS has developed a Cultural Resource Inventory System (CRIS) oriented more toward basic compliance and resource management needs. CRIS offers useful but perfunctory data for resource managers regarding the location and identity of specific identified sites. It contains technical data such as location, site condition and resource type. Separate subunits of the database include such basic information for archeological sites, specific built features in the cultural landscapes, ethnographic sites and historic structures [14]. Nuanced ethnographic information is a poor fit for the existing CRIS model and is poorly represented in this format. So too, academic databases such as the Human Resources Area Files (HRAF) provide database tools and models; the database tools and models are maintained by Yale University with contributions from a range of researchers, HRAF indexes and codes covering vast stores of ethnographic knowledge across over 400 cultures with the intention of supporting cross-cultural comparison and study [15]. NPS staff seldom access the HRAF system, however, as this database's general focus on cultures writ large, with few geographically specific details, seldom speaks to the specific needs of park managers.

In this context, within almost every national park, ethnographic data has been aggregated on an ad hoc basis. Certain specific projects, such as infrastructure development in a particular corner of the park, often drive the development of files relating to a particular topic or area within the park. Other topics or places remain unexamined—and, all too often, separate sets of files are spread between multiple offices with no clear way to identify or reconcile them. In this context, the basic CRIS database has been of little use. Anyone seeking to document tribal interests in a particular national park typically has to embark on a significant reconnaissance: moving from office to office within the National Park Service, seeking what information can be found in each, before identifying substantial data gaps that must be filled by recourse to collections outside of the park and to Native knowledge holders. Until recently, this was the case even at Yosemite—among the most visible flagship parks in the U.S. and the world.

Clearly, this situation has been less than ideal. The significance of lands within Yosemite National Park to certain Native American tribes and tribal organizations extends into the deep past and persists into the present. Many Native American communities have ancient and historic associations with landscape features, cultural sites and natural resources within the modern park boundaries. Importantly, these features remain highly significant to park-associated many tribal members to this day. Robust oral traditions demonstrate the enduring significance of traditional ceremonial and plant-gathering sites, of places that were venues for ancestors' activities such as former villages sites, and geographic features associated with precontact tribal oral tradition for example. These oral traditions demonstrate a degree of continuity in precontact activities, and enduring connections not only for entire tribes but for specific Native American families and individuals with direct ties to places within Yosemite. Today, Yosemite National Park recognizes these enduring connections, engaging in legally mandated consultation with seven "traditionally associated" tribes and tribal organizations: the Tuolumne Band of Me-Wuk Indians, the Bridgeport Indian Colony, the Bishop Paiute Tribe, the North Fork Rancheria of Mono Indians, the Picayune Rancheria of Chukchansi Indians, the Mono Lake Kutzadikaa and the Southern Sierra Miwuk Nation (a.k.a. the American Indian Council of Mariposa County). In this context, the absence of a single, coherent organization of ethnographic data has been a serious impediment to tribal consultation, and to the engagement of tribal interests in the management, preservation and interpretation of places within Yosemite National Park.

This situation inspired the creation of the Yosemite Ethnographic Database, a comprehensive collection that provides easily accessible Yosemite-specific ethnographic data designed to address resource management and research needs. A combination of models inspired the Yosemite database. These include a Bureau of Ocean Energy Management (BOEM) database created in collaboration with the Makah Tribe, Confederated Tribes of Grand Ronde Community of Oregon and Yurok Tribe to address the potential effects of offshore energy development on culturally significant places [16,17]; and comprehensive ethnographic data compilation efforts undertaken by Douglas Deur, Fred York and others for certain Pacific-West regional parks. Deur and an architect of the BOEM database, Eirik Thorsgard, co-managed the initial development of the Yosemite ethnographic database, with much of the work of database design and construction being undertaken by Rochelle Bloom, Mary Feitz and other interns recruited with the support of the National Council for Preservation Education (NCPE). Shared with tribes and park managers alike, the Yosemite Ethnographic Database has brought new transparency to efforts at natural and cultural resource planning, added a potential tool for collaborative park-tribes interpretive and planning efforts, and potentially contributed to broader shifts in park-tribes relations.

The Yosemite Ethnographic Database is a particularly useful tool for conducting research into Native American uses of lands and resources in Yosemite National Park. A broad review of ethnographic and historical literatures facilitated its development, incorporating ethnographic notes and notebooks, tribal consultation records and other materials currently housed in park collections and other repositories. In compiling the database, researchers systematically reviewed written sources for references to lands and resources used, visited or identified by tribal members as significant in Yosemite Valley. From references gathered from over 575 sources, the database comprises over 13,000 entries. It includes data derived from historic reports, early historic accounts written by visitors to Yosemite, ethnographies, ethno-ecological studies, oral histories, historical and contemporary newspaper articles and more. The collected data relates either specifically to Yosemite National Park, to the immediate surrounding area, or represents general regional data related to tribes traditionally associated with the park. Significantly, it is a living database, meant to reflect the dynamic nature of tribal culture. Therefore, information is derived through tribal consultation, and new research is added regularly. The data is largely qualitative and stored in an Excel spreadsheet, with the intention of making it easy to use by a variety of people with differing levels of database and research experience. The database is intended for in-house use and not for global distribution, and though linked to particular landmarks, does not georeference its contents with precise geographical coordinates.

The database provides a wide range of searchable data including information on archeological, hydrological, botanical and other natural and cultural resources with traditional cultural significance to the American Indian tribes and groups traditionally associated with the Park. Some of the specific resource categories include culturally significant and utilized plant and animal species, plant gathering areas, traditional ecological knowledge (TEK) and management (TEM), landscape features described in oral traditions, village sites and other habitation areas, historical and ceremonial sites, bedrock mortars and other archaeological site features, burials and cremation sites and trails. While the database includes references to archaeological sites and material culture, it is not intended to be an archaeological database. These sites and items were included because of their enduring cultural importance to modern tribal communities. In fact, one of the many important functions of the database is to indicate to resource managers that such material sites should not solely be considered relics, but as loci of enduring meaning within living Native societies.

Among the most unique aspects of the database may be its suitability to the needs of the ethnographic data, rather than the reverse. Categories and sub-categories were amended and added to better reflect data collected, allowing inquirers to access it more accurately. As a result, various specific, as well as general, sub-categories were tailored to account for how ethnographic information is presented in the literature. A breakdown of the different sub-categories can be found in Table 1. The taxonomy for entering resource information involves a narrowing classification scheme: *Resource Type→Resource Subtype→Resource Name→Resource Component*. Entered into the database, an example of this might be: *Flora→Tree→Oak, Black→Acorn*. Table 2 summarizes the various resource types included in the database. Entries can be searched, filtered and sorted by any of the individual subcategories. Entries provide full quotations with relevant information and citations referencing source material. Table 3 provides a sample database entry to demonstrate how information derived from the text is organized into different fields.

Table 1. Excerpt from Ethnographic Database Metadata with Description of Field Content [18].

Field Name	Description	Examples
Tribe/Band	Tribe/band being described *(using terminology and spelling of original document)*	Chow-chilla; Chook-chan-sie; Me-wuk; Tenaya's band of Yosemites
Family/Individual	Family and/or Individual being described	Telles Family; Bridgeport Tom
Resource Type	Broad description of the resource; Kingdom	Flora; fauna; fungi
Resource Subtype	Used to further classify the type of resource, if necessary.	Tree; forb; grass
Resource Name: Common/English	Name of the resource described, in English.	Soaproot; manzanita; mule deer
Resource Component	The specific part of the resource used, as described in the text (in singular form, unless doing so would be grammatically incorrect or unclear)	bark, nut, bone, stem
Resource Name: Scientific/Latin	Resource Name: Scientific/Latin *Note: Names can change over time, include only explicitly what is in the text*	*Quercus kelloggii; Sequoiadendron giganteum*
Resource Name: Native	Resource Name: Native *Note: Specify which language the name is in, if mentioned in the text.*	*Chiikele* (Southern Sierra Miwuk)
Activities	Activities mentioned in the text. If direct quotes are longer than 4 sentences, paraphrase here rather than in "Quotes" column. Be clear and concise about what activities are being referenced, so that they can be found through a document search.	Acorn gathering, acorn pounding, acorn storage, leaching, ceremonial uses, food preparation
Location	Location of resource and/or associated activities, if specified in text. Describe in as much detail as known, for future geospatial referencing in GIS.	Bridalveil Meadow; Sierra Nevada
Period	Time period being described *(if not the same as source publication date)*	Mid-nineteenth century; 1970s; before entry of the Mariposa Battalion
Timing	Timing and duration of resource use/harvest/ management *(specific year(s), time of day, season, etc.)*	Spring; 2–3 times a year; September
Author	Source Author *(Last Name, First Name*	Bates, Craig; Bunnell, Lafayette
Consultant	Tribal "consultant" (if applicable and known)	Captain Dick; Lucy Telles

Table 1. *Cont.*

Field Name	Description	Examples
Quotation	Exemplar Quotations Note: Quotes more than 4 sentences (depending on source/length) should be paraphrased in Activities Column. Direct quotes from informants should be given highest priority and kept intact, where possible. Explain in recorder's notes if there is more pertinent info found in the text.	
Citation	Abbreviated citation for source—full citation goes in bibliography (including page number/s in AAA style).	Bibby 1994: 15–18
Notes	Recorder's Notes	A more extensive description of the acorn leaching and cooking process can be found in Chapter 5, pp. 103–106.

Table 2. Summary of Resource Types [18].

Resource Type	Explanation	Resource Subtypes (Examples)	Resource Name (Examples)	Resource Component (Examples)
Flora	Includes all references to plants	Grass Tree Shrub Forb	Deergrass Oak, Black Manzanita Milkweed	Seed Acorn Berry Fiber
Fauna	Includes all references to animals, mythological or real	Bird Reptile Mammal Insect Fish Shellfish	Eagle Snake Deer Worm, Silk Salmon Oyster	Feather Skin Antler Silk Meat Shell
Fungi	Includes all references to fungi	Mushroom Lichen	Mushroom, White	Cap Stem
Mineral	A solid inorganic substance of natural occurrence		Obsidian Quartz Granite Salt	Arrowhead Mano Pestle
Landscape Feature	A naturally occurring feature or landmark	Mountain Waterfall River Valley	Half Dome Bridalveil Fall Merced River Yosemite Valley	Face Pool Head
Mythology/Oral Traditions	A story passed orally through generations, usually intended to explain the state of the world			
Ethnographic Site	A place which has a cultural, historical, or mythic significance to a group of people (not necessarily an archaeological site)	Cave Ethnographic Village Seasonal Encampment	Bower Cave *Wahhoga*	

Table 2. *Cont.*

Resource Type	Explanation	Resource Subtypes (Examples)	Resource Name (Examples)	Resource Component (Examples)
Archaeological Site	A location where there is physical, material evidence of cultural activity or occupation	Archaeological Site Bedrock Mortar Lithic Scatter	CA-MRP-56	
Structure	Any reference to a structure used or occupied by a cultural group	Ceremonial	Roundhouse	
		Storage	Acorn Granary	
		Dwelling	Bark House	
		Other	Assembly House	
Trail	A historic route used by groups or individuals for travel, trade, etc.		Mono Trail	
Ceremony/Ritual	A ritual or ceremony practiced by a cultural group	Death	Burial	
		Annual	Acorn Harvest	
		Contemporary	Bear Dance	
Astronomical Body	Any variety of stars, satellites, or groupings thereof	Stars	Pleiades	
		Misc. Celestial Body	Moon	
Meteorological Phenomena	Anything relating to weather and/or sky conditions		Snow Rainbow	
Other		Traditional Ecological Management; Social Organization	Burning Pruning Moieties	

Table 3. Sample Entry in Database Demonstrating how Information Derived from the Text is Organized by Field.

Field Name	Sample Entry Information
Tribe/Band	Miwok
Family/Individual	(unspecified)
Resource Type	Flora
Resource Subtype	Tree
Resource Name: Common/English	Oak, California Black
Resource Component	Acorn
Resource Name: Scientific/Latin	*Quercus kelloggii*
Resource Name: Native	*telē'lī* (Plains Miwok, Northern Miwok); *tele'lī* (Central Miwok), *te'lelī* (Southern Miwok)
Activities	Harvesting
Location	Sierra Nevada Region (General)
Period	(unspecified)
Timing	Late Autumn; Early Winter
Author	Barrett, S.A. & E.W. Gifford
Consultant	(unspecified)

Table 3. *Cont.*

Field Name	Sample Entry Information
Quotation	"Acorns were gathered in burden baskets... when they fell from the trees in the late autumn and early winter. Especially in times of shortage, the trees, in which the California woodpecker had drilled holes and stored acorns, were examined and the fresh acorns pried out with a pointed instrument (*welup*, Northern Miwok) of deer antler (*kī'lī*, Northern Miwok)."
Citation	(Barrett & Gifford 1933:143)
Recorder's Notes	Further detail on acorn harvesting and processing can be found within the text- R.B.

The database also contains columns with checkboxes for the presence or absence of certain attributes, making it easy to filter results for specific topics of interest, or for types of information relevant to research and management decisions. This permits researchers to limit their queries to entries containing certain types of information, such as first-person accounts, traditional ecological knowledge (TEK), harvesting locations, oral traditions, maps or sensitive information necessitating differential access.

While the concept of an ethnographic database is certainly not new, the Yosemite Ethnographic Database offers a unique level of nuance and comprehensiveness for a specific study area. It performs a different function than most, bridging the divide between academia and applied anthropology. In contrast to earlier database development efforts, such as CRIS, the Yosemite Ethnographic Database gathers the majority of all available data on a specific study area and its associated people, organizes it, and makes the associated text searchable. Due to cultural sensitivity, access is limited according to security level, yet the database has applications for both research and compliance. It is intended for use by NPS cultural and natural resource staff, tribal communities and qualified researchers.

3. Results

Current and Potential Uses for Resource Managers

Originally developed for cultural resource staff, the Yosemite Ethnographic Database was intended for conventional and routinized uses of ethnographic data in a public land management context. For example, NPS staff have often used the database to assist in preliminary research to facilitate formal and informal discussions with Native American tribes and organizations regarding lands that may be affected by proposed agency activities. Database applications have included cultural affiliation studies, Traditional Cultural Property (TCP) studies and review of Section 106 undertakings for potential impacts to cultural sites. In addition to being useful to resource staff, the database proves useful in assisting park interpretive staff to locate ethnographic information toward the goal of educating park visitors. Interpretive research requests have included those related to Indigenous placenames for park landmarks, and information needed to contextualize online museum artifact descriptions.

The database has been useful in identifying landmarks within proposed areas that are known or likely to be of significance for contemporary tribal members. The types of information considered in these analyses are diverse. Oral tradition, combined with the archaeological record, provides insight into the distant past—a period undocumented in most post-contact historical and ethnographic literature. Then ethnographic data, mostly in the form of past ethnographic studies, have been useful in providing accounts of Native life at the time of Euro-American contact and in subsequent years. Additional information on the contact era and its aftermath comes from firsthand accounts of early settlers, park visitors and park employees dating from the late 19th century to the present. These perspectives within the database are then combined with consultations with contemporary tribal members, providing their recollections on life, traditions, and family associations within the park over the past century. Finally, information derived from analyses of historical photographs and paintings depicting village sites and tribal members has augmented evidence for the identification of known or culturally important locations that would otherwise be less accessible.

It soon became evident that the format and usability of the database made it uniquely valuable for natural resource management and multidisciplinary research, beyond being useful for cultural resource management. The database presents a range of opportunities for assisting with protected area and species management, research and decision making; it has been used to incorporate Native perspectives on management of natural resources and entire natural landscapes, and not just resources conventionally designated as "cultural" such as archaeological sites. In part, this reflects the evolution of federal policy, such as National Register of Historic Places guidance on the protection of "ethnographic landscapes" and "traditional cultural properties. It is also a reflection of the growing academic and public appreciation that Native peoples hold the entirety of the landscape and associated species to be significant, while also possessing unique insights into their management.

Biologists and ecologists often wish to incorporate ethnographic information in their studies, as it provides them with a stream of evidence in support of their research, potentially providing insight into species and landscapes predating that provided by recorded scientific studies. Early ethnographic accounts of resource use, as well as descriptions of material culture, lend insight into the presence of, or access to, certain species historically. This has assisted with identification of historical species' presence within study areas, and of historical landscape conditions. Oral traditions have been used to identify both landscape features and animal and plant species that hold significance for associated tribal members. They also provide information on how landscapes and species were utilized and managed, and on cultural beliefs associated with them. The most prominent example of this in recent times is the incorporation of Indigenous information in the form of traditional ecological knowledge (TEK) for ecological restoration projects [8,9]. The ethnographic data within the database provides valuable insight into various techniques that Native resource managers employed to tend different species, as well as the seasonality of these activities.

As it has reframed cultural data in a positivist framework, the database represents the rigorous application of scientific methods to create an objective understanding of the past, thus making it appealing to natural resource managers. Because it more closely correlates with their own quantitative data, they can more easily incorporate this data into their projects. While obviously not a substitute for research or consultation, such tools are useful for facilitating research and aiding in accelerated acquisition of reference material before initiating consultation. It is therefore particularly useful for researchers unfamiliar with the available ethnographic material who would need several months, if not years, to search and synthesize, or even find data relevant to their projects. The database potentially provides researchers with information they might not know how to find, allowing them access to sources they might not otherwise encounter, thus allowing them to approach problems from a different perspective.

4. Discussion

4.1. Caveats and Contradictions

While the database represents the most comprehensive collection of available ethnographic data on Yosemite and has a wide range of applications for cultural and natural resource management, it is important to acknowledge the limitations of this research tool. The development and use of the ethnographic database are rooted in the tenets of positivism that dictate how anthropology can be used in a resource management framework. As is often the case when finding ways for culture to be "useful" within the positivist framework favored by the NPS and other government agencies, it is typically necessary to reframe qualitative and often intangible heritage to make it more readily understood within a Western scientific framework. The emphasis has been on practical applications, turning away from historical understandings of the past to create generalizations about human behavior [19] (pp. 767–769); [20] (p. 408). By finding ways to make cultural data "quantifiable," it can therefore meet the needs of a compliance driven framework in which objective, scientific rules and generalizations can be formulated [21] (p. 20). This derives from the early days of the discipline when scientific rigor was needed to provide anthropology with legitimacy and acceptance by the wider scientific community.

Assumptions of the ethical neutrality and objectivity of such approaches are rooted in frequently unexamined empiricist paradigms, contributing to the belief that "data can speak without intervening theory" [19] (p. 773). Empiricism requires an unquestioning assumption of the similarity of different cultures and that contextualization and interpretation of data is not necessary. It does not account for the different ways cultures experience and interpret events; it tries to subsume them under a single perspective [21] (p. 19). It also assumes a collection of detached, objective data without the need for interpretation, failing to identify the bias necessarily injected by ethnographers in the construction of data [22] (p. 495); [21] (p. 19). This is particularly problematic when those biases are not explicitly identified and collected data is accepted uncritically.

However, empirical data, with all of its limitations, is more familiar to natural resource managers, and is thus more readily understood and adopted, allowing for incorporation of cultural data among a more diverse group of researchers and in multidisciplinary research. Resource managers tend to want unambiguous, quantifiable data with concrete boundaries that can easily be entered into GIS for mapping. Ambiguous and contradictory information, a hallmark of ethnographic research, does not fit neatly into the framework most Western scientists operate within.

While the database is useful for providing natural resource managers and compliance personnel with a quantitative version of cultural data that is more easily reconciled with the needs of a Western scientific framework, certain characteristics of ethnographic data must be considered and used in a proper manner. Unlike the natural sciences, which allow for unproblematic application of empirical observations, cultural information requires a hermeneutic approach. Though the material manifestations of cultural actions can be observed, social phenomenon are only meaningful through the interpretative lens of relevance to the associated community [22] (p. 495). Using cultural data in an uncontextualized manner ignores underlying contradictions, complexities, and ambiguities, and does not account for theoretical underpinnings. Additionally, disregarding differing perspectives and failing to identify bias results in the creation of false coherent narratives. With access to a tool like the Yosemite database, resource managers risk using only the information that easily "translates" into quantitative data, thus privileging those categories of ethnographic knowledge while ignoring less quantifiable, intangible information not readily engaged or validated by Western science. Complicating this further, even the notion that Indigenous information must be validated through the methods of Western science can be deeply offensive to Indigenous peoples.

The dangers of uncritical imposition of positivism on ethnographic data within certain databases, and the underlying assumptions inherently held by many who create and use such data, can be demonstrated in the criticism of the Human Relations Area Files (HRAF), mentioned earlier in this paper. Wax [21] (p. 19) specifically calls out the Human Relations Area Files (HRAF) as an example of the issues involved with forcing ethnographic data into a positivist framework, referring to it as the "positivistic project par excellence of cultural anthropology." Some of the criticisms are similar to what we have discussed. The HRAF assumes that ethnographers are capable of sufficient detachment to record data objectively, and that the cultures were static and atemporal, permitting creation of a universal system in which different cultural elements could be delineated and organized [21] (p. 19).

Rather than assuming the neutrality of the data, information must be approached critically, without making assumptions about accuracy or "authenticity." Cultural relativism is therefore necessary when considering how to apply ethnographic data, and it is then necessary to "translate" between cultures [19] (pp. 773–774). Particularly in sharing cultural information with personnel who specialize in the natural sciences, it is important to convey the necessity for critical interpretation of data and for rejecting unquestioning empiricism, or the tendency to force data into performing certain functions.

Listing ethnographic data in a database also raises the risk of ossifying it, thus treating it as the final word on resource significance. This may be particularly problematic when the database is employed by natural resource managers tempted to use Indigenous cultural information as they would use natural data. The discipline of anthropology has for generations confronted this tendency, which is rooted in racist assumptions. The issue is often manifested through assertions of the authenticity of only pre-contact traditions, privileging older ethnographic data over information shared by contemporary tribal members and giving the views and interpretations of Euro-American ethnographers primacy over those of tribal members.

It is therefore necessary to avoid reinforcing past prejudices by using ethnographic data in the manner in which one would use natural data. This practice often relates to the historical tendency to equate Native peoples with nature, as represented by the storage of their material culture in natural history museums, by extension imagining their culture as unchanging [20] (p. 187). Connotations of the "noble savage," depicting Indigenous peoples as a part of nature, unchanging and leaving no impact on the landscape, have long been a feature of the discourse at Yosemite [23] (p. 554); [24] (p. 146); [7] (p. 34). The racist view of Native peoples as inherently primitive and culturally static, denying their cultural dynamism, was particularly influential in the nineteenth century and survived into the mid-twentieth century. This belief that their technologies and cultures remained unchanged throughout prehistory allowed for easier ethnographic analogy and projection of interpretation into the distant past [20] (pp. 179, 189, 191). As such, it is important to note that the data recorded in the Ethnographic Database is not the final record of sites and resources significant for Traditionally Associated Tribal peoples. Significance is not static. Rather the database is meant to assist in contextualizing and supplementing information provided by tribal members in consultation, incorporating new data to provide a richer pool of information.

It is also necessary to recognize that this database, like any database concerned with organizing data for resource management, is a fundamentally Western tool of data management; it is first and foremost a research tool intended to facilitate resource management, as well as to support academic study and tribal cultural documentation within the park. While useful to Tribes to supplement their own research relating to traditional resource use, genealogical studies, federal recognition or other actions within a Western framework, it is not in any way meant to replicate or supplant Indigenous methods of knowledge transmission. The database primarily represents a method of packaging data in a way that makes it accessible to park resource managers and permits integration with bureaucratic and scientific management frameworks [25] (p. 10). This has necessarily involved distilling and conveying knowledge using language, epistemologies and methods of transmission through which it was never originally intended, separating it from its cultural context [26] (p. 5).

Certain characteristics are typically ascribed to Western science and Indigenous Knowledge in order to distinguish between the different epistemological frameworks: Western science tends to prioritize hierarchically categorized information that is quantitative, analytical, product-oriented and transmitted textually, while Indigenous Knowledge generally tends to organize information in contexts that are holistic, qualitative, intuitive, process-oriented and transmitted orally [25] (p. 9); [26] (pp. 75–76). In general, the method of transmitting knowledge is different in Western and Indigenous cultures. Western learning involves asking questions and obtaining information from written sources. In contrast, Indigenous learning is undertaken through participation and observation over long periods of time, and is typically transmitted through generations by way of oral tradition that places information in layered social, ecological, and historical contexts [27] (p. xxii); [26] (pp. 23, 33–36). The database takes a compartmentalized approach to organizing knowledge, permitting entries to be entered, filtered and sorted according to ever-narrowing categories of classificatory schemes. This compartmentalization is a key feature of Western frameworks [25] (pp. 5–7). This contrasts with the more holistic, integrated, "gestalt" way of knowing in Indigenous thought, in which different elements cannot be understood separated from the greater whole [27] (p. xxii). Also, while the database allows for new information to be recorded, it conveys written forms of oral traditions and other forms of knowledge that was traditionally conveyed in oral form. This separates knowledge from the context which gives it meaning and translation from its original language can result in inaccuracy and the inability to articulate certain Indigenous concepts [28] (p. 4); [26] (pp. 69–75); [29] (p. 134). The contents of the database can therefore serve as touchstones, and as points of entry into Indigenous knowledge systems, but are scant representations of the larger whole. Native American representatives using such databases generally perceive both the limitations and the opportunities of such tools—which provide points of entry into discussions of traditional knowledge, rather than meaningfully replicating the vast and interdependent domains of Native knowledge relating to park lands.

Also, importantly, by virtue of being recorded in a government database, one must acknowledge that there is a risk that a database, with its tangibility and academic imprimatur, can become the authoritative reference rather than the original Traditional Knowledge holders [28] (p. 4); [30] (pp. 5–6). In some cases, databases invite the risk of displacing Native ways of knowing, and Native knowledge-holders. Underscoring this point, Stevenson [30] (p. 5) notes:

> The most common practice is to take specific elements of [Traditional Knowledge] that are of interest to the conservation bureaucracy out of context and then insert them into the dominant framework of western scientific knowledge. This procedure almost always entails sanitizing and rendering [Traditional Knowledge] into a form that is palatable, recognizable, and usable to the dominant culture.

As such, by its very nature, this framework risks perpetuating unequal power dynamics and privileging Western knowledge and Western scientific reconceptualization of Indigenous Knowledge [25,28].

4.2. The Context of Ethnographic Study at Yosemite

While it is instructive to offer criticism of positivist frameworks for cultural data in the abstract, an in-depth analysis of the opportunities and constraints at Yosemite offers deeper nuance and insight. An overview of the complexity of Yosemite's cultural data, the park's early historical context and the biases impacting the recording of ethnographic data illustrate the necessity for caution when using the database. This overview entails a discussion aimed at demonstrating the limitations and dangers of selectively harvesting "useful" data that conforms to certain scientific characteristics without an understanding of the deeper context.

The Yosemite database contains early ethnographic data, including a significant amount collected in the mid-19th and early 20th centuries, beginning as soon as Euro-Americans entered Yosemite. Though some might assume the early date of cultural recording mean that are indicative of pre-contact conditions, it is dangerous to use accounts with unknown accuracy or potentially impacted by unknown historical events as direct analogies for the more distant past.

For example, Lafayette Bunnell, a doctor who in 1851 accompanied the Mariposa Battalion, authored the first account describing Yosemite Native lifeways, providing a useful firsthand account of the events and circumstances at contact [31]. In 1851, the Mariposa Battalion, a militia unit, was sent into Yosemite Valley to launch a campaign against its Native inhabitants, an effort representing the first official entry of Euro-Americans into the future park [32] (p. 26); [13] (p. 9); [33] (p. 25). While Bunnell's account included the Native names of geographic features he obtained from translators, the locations of Native trails and the identities of villages he observed on the valley floor, his perspective was much skewed by his role in military operations against the valley's inhabitants. As with many of the early, and even later, recorders of Native lifeways in Yosemite, Bunnell lacked the expertise to reliably comprehend the nuances of the culture he recorded. His lack of fluency in the relevant Native languages and overreliance on potentially untrustworthy translators compounded his shortcomings as a cultural interpreter.

Furthermore, tribal identity itself has long been a complex matter in the Yosemite region. Well before direct Euro-American contact, people from many tribal communities converged at Yosemite. Tribal peoples from east and west of Yosemite Valley—Paiutes, Miwok, Yokuts, Western Mono and others—often gathered there, married, and shared other long-term economic, social, and kinship connections. With the advent of the Gold Rush and increasing Euro-American settlement of the surrounding region, the population and lifeways of Yosemite associated tribes were impacted—this long before the physical arrival of the newcomers participating in the Mariposa Battalion. Disease had accompanied the influx of Euro-Americans to the wider California region before the military incursion, spreading indirectly into the Yosemite area to decimate Native populations [34]. Major tribal shifts in the generations prior to 1851 are likely to have occurred. Indeed, as an ancient site of Native American settlement, Yosemite became a refuge for families displaced from other parts of California—the new families often integrated into preexisting villages and social networks within the valley [35] (p. 78); [7] (p. 31).

The official arrival of Euro-Americans to Yosemite Valley in the mid- to late nineteenth century further complicated matters, ushering in a period of violence, disease, and displacement of Native peoples throughout the region. In particular, after the entry of the Mariposa Battalion a series of events rapidly impacted and further disrupted the lifeways of Yosemite associated tribal communities—namely a series of violent altercations, some deadly [32] (p. 27); [36] (p. 503). In the early 1850s, attempts had been made to forcibly remove Yosemite's Native inhabitants to the newly created Fresno River reservation [32,33]. This proved unsuccessful, however, as the removed peoples quickly returned [32] (p. 27). But soon after the arrival of the Mariposa Battalion in 1851, Euro-American visitation and settlement flooded the Yosemite region, dramatically affecting Native life and the character of the valley. The latter half of the nineteenth century was thereafter marked by drastic reductions in Native populations, relocation, restrictions on gathering and traditional landscape management and many other changes to social, ceremonial and economic life [32] (p. 27). In 1864, Yosemite Valley was placed under the administration of the state park commission, and then established as a national park in 1890. In short order, further changes came to the people of the valley—especially restricting traditional mobility, access to certain locations, and traditional resource practices like gathering, hunting and landscape management [37] (p. 11); [38] (pp. 16–19); [39] (p. 2).

As subsistence and other cultural activities were relegated to the margins of ancestral lands, Native villages were soon displaced and consolidated into more restricted enclaves. Over the course of the 20th century, the NPS increasingly made residence in the valley contingent on tribal members' employment with the NPS or its concessionaires, with tribal members increasingly engaged in paid employment for collecting and cutting firewood, overseeing maintenance work, assisting in construction, working as interpreters of Native culture, and in other roles. Well into the 1990s, a small number of individuals continued to reside in the valley, allowed to stay by virtue of their status as NPS employees [13] (pp. 105, 111–113); [40] (p. 49); [41] (pp. 205–206).

For these and other reasons, elucidating Yosemite Native identity requires a nuanced approach —an approach obviated by the frequent oversimplifications and misrepresentations within the original ethnographic text. The concept of what constitutes a "Yosemite" Native person has been contested from contact to the present. As early as 1851, Lafayette Bunnell remarked upon the complex nature of Yosemite tribal identity, writing in *Discovery of the Yosemite* [31] (p. 199) that the "Yosemites were a composite band, collected from the disaffected of other bands in that part of California, and what is now Nevada." He further related that Major James Savage, who knew elements of local dialects, asserted that "the dialect in common use among them was nearly as much of a mixture as the components of the band itself, for he recognizes Pai-ute, Kah-we-ah and Oregon Indian words among them."

Early writers passing through Yosemite without this historical context conveyed much more simplistic views of tribal associations with the park, often referring generically to "Yosemite Indians," without attention to specific tribal designation. Alternatively, they simplistically assumed that all tribal peoples belonged to the Southern Sierra Miwok without further comment or clarification. Consequently, even in more recent times, NPS interpretation has continued to accentuate Southern Sierra Miwok in their public depictions of tribal history, with relatively little mention of other communities or the great complexity of this history. A result of these developments and others has been a persistent uncertainty and debate regarding the identification of tribes historically linked to the park.

Notably, even the name "Yosemite" represents a mistranslation and misunderstanding of the Native people inhabiting the valley. Bunnell originally suggested naming the valley for the Native occupants, whom he understood to be called the "Yosemites." He, and some subsequent observers, later learned the tribe identified themselves as the "Ahwahnechee"; but by then it was too late. The incorrect name was already adopted [36] (pp. 503–504). A diverse set of explanations have been offered regarding what "Yosemite" actually denotes, with possible suggestions including "grizzly bear," "killer," "great hunter" or relating to tribal moieties [35] (p. 4); [42] (p. 59); [43] (p. 2). In general, however, sources agree it was not the name of the tribe.

As database entries are solely a review of available literature, they reflect the biases contained within original source materials. The database employs terminology used in the original sources and makes no assumptions about the accuracy of accounts. As a result, it contains oversimplifications of tribal identity and associations as well as racially insensitive language and stereotypes. Early writers ignored the complexity of both nineteenth and twentieth century tribal identity, erasing the significant presence of various tribes in the park and projecting simplistic understandings into the distant past. In particular, the park has faced accusations of underrepresenting Paiute and other connections to Yosemite Valley. Attempting to use the data to definitively and uncritically identify tribes can have potentially disastrous results. Particularly dangerous implications exist if data is misused to assert affiliation in a way that disenfranchises or misappropriates cultural traditions or connections, potentially erasing complex tribal identities and denying tribal communities rights or recognition based on biased readings of the material.

The information contained in the database also reflects gaps in the ethnographic record. Notably, the written record is incomplete regarding lands and resources of concern to Native American communities. Relevant to this discussion, Anderson [44] (pp. 112–115) details the limitations of ethnohistorical descriptions of California Indian plant species identification, which necessarily impact the available information within the database. Few of the early ethnographers and travelers who documented early resource use among Yosemite Native peoples were trained botanists or ecologists. As a result, much of the recorded information was incomplete, oversimplified, ignored or inaccurate. Early ethnographers often grouped plants together in generic categories since they were unable to identify species. Furthermore, many of these researchers undertook their field work at settlements instead of at traditional resource gathering or management sites and missed crucial details. They often relied upon remembered descriptions from interviews instead of first-hand observation. Another key issue with available plant data is that much of the field work was undertaken exclusively by men who failed, by interest or access, to obtain key information from female Native consultants on a wide range of topics associated with women's knowledge, from gendered social and ceremonial knowledge to the traditional procurement and use of plants.

The database is also especially weak in documenting perspectives of contemporary tribal members whose enduring attachments to Yosemite Valley are essential to understanding the significance of Yosemite Valley resources. In addition, facts that past generations of tribal members viewed as too sensitive to share, or that were simply difficult to convey across cultures, are often omitted from their accounts. Accordingly, available information tends to focus on material objects, underemphasizing intangible values and the deeper cultural importance and meaning of those objects to Native American people.

As a result of both the availability of information and the funding for the project, Yosemite Ethnographic Database materials are largely focused on Yosemite Valley at the expense of other parts of the park. A combination of factors—including accessibility, weather conditions and the absence of certain notable landmarks—mean that other park areas receive less visitation and, consequently, less written attention historically and today. The comparatively scant record of early cultural activity in more remote parts of the park compounds the skew of data toward tribes closely associated with the western portion of Yosemite.

Furthermore, the ambiguous, conflicting, dynamic, and holistic nature of cultural information does not conform well to a positivist framework. The identification of individual culturally significant lands and resources by consulting itemized entries in the database is inherently reductionist, and must be done advisedly. As Native American communities hold the entirety of Yosemite to be significant, a holistic review would typically indicate that no land or resource within the valley may be deemed culturally *insignificant*. By extension, tribal representatives may reasonably suggest through consultation that the entire valley be construed as one large, contiguous area of significance without differentiating between specific "contributing resources" therein. Again, it is critical to avoid the assumption that places or resources not identified as significant within the database, that the gaps in the maps of such places, are by definition "insignificant." Such matters require a broader understanding, aided by direct engagement with tribes through consultation.

It is also important to recognize the implicit ambiguity of most ethnographic site boundaries, particularly in attempting to assign them distinct spatial locations in a manner conforming to expectations of quantitative data. Many categories of ethnographic sites, including village areas, gathering sites and trails, did not possess distinct boundaries. Perimeters sometimes changed depending on environmental factors and seasonal conditions, differing habitation patterns, and personal preference. As a result, ethnographic villages tend to possess amorphous boundaries that do not necessarily represent the structural components of sites and material culture associated with them. While overlap may exist with archaeological sites, which do have definite boundaries, they are not necessarily the same. Reoccupation of certain desirable sites was inevitable in view of the long occupation history of the valley—especially when combined with the small size of the region and preference for areas with exposure to sunlight, flat ground and proximity to key resources. Additionally, the ethnographic sites listed in the database represent the names and locations as recorded in the late 19th and early 20th centuries, or within living memory of tribal consultants at the time, and do not necessarily represent their identity throughout antiquity.

Plant harvesting areas represent another site category that is difficult to quantify. Gathering patterns have been impacted by a variety of changes since Euro-American settlement and the ensuing creation of Yosemite National Park. Changes in hydrology, construction of park infrastructure, prohibition of traditional ecological management, proliferation of tourists and federal gathering restrictions have altered both the quantity and quality of plants, as well as the locations in which tribal members can gather. The desire to avoid tourists and heavily trafficked areas causes many tribal members to shift their gathering to margins of the valley where they face less scrutiny. This has sometimes meant shifting to less productive or less desirable areas. As such, when harvesting locations are identified within the database, the sites represent preferences of specific tribal members at a specific point in time. While useful for identifying species, personal attachment and cultural continuity, they do not infer static locations, delineated boundaries or the extent of all areas in which plant species are found and gathered. Notably, in past studies and consultation, tribal members were adamant that sites for plant gathering should not be mapped, suggesting that while patterns of plant gathering were intense throughout the valley historically, they must now be highly dynamic in response to changing vegetation conditions and the impacts of park infrastructure, management and visitation on gathering opportunities [45]. To identify and map specific sites in this context may constrain the geography of harvesting options and, by extension, undermine tribes' resource resiliency. Thus, tribal members have indicated that for purposes of plant gathering, the entire valley floor must be considered as one large and integrated whole. As such, in an effort to better reflect the cultural and historical realities of these sites, it is typically more appropriate to provide qualitative descriptions of site locations where necessary, demonstrating their amorphous and dynamic nature.

The use of information contained in oral traditions is also done advisedly. In many cases these were written and transmitted by early visitors to the park or early residents, such as hotelier and magazine owner James Hutchings, who sought to sensationalize the park and its Native inhabitants [46] (pp. 103–106); [47]. Oral traditions compiled by Hutchings and others [48–51] were often embellished and romanticized, incorporating fantastical elements that would appeal to Western readers. The reality is best exemplified by the response of Choko, Stephen Powers' Yosemite Native consultant, to such versions: "White man too much lie" [52] (p. 368). Furthermore, it is necessary to accept the necessarily ambiguous nature of oral traditions even when they are faithful retellings. By their nature, oral traditions are emblematic of the dynamic nature of culture. Rather than provide a static account, individual storytellers transmit cultural knowledge through the generations with changes that reflect the particular recounting. As such, while the core narrative might provide insight into species presence and management, geological changes, and historic events through creation stories and cautionary tales, direct analogy is inappropriate.

5. Conclusions

Since its inception in 2016, the Yosemite Ethnographic Database has proven to be one potentially useful way to "restore a presence" in national park settings [10]. The database permits specific queries about a variety of topics, such as: information on the identity and enduring significance of archeological sites, the use and significance of culturally significant flora and fauna on park lands, the significance of particular landscapes or places to tribes, specific ceremonial or oral traditions that explain the intangible value of the park and its places to tribes or the places and circumstances of historic events in the park involving Native communities.

With such information in hand, National Park Service managers are able to avoid development impacts on culturally significant sites, negotiate collaborative solutions for plant community management and envision interpretive opportunities with much enhanced speed and clarity. The framework of the database has allowed greater access to information and to an audience beyond National Park Service staff. Additionally, to the extent possible within the protocols for sensitive data, the database democratizes access to knowledge regarding the cultural significance of park lands—returning this knowledge to Native peoples and, at their discretion, a wider range of researchers and interested parties. With roughly 13,000 independent entries on numerous topics, the database brings into any park planning process an unprecedented level of cultural detail—a richness of data about tribal interests that would have been impossible in more conventional planning and tribal consultation efforts. Some tribal members, too, find the database to be an astonishingly useful tool, bringing the knowledge and perspectives of many elder consultants, assembled across the generations, to bear on particular topics in a way few living individuals could offer. Presently, a number of other NPS units in the western United States have requested that the team that constructed the Yosemite Ethnographic Database begin constructing similar databases for their parks as well.

While this approach to Native American historical and cultural data provides tribes and park managers with a powerful tool, it is a tool both unwieldy and potentially hazardous if used without attention to its limitations and sensitivities. Placing so much potentially sensitive cultural information in one place, where it can be immediately beheld and transmitted, is fundamentally problematic. In Yosemite's case, negotiations regarding who may hold or access the database is fraught with uncertainty and enduring distrust. Tribal communities express delight in receiving the database, but fear its diffusion, for example, into the hands of private promoters or potential looters of archaeological sites. In this respect, databases demand negotiated agreements as to restrictions to guide sharing and distribution of information. Prior to Yosemite's database construction, those with nefarious intent had to undertake extensive research, often in multiple collections with their own safeguards, and even the most motivated pillagers often were not successful. Today, they might gain access to a world of information with a few keystrokes. Formal agreements between parks and Native communities are required, and in the case of Yosemite, imminent, if all parties are to provide consent for long-term database development, use and sharing.

While much of the database is derived from publicly accessible materials, some of it is not. Therefore, the Yosemite database contains sensitive data, such as information regarding tribal religious practices and the locations of culturally significant sites. This information cannot be shared with the public, and in many instances perhaps might not be shared with park staffs who have not been granted explicit approval. It is therefore necessary to develop a system and protocol ensuring different levels of access and securing the data. At Yosemite, the data is encrypted and stored on a federal government network; access is limited to specific cultural resource personnel with accredited professional credentials who have been granted clearance. Yosemite tribal partners also have copies of the database. If natural resource managers wish to gain access, they may submit a request for use of a database version without sensitive information. Parks wishing to extrapolate from the Yosemite experience might consider this structure of multi-tier access; alternatively, parks can produce two-tier databases, with highly sensitive information not present in the version that is widely available.

For ease of access, a tool like the Yosemite database has forced a great deal of complex cultural information into a crudely positivist framework. The tool's ease of access therefore requires particular cautions. Certain agency contrivances, such as maintaining standing lists of "ethnographic resources" to be managed on public lands, are useful for compliance with federal laws, but are not an accurate representation of cultural realities. We find that agency database users, such as park resource managers, tend to perceive the items in the database as if they represent the sum total of all Native interests—the alpha and omega of what is of value and must be protected. They tend to focus on static objects of cultural interest—for example, landscapes, archaeological features and plant gathering areas—in curious isolation from the dynamic context of their significance, which is the complexly evolving realities of Native engagement and attachment with park lands. In worst case scenarios, databases can provide land managers with false confidence, and a plausible excuse for not directly engaging Native communities and forming relationships of mutual trust.

Indiscriminate use of the database also risks ossifying ethnocentric biases in the historical and ethnographic written record and privileging the past as recorded largely by Euro-Americans. Using terminology from original texts without interpretation, the database contains recorder bias, even racially insensitive terms, concepts, and stereotypes that cannot be accepted uncritically. In an attempt to address this, the Yosemite database contains a column that includes recorder's notes, allowing for a degree of clarification, though this too is often insufficient and potentially subject to bias. These risks are aggravated when such a tool is employed by an audience with little or no prior exposure to the topic of Native American cultural values and practice, many of whom are likely unaware of the existence of these epistemological problems, let alone of how to navigate them.

Any park or protected area that seeks to produce a database must consider these challenges, then, and develop enduring procedures and guidelines to accommodate Native knowledge and practice within the management and interpretation of park lands. While such tools are meant to simplify and synthesize data for the sake of intelligibility and accessibility, tribal members and anthropologists must be vigilant, contextualizing the data, highlighting its complications, contradictions, and nuances, and anticipating its misuse with proactive policies, procedures, and metadata. In some respects, then, tribes and anthropologists must simultaneously construct and problematize the database.

In doing so, it is necessary to critically examine and openly discuss the specific political, cultural, historical, and theoretical contexts that created the data within the database. The accessible written record is incomplete and does not represent the full extent of issues, values, and places of concern to Native American communities. In many cases, tribal members have deliberately chosen not to share information due to reasons of sensitivity. Moreover, tribal cultures, traditions and preferred locations are dynamic and certain practices, values and cultural geographies change over time. However, explaining these complications to park administrators requires a delicate balance. Contextualization, acknowledging the ambiguity and complexity of ethnographic data, may undermine park managers' trust and use of the database if not conveyed in terms that speak pragmatically to management tradeoffs. For example, simply resorting to academic explanations of the "crisis of representation" can (and has) undermined NPS use of ethnographic databases and ultimately undermined Native interests in park lands [53]. Conversely, utilizing a database as a tool that parallels broader ongoing conversations between park managers and Native American tribes, facilitated by anthropologists or other cultural resource specialists to provide context, has proven more effective than use of a database alone. A database does not obviate the practical and legal imperatives for direct tribal consultation. Furthermore, through direct engagements tribal members may make contextually appropriate decisions about what is proper to disclose, what is relevant, and what is inadmissible within the context of an ongoing exchange between park managers and park-associated tribes.

Responding to many of these concerns, the Yosemite database has been designed as a living record of cultural significance. It contains both historical and contemporary data and—funding and staffing permitting—continues to be updated with information emerging within ongoing tribal consultation, reflecting the dynamic values and guidance of park-associated tribal communities. Thus, when identifying plant harvesting locations, managers can account for the gradual transformation of those places in the context of climate change, emerging tourist pressures and dynamic tribal plant uses and needs. Indeed, tribal members at Yosemite have resisted mapping of such sites—not so much because of the sensitivity of the data, but because they express a concern that this will "lock them in" to particular gathering areas when the actual pattern of plant gathering has been highly dynamic and adaptive to changing environmental conditions, tourist pressures, and cultural preferences of Native peoples [45]. A place that was good for gathering when anthropologists arrived in the early 20th century, they note, might not be a suitable place for gathering today. In lieu of mapping sites, these tribal members suggest active engagement and ongoing data collection to protect plant gathering interests writ large—a goal achieved by maintaining the ethnographic database continuously over time and allowing the contents to evolve as the cultures and landscapes also evolve. If park staffs collaborate with tribes actively, reviewing database protocols and outcomes together, such databases and their use can be improved over time—eliminating such sources of error and continuously calibrating these tools to fit the cultural, legal and ecological realities of protected lands.

By sincerely seeking to engage Native communities, and by maintaining a pragmatic view of ethnographic data—duly balancing respect for and critique of that data—parks may develop databases with confidence. While recognizing that Native communities as well as landscapes change even as certain relationships endure, databases can be constructed as living documents continuing to evolve over time. Certainly, forcing the particulars of very long-term human relationships with park landscapes into a crude positivist framework is a fraught exercise. Nuances are surely lost in translation, facts become ossified and sensitive information is aggregated in ways laden with both threat and opportunity. Conversations between park managers and tribal representatives therefore must be direct and ongoing regarding places and resources of significance, their meanings, their importance within Native societies and the right ways to document and share this information within and between organizations. Approached in this way, the Yosemite Ethnographic Database has begun to demonstrate the potential for innovative uses of ethnographic data in resource management. While not comprehensive, it encompasses a vast amount of information, allowing for ongoing efforts to incorporate Native values and needs into park planning. The accessibility of the data has facilitated multidisciplinary conservation and restoration undertakings, promoting meaningful collaborations between park resource managers and tribal communities. Critically, the database places tribal interests in a much richer historical and cultural context. It can be used to address longstanding grievances and to meaningfully build long-term relationships between park staffs and Native peoples. Developed as a collaborative tool, the database now helps bring a much enhanced understanding of the significance of Yosemite's resources and landscape to management and conservation efforts—for the benefit of future generations, Native and non-Native alike.

Author Contributions: R.B. and D.D. conceptualized and designed the study and both contributed to designing the database. Both authors analyzed the data and wrote the paper. Both authors have read and agreed to the published version of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the USDI National Park Service through Cooperative Ecosystem Studies Unit agreements with PSU under Cooperative Agreement H8W07110001.

Acknowledgments: We would like to express our gratitude for the time and assistance of the many park staff, tribal partners and others who made this research possible: Mary Feitz, Kristin Herrick and Katie Donlan; Eirik Thorsgard and Scott Carpenter; Tricia Gates Brown; Jason Lyon and four anonymous reviewers; the Tuolumne Band of Me-Wuk Indians, the Bridgeport Indian Colony, the Bishop Paiute Tribe, the North Fork Rancheria of Mono Indians, the Picayune Rancheria of Chukchansi Indians, the Mono Lake Kutzadikaa and the Southern Sierra Miwuk Nation (a.k.a. the American Indian Council of Mariposa County) for their participation in the original research.

Conflicts of Interest: The authors declare no conflict of interest.

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Accessing Local Tacit Knowledge as a Means of Knowledge Co-Production for Effective Wildlife Corridor Planning in the Chignecto Isthmus, Canada

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Received: 30 July 2020; Accepted: 15 September 2020; Published: 20 September 2020

Abstract: Inclusive knowledge systems that engage local perspectives and social and natural sciences are difficult to generate and infuse into decision-making processes but are critical for conservation planning. This paper explores local tacit knowledge application to identify wildlife locations, movement patterns and heightened opportunities and barriers for connectivity conservation planning in a critical linkage area known as the Chignecto Isthmus in the eastern Canadian provinces of Nova Scotia and New Brunswick. Thirty-four local hunters, loggers, farmers and others with strong tacit knowledge of wildlife and the land participated in individual interviews and group workshops, both of which engaged participatory mapping. Individuals' data were digitised, analysed and compiled into thematic series of maps, which were refined through participatory, consensus-based workshops. Locations of key populations and movement patterns for several species were delineated, predominantly for terrestrial mammals and migratory birds. When comparing local tacit-knowledge-based maps with those derived from formal-natural-science models, key differences and strong overlap were apparent. Local participants provided rich explanatory and complementary data. Their engagement in the process fostered knowledge transfer within the group and increased confidence in their experiential knowledge and its value for decision making. Benefits derived from our study for conservation planning in the region include enhanced spatial data on key locations of wildlife populations and movement pathways and local insights into wildlife changes over time. Identified contributing factors primarily relate to habitat degradation and fragmentation from human activities (i.e., land use and cover changes caused by roads and forestry practices), thereby supporting the need for conservation measures. The generated knowledge is important for consideration in local planning initiatives; it addresses gaps in existing formal-science data and validates or ground truths the outputs of existing computer-based models of wildlife habitat and movement pathways within the context of the complex social-ecological systems of the place and local people. Critically, awareness of the need for conservation and the value of the participants' shared knowledge has been enhanced, with potential influence in fostering local engagement in wildlife conservation and other planning initiatives. Consistent with other studies, engagement of local people and their tacit knowledge was found to (i) provide important insights, knowledge translation, and dissemination to complement formal, natural science, (ii) help build a more inclusive knowledge system grounded in the people and place, and (iii) lend support to conservation action for connectivity planning and human-wildlife co-existence. More broadly, our methods demonstrate an effective approach for representing differences and consensus among participants' spatial indications of wildlife and habitat as a means of co-producing knowledge in participatory mapping for conservation planning.

Keywords: local tacit experiential knowledge; participatory mapping; conservation planning; connectivity conservation; wildlife movement pathways; ecological corridors

1. Introduction

Connected systems of effectively protected and conserved areas are considered critical to addressing both biodiversity and climate crises [1–5]. Ecological connectivity allows for genetic flow and is imperative to maintaining natural ecosystem processes [6,7]. Discontinuous and fragmented habitat can restrict the movement of wildlife and gene flow with adverse effects on populations and the persistence of species [8,9]. Connectivity facilitates genetic exchange among subpopulations [10–13] helping to maintain genetic diversity and metapopulation viability [14,15], which support species resilience to changes such as disease and climate [16–19]. In the face of climate change, ecological connectivity is considered crucial to species adaptation strategies [1,20]. As temperatures rise, connectivity can enhance the ability of species to move in response to range shifts by utilizing ecological corridors [19–22].

Given the importance of connectivity, and on-going threats to it, conservation measures are warranted to maintain and restore key ecological corridors [2,5,23]. With competing demands on a limited land base, however, any plans for additional protected or conserved areas need to be grounded in rigorous evidence and supported by local people [24–27]. Conservation issues are multi-faceted and involve complex social and natural systems that require both the natural and social sciences to solve [28]. For effective conservation decision-making processes to occur, there must be a mobilization of diverse forms of knowledge and ways of knowing. Knowledge systems that combine social and natural sciences, including local perspectives, are often difficult to generate and mobilize [29–33]. Yet, the importance of local and inclusive knowledge in conservation planning is increasingly recognized [34–36].

This paper accesses and generates local tacit knowledge of wildlife locations, movement patterns and landscape features that represent opportunities and barriers for connectivity conservation planning. The study area is the Chignecto Isthmus, a primarily rural region that serves a critical landscape linkage function in the eastern Canadian provinces of Nova Scotia (NS) and New Brunswick (NB). While the local findings and outcomes are important in their own right, the work contributes to the growing body of conservation planning literature that demonstrates the value and utility of local tacit knowledge as complementary, accurate information for decision making in diverse contexts. The generation of local experiential knowledge in study regions where formal-natural-science data and resources are sparse may represent a particularly important source of relevant data to address data gaps, validate or ground truth modeling studies, and weave in important social and ecological knowledge particular to the place and people. Even in areas where formal-science data are available, the engagement of local people and their tacit knowledge is important to opening up research to different ways of knowing, breaking down western-scientific notions of science and whose information counts. At the same time, inclusion in the research process may increase awareness and potentially mobilize locally influential participants to engage in associated planning and management initiatives. In our case, the research process may foster consideration of wildlife and key wildlife movement pathways in government efforts to identify engineering solutions to protect infrastructure from sea-level rise and engagement in on-going collaborative wildlife conservation initiatives in the Chignecto Isthmus.

The Chignecto Isthmus is a narrow strip of land (currently ~25 km in width, ~19 km as dry land) that connects NS and southeastern NB to the rest of mainland North America. It is threatened by sea-level rise [37–39], storm surges and flooding [40], along with increasing human developments such as roads, railways, and energy and communication infrastructure [41,42]. Effective mechanisms to conserve wildlife movement patterns are critical to biodiversity conservation and climate resilience and adaptation for species in this region. Although previous conservation planning studies have identified the region as of critical importance to species at risk and broader ecological connectivity [43–45] there have been relatively few empirical and spatial analyses. Most assessments of wildlife habitat and connectivity have been based on computer-based models [46–48], often at larger provincial and eco-regional scales [43–45]. In their 2005 study, Macdonald & Clowater noted that scientific knowledge of local species distribution in the region is lacking, making it difficult to assess habitat connectivity [46]. This situation remains at present. Wildlife monitoring and management by provincial government agencies is not coordinated across NS and NB and the empirical wildlife data that do exist remain provincially specific and not readily accessible or compatible for application across the Chignecto Isthmus region [46]. Recent predictive modelling by the Nature Conservancy of Canada (NCC) has identified high-probability wildlife movement pathways between protected areas in the region, with the recognized need for model verification and more detailed assessment of identified 'pinch points' to assist in future land management and conservation in the region [47,48]. Some model validation has occurred through roadside surveys of wildlife roadkill [49,50]. Capacity for wildlife research is limited in the area, with a lack of financial and other resources for field studies across the entire region.

To date, regional efforts to mobilize knowledge have largely focused on natural science and nature conservation, rather than on local tacit experience and perceptions. Yet, local forms of knowledge and ways of knowing are as important as those generated through formal natural sciences and models. It is likely that there is a strong base of knowledge of the land and wildlife in the region, given long-standing traditions, livelihoods, and pastimes associated with living off the land, seasonal hunting, trapping, and fishing in the area, and other natural resource uses. Indigenous peoples—the Mi'kmaq—have lived here, in their ancestral and unceded territory—Mi'kma'ki, for 15,000 years and Euro-American settlements began in the 1600s.

Realizing that human factors have been largely neglected in conservation science [51–56], our work aims to enhance the generation and use of local tacit knowledge for connectivity-conservation planning and broader norms of human-wildlife co-existence in the Chignecto Isthmus. More specifically, our study seeks to address data gaps and limitations by engaging in participatory research with local knowledgeable people as a means of garnering important insights on wildlife habitat locations and movement patterns that are likely not adequately represented in the existing empirical and spatial data. At the same time, we hope to enhance the participants' support and engagement in conservation planning initiatives. In doing so, we aim to contribute to a more inclusive knowledge system and capacity base for potential infusion of local knowledge into conservation and other land planning initiatives in the region. Beyond the study area, our research contributes to the growing body of literature related to conservation planning, particularly for wildlife connectivity and the use of public participatory geographic information systems (PPGIS).

1.1. The Chignecto Isthmus in Context

The Chignecto Isthmus is a unique study region as it plays a critical role in landscape connectivity [43–46] (Figure 1). Recognized nationally and internationally as a high priority corridor, both for wildlife movements and linear human infrastructure such as roads, railways and energy pipelines, this region is key to maintaining connectivity between NS, southeastern NB and continental North America [48,57,58]. Its ecological importance is recognized through designation as one of Canada's 15 Community-Nominated Priority Places[1] [59]. Enhanced local awareness of its role in species' population persistence has been raised through NCC's 'Moose Sex' project [60,61]. Several challenges emerge, however, in understanding, maintaining, and restoring connectivity for wildlife and other ecological processes through this narrow region, particularly in the context of complex networks of roads and other human infrastructure. Bounded by the Northumberland Strait and the Bay of Fundy, the Isthmus is fragmented by seven two-lane roads that transect the region [46,50] and the Trans-Canada Highway and Canadian National Railway that transverse the region [42,62].

[1] NS and NB—'A community of practice to protect and recover species at risk on the Chignecto Isthmus': Nature Conservancy of Canada and partners (e.g., Birds Canada, Community Forests International, Fort Folly Habitat Recovery Program, Confederacy of Mainland Mi'kmaq-Mi'kmaw Conservation Group) aim 'to build and strengthen community relationships, develop a conservation plan, build public awareness and deliver programs benefiting species at risk. The project will benefit 20 listed species at risk ... and 20 additional species of concern. It will occur in the Chignecto Isthmus region of both Nova Scotia and New Brunswick, covering 739,596 hectares.' [59].

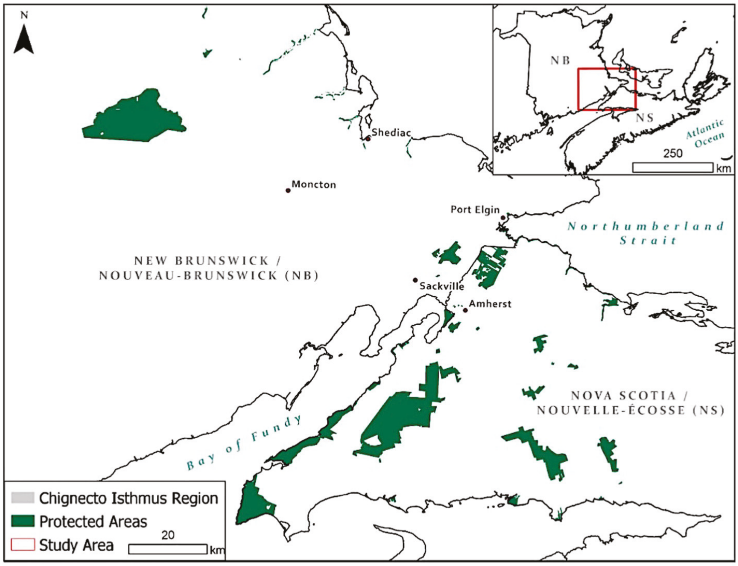

Figure 1. The Chignecto Isthmus Region in NS and NB, Canada. The region is delineated as a level 2 watershed [48]. Protected areas are from the Canadian Protected and Conserved Areas Database [63] for terrestrial protected areas and other effective area-based conservation measures, compiled by Environment and Climate Change Canada.

Sea-level rise [38,39], storm surges, and flooding [40,64] threaten terrestrial connectivity across the Isthmus, compounded by habitat loss and fragmentation [41,42]. Drivers include urban and rural development; transportation, energy and communications infrastructure; forestry and agricultural activities; and climate change [46,58,65]. At times, historically and during the Saxby Gale in 1869 [66,67], the Isthmus has been inundated with waters from the Bay of Fundy [37,68]. Storm surges funnel up the Bay of Fundy—a dynamic marine system with the highest recorded tides in the world (16.3 m)—culminating in the Chignecto Bay [69–71]. The elevation of the entire region is less than 90 m above sea level and is dominated in the southern region by low-lying salt marshes, wetlands, and bogs [46]. Beginning with French Acadian settlement in the late 1600s, large areas of salt marsh were transformed into dykelands for agricultural use [69,72]. The northern portion of the region is at higher elevation and relatively better drained, supporting mixed forests [46]. Higher elevations also occur towards the Northumberland Strait, rated by Canada's Climate Change Impacts and Adaptation Program as of 'medium' sensitivity to sea-level rise compared to areas of 'high' sensitivity in the Isthmus' southern portion [58].

Projected sea-level rise[2], extreme weather events and storm surges threaten to breach the dykes, flooding parts of the Isthmus including the towns of Sackville, NB and Amherst, NS [38–41,73]. Over the past two centuries, major storm events have breached the dykes and caused extensive flooding around the perimeter of the Bay of Fundy [73]. Flooding threatens the Trans-Canada Highway and

[2] An average measure from tide gauge records at Saint John, NB, estimates sea-level rise as 22 cm over the past century in the Bay of Fundy. This suggests that the current level is approximately 32 cm higher that at the time of the Saxby Gale when a storm surge breached the dykes, causing flooding that temporarily severed NS from NB [73] (p. 9). Historic trends and modelled projections show that even in the absence of climate change an increase in tidal high water in the order of 0.3 m can be expected in the Bay of Fundy over the next century. Combined with the influence of climate change, "high water in the Bay of Fundy is predicted to rise on the order of 0.5 m over the next 50 years, and on the order of 1 m by the end of the century" [71] (p. 274).

the Canadian National Railway, which move an estimated 50 million CAD per day in trade [58], potentially causing detrimental economic impacts [74]. As climate change adaptations become necessary, human infrastructural demands could put increased adverse pressures on wildlife habitat across a narrow five-kilometer-wide strip of higher elevation land at the NS-NB border [48]. Further fragmentation of habitat would restrict the movement of wildlife, with negative consequences for the persistence of populations of wide-ranging, sensitive and vulnerable species [8]. Alternatively, carefully planned adaptation measures could potentially provide opportunities to mitigate barriers and pinch points to wildlife movements. Conserving connectivity would facilitate geneflow between subpopulations of species, helping to maintain genetic diversity and species resilience in response to climate and other changes [8].

NCC's recent predictive modelling [48] of high-probability wildlife movement pathways in the region may serve to identify priority areas for conserving connectivity. They modelled habitat suitability and least-cost paths for 15 terrestrial species selected to capture a range of territory sizes and habitat requirements[3]. Their analyses identified routes predicted to require the least energetic cost, providing the lowest risk to mortality, thereby minimizing risks to movements among habitat patches between five protected areas in NS and NB. The predictive modelling of potential corridors and pinch points has provided key information for future land management and conservation in the region [48]. Subsequent roadside surveys and roadkill hotspot analyses have helped to validate some of the model outputs [49,50]. Yet, further validation and consideration of areas outside of modeled and field-surveyed sites are warranted.

At the same time, there are increasing pressures to protect human infrastructure in the Chignecto Isthmus from impacts of climate change. In January 2020, the Province of NB sought professional assistance to explore climate mitigation solutions for the transportation corridor [75]. An engineering firm is leading, with the Provinces of NB and NS and the federal government, a 700,000 CAD feasibility study, with the aim to design engineering adaptations that are resilient to climate change and protect the trade corridor by preserving roads, dikes and infrastructure [76]. A previous cost–benefit analysis of adaptation measures to mitigate the impacts of sea-level rise and storm surges included scenarios of reinforcing and raising dikes and barricades, building new dykes further inland, and relocating and re-routing current transportation routes [77]. The need to 'engineer' new 'solutions' provides a potential opportunity to infuse an ecological lens into the mix, such as by considering opportunities for maintaining wildlife connectivity. It is imperative to identify and accommodate critical areas of ecological significance, especially if there is the need to relocate infrastructure and mitigations that could impact wildlife, positively or negatively. Critical areas should include pathways that are important to wildlife, as the Isthmus plays an essential role in not only trade and transportation but wildlife connectivity between the provinces. Successful implementation of any such conservation solution or initiative, however, will require political support, including engagement and buy-in by local communities.

1.2. Conservation Planning and Local Knowledge

Over the past 20 years, there has been a shift in the way science has been used in conservation planning [24,25], recognizing the importance of considering social factors along with ecological ones [78]. The social and natural sciences are now seen as complementary, with the challenges now being how to bring them together without privileging one over the other and how to infuse them into conservation planning and practice [34,78,79]. As such, conservation planning has begun to draw on transdisciplinary approaches from human geography, social-ecological systems, PPGIS and others. Such concepts are

[3] The 15 focal species in NCC's Chignecto Isthmus connectivity analysis are moose, black bear, red fox, bobcat, snowshoe hare, fisher, northern flying squirrel, Barred Owl, Northern Goshawk, Pileated Woodpecker, Yellow Warbler, Brown Creeper, Ruffed Grouse, Boreal Chickadee and Blackburnian Warbler [48].

commonly applied in mapping and modeling studies of human-environment relationships, such as spatial patterns of land use and land cover [79]. Core principals are that conservation efforts ought to be systems oriented and cognizant of dynamic social-ecological interconnections between humans, culture, wildlife and ecosystems that are influenced by broad scale political, economic and biogeochemical conditions [28,34,80–82]. Ideally, both society's and science's perceptions of conservation issues should be collaboratively considered [28,83–85]. As such, conservation planning is challenged to apply innovative models through engagement of diverse communities, facilitate co-learning about conservation and derive solutions through the co-development of knowledge and practice [79,86,87]. Accordingly, there is a growing interest in engaging local people and diverse forms of knowledge to help interpret, frame, verify[4] and otherwise complement knowledge gained through formal-natural-science methods, including addressing its gaps and limitations [88–90].

There is ongoing debate about the use of the term 'integration', referring to the inclusion of both local knowledge and scientific knowledge within environmental management [91], with important relevance for conservation planning. While the value of including local knowledge has been acknowledged, studies focused on knowledge 'integration' can struggle with considering which forms of knowledge are being privileged, sometime favouring scientific over local knowledge [56]. Differing epistemological beliefs about what and how things are known may constrain researchers' abilities to engage fairly with the process of integration [56,91]. Challenges may also arise with distrust among researchers and local knowledge holders and through institutional power dynamics and privilege [55,56]. Such issues are inherent in attempts to 'validate' local or traditional knowledge with science. The desire to validate can derogate the legitimacy of local tacit and experiential knowledge, especially when the forms of knowledge and ways of knowing derive from fundamentally different epistemological systems, such as with traditional and scientific knowledge [92,93]. To acknowledge and address these challenges and barriers, conservation planning approaches are needed that facilitate the co-production of knowledge, engage more inclusive knowledge systems, and represent different forms of knowledge.

Connectivity conservation is a subset of conservation planning in which inclusive and collaborative efforts are particularly necessary, as it aims to address the conservation of public and private lands and Indigenous territories between protected areas [5,94–96]. The broader landscape is often highly contested space, with multiple demands and claims over a limited land base. Nonetheless, it is important to maintain and restore connectivity across human-dominated landscapes because habitat fragmentation is a key cause of wildlife decline [5]. Linear human developments such as roads are increasingly recognized as predominant impediments to habitat connectivity [97–101]. Yet, there are few studies that address wildlife and linear development patterns at broad-regional scales, despites calls for such attention [102–105]. There is also growing recognition that, particularly in coastal areas, responses to sea-level rise will require adaptation measures such as relocations of linear and other infrastructure from low-lying areas to higher elevations, with potential risks of further incursions into wildlife habitat and disruptions to wildlife movement patterns with implications for population persistence. In order to protect and maintain ecological connectivity, appropriate conservation planning strategies must be developed at local, regional, and national scales underpinned by an understanding of species distribution, barriers to movement and threats to their persistence, consideration of complex social-ecological contexts, and broad support of local people.

Given the challenges inherent to considering multiple, diverse layers of natural and social information and landscape spatial patterns in conservation planning, computer-based GIS are often

[4] Terms such as 'validate' and 'verify' can be contentious when talking about bringing together formal science and local tacit knowledge. Such words can imply a privileging of one form of knowledge over the other in terms of veracity, value, etc. What we mean by 'verify' is a form of 'ground truthing' based on local experiential and tacit knowledge, to identify areas of agreement and disagreement, which may then be further explored. In light of such concerns, we at times use 'verify' and at others 'ground truth', although we have not done ground checks in the field.

used to facilitate data compilation and analyses [80,106]. The mapped outputs of such analyses are powerful tools for communication and decision support, yet they are strongly influenced by the choices of input data and the rules around interpreting it, such as in setting goals and targets for conservation modelling. These technologies, data sets and decisions about objectives and rule setting have been dominated by formal-natural sciences. To make these systems more inclusive and transparent, PPGIS approaches have been developed [107]. While helping to democratize the planning process and enrich the data, questions remain as to how best to reach consensus and how to accommodate and incorporate differences in knowledge and values [108]. Methodologies for representing differences and building consensus in participatory mapping are needed. This is especially important given that including local knowledge in planning and decision making is always troubled with questions of whose knowledge is included and privileged [56,91,92]. The idea of a homogenous community has been deeply critiqued in the literature and PPGIS methods provide an interesting model for engaging multiple viewpoints without assuming sameness in a local community [109]. Distinct from building consensus among diverse stakeholder groups, managers and planners, the question arises as to how to build consensus 'within' distinct groups, such as among local knowledge holders engaged in a participatory mapping exercise.

While the infusion of local perspectives in participatory mapping has expanded over the past two decades [90,110,111], there has been relatively little uptake in its application to wildlife connectivity planning. Local knowledge provides a key tool for understanding the complex social and ecological systems in which conservation planning operates and for which solutions are increasingly coming from models that are unconnected to local people and place. The Chignecto Isthmus provides a study area where conservation planning is not only imperative for maintaining local wildlife, but also for broader scale wildlife connectivity. Monitoring of wildlife movement, distribution and abundance is time consuming and costly and large gaps in knowledge for conservation planning remain. Local knowledge provides a means to help address these data gaps and limitations, while engaging local people and contributing to a more inclusive knowledge system. Accordingly, this study focuses on generating local tacit knowledge to help identify areas important to wildlife connectivity at a regional scale through an exploratory analysis using a participatory mapping approach. We focus on the local experiential knowledge of wildlife species, locations and movement pathways and landscape features that present opportunities or barriers to then. We address how such local knowledge enriches existing data and models, not simply through gap filling but by offering a deep understanding of interrelating factors that influence wildlife patterns within the region. We explore means of spatially delineating 'fuzzy' boundaries, representing diverse perspectives and generating consensus in local knowledge. The mapped outputs may be used to supplement and validate formal-scientific data and models relevant to delineating areas for wildlife connectivity and adapting human infrastructural developments in the region. Through the process, we seek to enhance local participants' confidence in their knowledge and foster their support and future engagement in local conservation and other planning initiatives in the region, while contributing to more inclusive knowledge systems. We propose that the generation and engagement of local experiential knowledge can enhance understanding and support for wildlife connectivity planning. Our study provides broad intellectual contributions around validating or ground truthing modeling studies, where local knowledge provides a key tool for understanding knowledge about complex social-ecological systems that is increasingly coming from models that are unconnected to place and local people. As such, our approach and findings contribute to the scholarship and practice of connectivity conservation planning and PPGIS.

2. Materials and Methods

We used a mixed-methods approach engaging qualitative and quantitative social and natural sciences to create a spatial data set of wildlife connectivity patterns across the region. A combination of participatory one-on-one mapping interviews and two focus-group mapping workshops elicited local, tacit knowledge. Individual participants' maps were digitised and compiled into a computer-based-mapping system. Spatial analyses were conducted to capture themes, similarities, and differences among the compiled mapped data from the individual interviews and group workshops. Maps were prepared to overlay local knowledge maps with NCC's modeled wildlife habitat and movement pathways for discussion purposes. Explanatory texts from the participants' interviews and workshop discussions were used to enrich, support, and interpret the participants' mapped data. The methodological details associated with each step are provided in the following sections.

2.1. Participatory Mapping Interviews

We conducted participatory mapping interviews [112–115] with local knowledge holders to gather textual and spatial data representing their knowledge of wildlife species, population locations, habitat and movement patterns in the Chignecto Isthmus. Recruitment purposefully targeted people with long-term, lived experience on the land such as subsistence harvesters, woodlot owners, farmers, naturalists and recreational users of the land and wildlife. We conducted initial recruitment through local and provincial hunting, trapping, fishing, and naturalist groups and in collaboration with NCC, who has preestablished relationships with individuals and organizations in the region. Supplemental 'chain-referral' or 'snowball' sampling [116,117] was then employed, wherein interviewees were asked to suggest other potential participants knowledgeable of the land and wildlife. Recruitment ceased when no new referrals were forthcoming. Efforts were made to represent both provinces, aiming for 15–20 participants in each, and a breadth of experience and backgrounds. The participant sample was designed to reach the most knowledgeable local people while achieving a reasonable complement (n = 30–40) in terms of pragmatic logistical constraints such as time and funding, balanced against obtaining a range of viewpoints from knowledgeable individuals. The intent was to explore the deep experiential knowledge within this sub-section of the population, rather than be generalizable to the broader public. Preliminary screening ensured participants were knowledgeable of the region, identifying the nature of their relationship to the land and the time they had spent there. For the purpose of our study, "the local knowledge of an individual is unrelated to any institutional affiliation and is the product of both the individual's cultural background and of a lifetime of interaction with his or her surroundings" [90] (p. 158). Knowledge sought from participants was to be based on the livelihoods and pastimes of the individuals and gained through "extensive observation" [118] (p. 1270) of the land and wildlife across the region over time. While it not possible to separate an individual's tacit knowledge gained through their time spent on the land from their training within organizations and institutions, we asked participants to share their personal and experiential views and information, rather than represent the perspectives or provide formal data gleaned from their employers or member organizations.

A total of 34 local people with tacit knowledge of wildlife in the region participated in one-on-one participatory mapping interviews. Often participants did not identify as one specific type of knowledge holder, but rather had experience through a variety of work and recreational activities. Participants were engaged in hunting and trapping for sport, sustenance and income; farming and agriculture; forestry both at industrial and private woodlot scales; wildlife rehabilitation and photography; as naturalists and trail groomers; and in other recreational uses such as fishing, canoeing, hiking, birding, snowmobiling, biking and cross-country skiing. Many participants have spent their lifetimes growing up and working in different capacities in the Chignecto Isthmus, with 11 participants from NS, 18 from NB and five who had lived on both sides of the border. While some participants are not originally from the region, their connection to the land is strong through their work and long-term residence in the area. The shortest time a participant has lived in the region is 10 years, with a large part of that involved being out on the land. We did not seek other demographic data from our participants as we did not intend to stratify our sample into sub-groups. Since we intentionally targeted recruitment toward people with longer histories of time and relevant experience in the region, participants tended to be ~40 years and older. Due to their long-term, deep engagement and familiarity with the region, we were able to collect a wide temporal range of data based on their knowledge from the past to the present. Although we made significant efforts to increase recruitment of younger adults, women and Mi'kmaw individuals, these were largely unsuccessful, with only five women and none who identified as Indigenous participating in interviews. Particularly, we recognize that the inclusion of Mi'kmaw individuals is important, as the Chignecto Isthmus is situated within Mi'kma'ki, their ancestral and unceded territory. Unfortunately, the time frame of the study was insufficient to develop the relationships of trust and Indigenous methodologies necessary to meaningfully engage Mi'kmaw individuals in culturally appropriate ways. We acknowledge this limitation in our discussion (see Section 4.1). Inclusion of the Mi'Kmaq in dialogues and decision making within their territory is important, as are the insights likely to emerge, and as such their engagement in co-production of knowledge should be sought in future efforts (see Section 4.2).

We conducted semi-structured, face-to-face interviews in June-August 2019 in both NS and NB, at locations convenient for participants, such as at their farm, hunting cabin, or a coffee shop in a nearby town. Interviews of 1–2-h duration explored how participants view and value wildlife and wildlife habitat within the region. Interview-guide topics centered around several key questions used as prompts as they arose in natural conversations (Supplementary Materials S1). Questions were not necessarily all asked or addressed in any specific order as interviews were conversational and participant driven, based on their own experiential knowledge of the region. The first portion of the interview established context and built rapport to learn more about where participants live, how they came to live in the area, where they have spent their time in the region and the activities through which they have experienced the land. The second portion focused on core topics involving wildlife species, population distributions, movement patterns, habitat, conservation, roadkill hotspots, threats, and mitigation.

We solicited spatial data during the interviews through a participatory-mapping component. Participants selected base maps from among five options at three scales (1:30,000, 1:60,000, 1:170,000) upon which to convey their knowledge of the region. The base maps were centered around the NS-NB border and showed major highways and secondary roads, towns, protected and conserved areas, lakes and rivers, forest cover and elevation contours, all sourced from 1:50,000 Topographic Data of Canada [119]. Land cover was classified simply as forest or non-forest where the forest cover layer comprises a single land cover category which does not classify dominant species or forest type [119]. Often, forest cover served to orient participants to specific areas in the region such as the location of a pipeline right of way (i.e., a distinct linear feature of non-forest) and frequent occurrences of wildlife road crossings (i.e., adjacent known patches of forest cover on both sides of a highway). Elevation contours were often used to identify areas of higher elevation around Hall's Hill and Uniacke Hill associated with known movements of terrestrial wildlife. Elevation contours were also useful for participants to orient themselves within the two main watersheds in the region and to identify two distinctive ridgelines in the region that were used as landmarks for recording wildlife observations. After the first few interviews, significant local landmarks emerged as identified by participants and were often used as points of reference for orienting and locating spatial data; these landmarks were added to the base maps. Key landmarks include the Old Ship Railway, a historical ship-railway route which is now used as a multi-use trail connecting the Bay of Fundy to the Northumberland Strait running from Tidnish to Fort Lawrence, and the Canadian Broadcasting Corporation (CBC) radio towers located in the Tantramar Marsh near Sackville, NB, which were distinctive landmarks at the border region for decades but have since been demolished.

Participants chose the map(s) on which they felt most comfortable identifying their key areas and observations, with the option to use multiple maps at various scales. Paper maps provide an integral elicitation and engagement tool and a means of physically recording participants' responses in a spatial way. Participants were encouraged to draw directly on the maps, indicating any insights and tacit knowledge pertaining to wildlife, such as wildlife presence, absence and movements, particularly around roads, areas of concern for conservation, features that represent barriers to or heightened opportunities for wildlife movement, key areas used for their livelihood or recreational activities and their perception or the spatial extent of the Chignecto Isthmus as a region.

Individually mapped data were scanned and georeferenced to align with base map coordinates within a Geographical Information System (ArcGIS). The maps were then digitized to identify specific species' presence, movement pathways and barriers to movement using layers of points, polylines, and polygons. The individual maps were compiled and organized to form a thematic series of maps representing participants' landscape-based and experience-based knowledge of wildlife presence and pathways in the region. These were combined and overlaid to form group-consolidated thematic maps providing a composite landscape-scale perspective of wildlife presence and pathways in the region. Following the proposed methods outlined by McCall [115] for representing local spatial knowledge through dynamic mapping, composite areas were shown as multi-layered zones with fuzzy boundaries in recognition that individually delineated boundaries were not identical to each other. Local spatial knowledge often includes descriptive spatial terms and fuzzy boundaries which are not always perceived by participants as the same place or as existing in isolation [115]. There are also multiple levels of detail that are not single occurrences of location but rather represent temporal and spatial ranges, such as those used for hunting and trapping, and seasonal wildlife usage. The need for precision in participatory GIS can change in accordance with the intended output and goals of the research. As outlined by McCall [115], there is a need for less precision and lower resolution to represent various levels of certainty and confidence in the data. Such flexibility is appropriate in PPGIS applications aimed at eliciting and transferring generational knowledge for analysis of conflict or consensus and management applications [115] such as in our study.

2.2. Participatory Mapping Workshops

Subsequent to the individual map-interview phase of our research, we held two sequential, half-day mapping workshops near the border in Aulac, NB, in January and February 2020. The aim was to review and refine the map series derived from the interviews. We invited a subset of 20 individuals from among the 34 interview participants, selected on the basis of their demonstrated, strong experiential knowledge of the land and wildlife in the region and high regard as such by those in the larger group. Eight of these individuals participated in the first workshop, in which we sought to verify the consistency and accuracy of our interpretations and compilations of the individual data. Spatial data were presented and discussed as a series of thematic consolidated maps of wildlife habitat, movement pathways and associated threats and barriers. The second workshop brought together the same group of participants with an additional two who were unavailable for the first workshop but were identified by others as important to include. Workshop participants continued to represent a mix of diverse roles and knowledge of the region including hunters and trappers, farmers, loggers, birders, wildlife rehabilitation workers, wildlife photographers, active members of the Chignecto Naturalist Club and conservationists. This active engagement across various livelihoods and lifeways provided the opportunity for a mix of diverse perspectives and expertise and allowed for strong consensus building across experiential domains to develop a robust data set of spatially mapped, local tacit knowledge.

Workshop participants were asked to comment on the consolidated maps and whether or not they thought they accurately and/or completely represented their knowledge of (i) areas of wildlife presence, habitat and movement pathways and (ii) areas that represent heightened opportunities or barriers to wildlife passage, such as landscape features or changes. They were encouraged to note areas of similarities and differences in the maps and factors such as level of confidence, agreement/consensus and rationale. The workshop facilitated the pooling of participants' knowledge and collective markings directly on the maps through roundtable breakout groups, where refinements were noted, such as additional or missing data and spatial revisions. Large printed maps were provided of the compiled, thematic spatial data. Participants were broken into two smaller groups to assess each map sequentially and provide opportunity to comment and draw on the maps, working through any areas of disagreement or uncertainty. Open focus-group discussions at the start and end of each workshop facilitated the sharing of participant's views, thoughts, and opinions on the mapped data, expanding upon conversations and topics that had emerged.

After consensus was reached at workshop 1 on refinements to the initial consolidated thematic maps, the maps were updated to reflect the received inputs. In preparation for workshop 2, the outputs from NCC's wildlife-movement-pathway model [48] also overlaid with the local knowledge holders' consensus maps to develop a new series of thematic maps. Maps of wildlife roadkill hotspots identified by Barnes et al. [49,50] were also presented for comparison. The resultant composite maps reflected themes based on species distribution, movement patterns and wildlife-road interactions derived from both local-tacit knowledge and formal-science models, privileging neither.

In the second participatory mapping workshop held with the same subset of participants, the composite maps were reviewed for accuracy and completeness and to explore whether and why there may be similarities and differences in the results derived from their knowledge and those generated from the two formal-science data sources: (i) NCC's model outputs of high-probability wildlife movement pathways derived from habitat-suitability and least-cost-path analyses for the focal species; and (ii) roadkill hotspots statistically derived from roadside survey data in the region [49,50]. Any differences between their tacit representations and the models were identified and discussed. Discussions also provided an opportunity to identify missing information in regard to other areas of habitat, wildlife movement or pathways and roadkill evidence. Questions explored whether they perceived problems with the model outputs; whether we had interpreted their feedback correctly or if further refinements were required in the maps; and why there may be differences between the model outputs and among their own knowledge of the land and wildlife. We also queried the most important patterns revealed through the maps, such as critical areas for supporting wildlife species and for addressing key threats to wildlife, and asked which species, if any, warrant heightened conservation attention.

After the second workshop, maps were refined based on participant feedback to create a series of final, local-consensus maps. Participants' input and remaining similarities and differences between local-consensus and formal-science-derived maps were thematically and spatially analyzed. Points raised by the participants during the second workshop were used to understand patterns that emerged in the local data and how they compared to the modelled data.

3. Results

3.1. Predominant Species and Threats

During the interviews, participants were first encouraged to speak freely about their knowledge of wildlife and wildlife movement in the region and were later asked about the species considered in NCC's modeling (see footnote 4). Species that featured prominently were closely tied to the livelihoods or relationships participants held with the land. These were predominantly large mammals, including moose, white-tailed deer and black bear, and other furbearing species that were hunted and trapped, including beaver, otter, mink, muskrat, coyote, hare and fisher. Others were porcupine, various bird species, including waterfowl, songbirds and birds of prey, along with fish, primarily gaspereau. Often these lesser-mentioned species were talked about more generally across the expanse of the region or as species affected by barriers, such as roads, but were not considered of conservation concern. A common theme was the general decline in species abundance across the region over the past few decades. As noted by a local forest ecologist, biologist and birder, "essentially every animal that belongs in this ecosystem is still there, although in depleted numbers, from predators to songbirds" (P27) [5,6].

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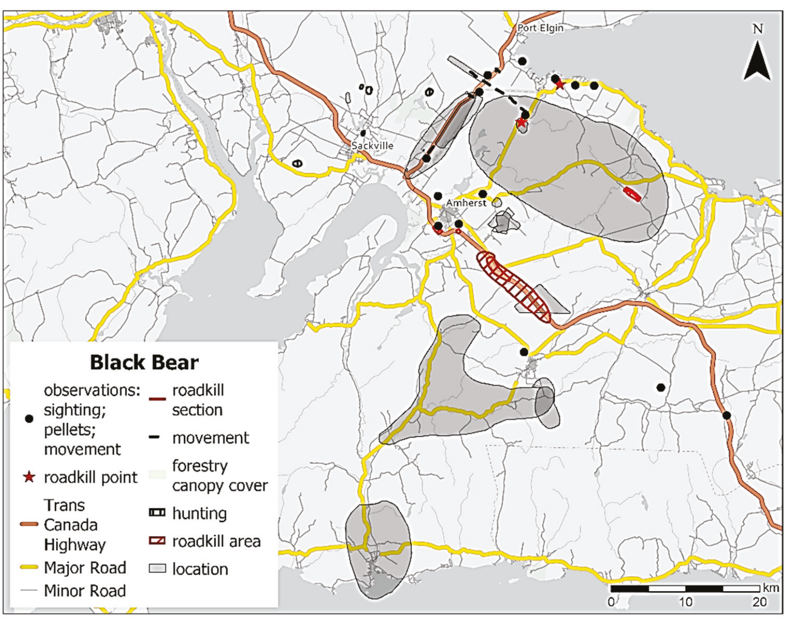
[5] We assume that by 'essentially' the participant meant 'almost', as wolf, eastern cougar, woodland caribou and other historically present species have been extirpated over the past few centuries since Euro-American settlement.

[6] Participant numbers (e.g., P27, P22) are used in reporting our results to de-identify individuals, consistent with our approved research ethics procedure for confidentially attributing paraphrases and quotes.

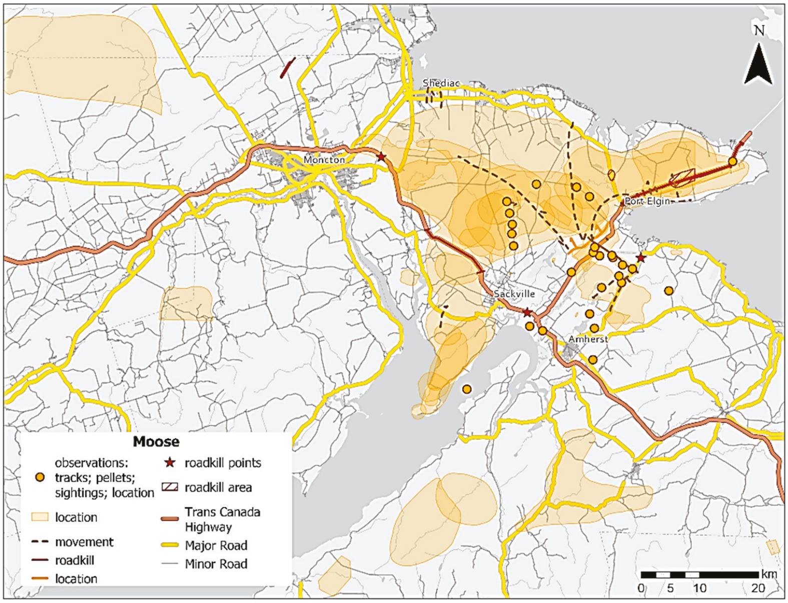
Of the species modelled by the NCC, participants elaborated only on four, namely moose, black bear, hare and fisher, and showed considerable knowledge of habitat, movement pathways and barriers for black bear and moose (Figure 2a,b). Bears were said to be numerous and increases in bear activity across the region were noted, especially in NS, and often associated with forestry practices and agriculture, both of which were considered to provide enhanced food sources for bear. While key areas of habitat and points of observation were mapped for bear (Figure 2a), the common response was that you could find black bear 'everywhere' and that the population was increasing: "years ago there was hardly a bear around, but now they're everywhere" (P25); and, "I mean, there's bears everywhere. More than people realize" (P15).

Moose were mapped very differently from bears by participants (Figure 2b). They noted many factors impacting the locations and movements of moose across the region, including competing deer populations and the associated brain worm, climate change, heavy tick loads, poaching and habitat fragmentation, consistent with published explanations (*P. tenuis* is a parasitic brain worm that deer can live with but is fatal to moose; for a summary, see [8]). Many participants commented on the abundance of moose in NB and the dwindling population that persists in NS, with limited explanations as to why moose are not as abundant there. An avid hunter, trapper and past wildlife technician noted that moose "wander from the NB side, there's no doubt about it, but they don't seem to wander very far. Once they hit the Cobequid, along here, they just don't seem to migrate much further than that" (P22). Participants recognized that there appears to be abundant moose habitat within NS but did not know why moose do not prefer that habitat, stating "I can't really draw a conclusion if they will [move into NS], because if they're not using it today, what's going to make them use it tomorrow" (P18), and "I often go into areas and scratch my head, 'why aren't there moose here?' The feed is there. The water is there. Everything is there for a moose, but there's no moose in the area" (P10).



(**a**)

Figure 2. *Cont.*



(**b**)

Figure 2. Observed and known locations, movement pathways and roadkill areas for (**a**) black bear and (**b**) moose collected and compiled from individual participatory mapping data collected in July and August 2019. Road data collected from Government of NS Geographic Data Directory [120] and GeoNB Open Data Licence catalogue [121].

There was speculation among participants as to why moose do not seem to persist in NS yet remain abundant in NB. Poaching of moose in NS was raised as a concern by hunter, fisher and wildlife-technician participants (e.g., P1, 7, 18). Because native moose (*Alces alces* Americana) are officially listed as provincially endangered[7], it is illegal to hunt them in mainland NS. Hunting for moose is allowed in NB, with limiting regulations managed by a lottery draw for a licence to hunt them each season and a bag limit of one [123]. However, illegal hunting was mentioned as a threat to moose moving across or on the NS side of the border: "Yeah, all over this area, here, . . . poaching goes on, . . . as you get back in the woods. I played golf with this guy three years ago and he said, 'We poach one every year'!" (P7).

Another explanation that participants provided for relatively low numbers of moose in NS is increased temperatures impacting habitat selection, exacerbated by climate change. As a wildlife rehabilitation specialist noted, "they're [moose] starting to move further north, like up into the highlands, because of the temperature changes where there's enough variance that you can still get colder, snowier areas. The moose aren't going to like hotter areas" (P29). This same pattern was observed by hunters, trappers and lifetime farmers who commented on temperature being a large factor and noted that populations of moose tend to persist further north in NB where it is cooler. Although information specific to the study area is not available to substantiate temperature trends, regional temperatures in the Atlantic provinces are projected to increase by 3–4 °C over the next 80 years [124]; and, annual

7 The native moose species (*A. alces* Americana) in NS was officially listed as provincially endangered in 2003 and remains only in small localized groups distributed across the mainland portion of NS, where hunting of this species has been prohibited since 1981; non-native moose introduced from Alberta in 1948–49 proliferate in Cape Breton Island, NS, where hunting of this introduced species is allowed (i.e., in Victoria County and Inverness County) [8,122]

average temperatures in NS have increased by 0.5 °C over the past century (1895–1998) [122]. Due to latitudinal and ocean influences, temperature changes in the Atlantic region are projected to be relatively moderate; however, even small changes are considered likely to have negative effects on populations of species at the limits of their thermal tolerances, which may be the case with moose in the Chignecto region and the rest of mainland NS [8,125]. Loss of mature forest cover adds to heat stress by limiting important opportunities for thermal regulation near forage in both summer and winter [8,125].

Some participants noted some relative changes in species abundance over many years, observed over generally extended temporal time frames spent on the land or hunting and trapping specific species. A common thread was consistency over time in the relatively high abundance of moose in NB as compared to NS. This trend remains evident in current distributions of moose shown in Figure 2b, where there is a dense amount of moose-related data recorded in NB versus smaller and more sparse pockets recorded in NS. This aligns with studies conducted in NS [8,122,126]. In the early 2000s it was estimated that there were approximately 1000 moose left in mainland NS, however recent aerial surveys conducted by T. Millette for NS Lands and Forestry has revealed very low numbers of moose, underlying concerns that there are likely far fewer left in the wild than previously thought [127].

Generally, when participants were asked to consider the focal species that the NCC used to model their wildlife corridor, they were reported as present and well dispersed across the Isthmus. Red fox and deer were described as more likely to be found around towns where they were safer from predators and near food sources. Deer and bear were said to be abundant around foraging areas such as farmers' fields and deer wintering areas. In terms of relative declines and increases in abundances, deer and hare were frequently mentioned, noting a cyclical nature based on predatory pressures, hard winters, and food availability rather than a steady trend over the years.

As for the factors affecting species, several key themes arose from the interviews. Participants identified several barriers to wildlife movement across the Chignecto Isthmus, indicating that while roads provide an obvious physical detriment to movement, factors such as highway speed and forest cover are likely compounding limiting factors. A resounding factor, deeply expressed and agreed throughout, was the relatively fast rate at which the landscape has been changing over the past 30, 10 and as recently as 5 years. Landscape changes were considered to have not only impacted the resilience and abundance of species, but also their ability to move freely between NS and NB. Participants remarked on the proliferation of roads, especially for forestry, which have also facilitated access into natural areas. They described an increase in extent and intensity of forestry activities, which have diminished old growth forests and converted habitat through frequent clear cutting and herbicide applications. Noticeable increases in road speed, traffic and tourism-related travel were also reported.

Though anecdotal and relative, these qualitative observations are consistent with landscape changes found in other studies. Human footprint (HF) scores in the Isthmus are higher than average across the larger Acadian/Northern Appalachian ecoregion, with HF scores of 21–30 (out of 100) assigned to most of the Isthmus and higher HF scores (41–60) in a broad swath dissecting the Isthmus; as such, the Chignecto Isthmus region is classified as 'high threat', defined as above average levels for the ecoregion [45,65]. In general, many wildlife species are negatively affected by roads (for overviews relevant to the study area see, [99,128]). Moose populations have been shown to be vulnerable to increased hunting pressure near roads, especially illegal hunting; and in NB, 92% of moose killed by hunters occurred within 1 km of forest roads [129]. Densities for roads and trails across the study region are 'moderate' to 'very high' [125,128] and higher than a suggested threshold (0.6 km/km^2) for sustaining mammal populations in naturally functioning landscapes [98]. Once road influence zones are taken into account, remnant forest patches are small and fragmented [46], average forest patch size across the region is <5.0 hectares [130]. Forestry practices, including clearcutting and herbicide spraying, have been criticized in NS (see [131] for an in-depth, independent review). Local species declines and the need for attention to such threats are documented in status reports and recovery plans for species at risk, provincially [e.g., 122, 126] and nationally [132,133], and reflected in the region's designation as one of Canada's Community-Nominated Priority Places for Species at Risk [59]. Accordingly, there is strong agreement between the participants' observations and the small number of potentially corroborating studies available, with the local descriptions infusing rich explanatory insights to the local socio-ecological context.

3.2. Patterns in Spatial Elicitation through Participatory Mapping

Based on predominant spatial data emerging from the participatory interview mapping, eight thematic maps were produced: (i) avian species presence, movement and roadkill; (ii) movement pathways of terrestrial wildlife; (iii) point locations, sections and areas of roadkill for terrestrial species; (iv–vii) location, movement and roadkill for black bear, moose, deer and other fur-bearing species; and (viii) overlapping moose and deer locations, movement patterns and observations (see Figures 2–4. These maps served as the basis of discussion for workshop 1. At the workshop, participants indicated that the locations of species and other mapped spatial forms of knowledge were reflective of what they had indicated in their individual interviews. Although there were instances where participants noted a gap, they later discovered that the data was included on a map other than the one they were examining at that moment. As a consequence, the participants neither added nor removed information and requested no refinements to the consolidated, thematic maps, although encouraged to do so. Despite being mapped separately by 34 individuals, participants noted a high degree of agreement in their spatial representations. Accordingly, participants considered group consensus to have been established for the mapped information presented regarding species locations, movement pathways and roadkill areas for moose, deer and black bear and a suite of furbearing mammals. Participants in the two consecutive workshops reported that they were able to see their knowledge, along with the compilation of data from other participants, reflected in the maps, and that this increased their confidence in their knowledge in terms of its veracity and spatial accuracy.

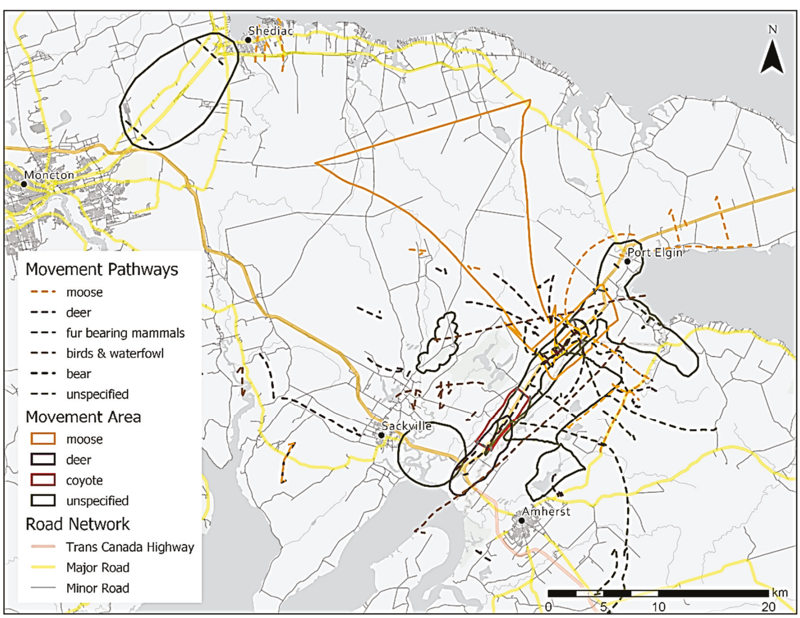


Figure 3. Movement pathways recorded and compiled from individual participatory mapping interviews (July and August 2019) identifying areas and pathways for terrestrial and avian species across the Chignecto Isthmus. Road data collected from Government of NS Geographic Data Directory [120] and GeoNB Open Data Licence catalogue [121].

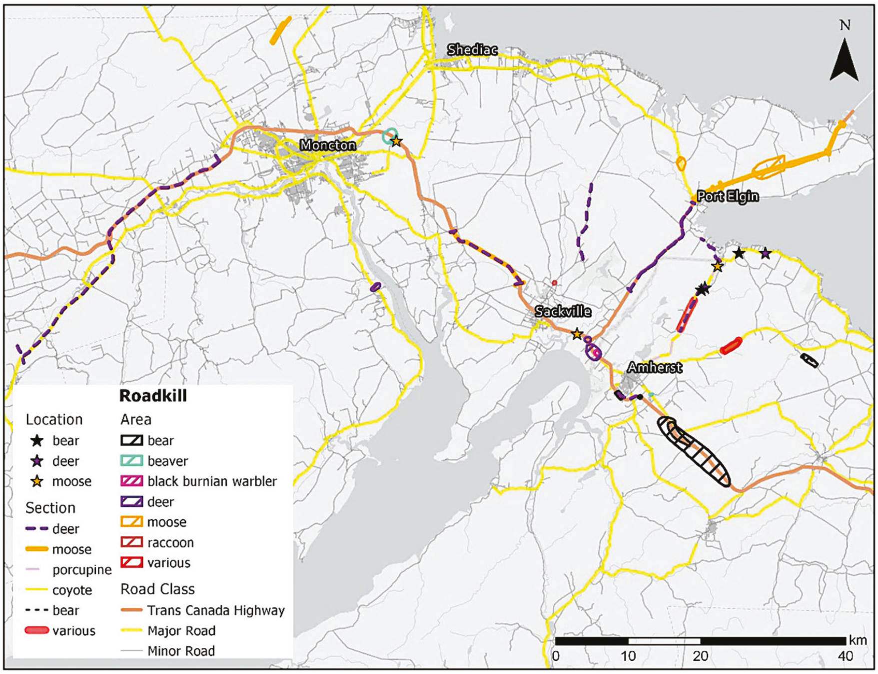


Figure 4. Points, lines and polygons of recorded areas of roadkill for various species, compiled from individual participatory mapping interviews, July and August 2019. Road data collected from Government of NS Geographic Data Directory [120] and GeoNB Open Data Licence catalogue [121].

That said, methods varied by which participants used base maps to record their knowledge. The spatial extent of their perceptions of the region, wildlife habitat, movement and barriers varied widely, drawing upon various map scales; 42 individual maps were produced at 1:30,000 (n = 11), 1:60,000 (n = 18) and 1:170,000 (n = 13). Some spoke broadly about general patterns and habitats across large geographical extents at a coarse level of detail, while others conveyed finely detailed knowledge in local vicinities, recording a total of 556 discrete points, lines, and polygons to record their knowledge of 47 different species. Their degrees of confidence varied across scales and background knowledge. Participants often demonstrated a desire to record a precise location, yet if they felt any uncertainty in spatial precision, they hesitated to place a mark on the map. In such cases, we encouraged them to make the mark according to their best judgment while representing uncertainty by a dashed line. Interestingly, when data were later compiled and collectively reviewed during the workshops, it was clear that there was much consensus in the various attributes that had been marked by individual participants, with uncertainty at the individual level overcome at the group level.

3.2.1. Wildlife Movement Pathways

A total of 129 discrete points, lines and polygons were drawn for 15 different species to indicate movement pathways (Figure 3) along with 41 records of roadkill sections (Figure 4) on key stretches of road, which also are indicative of wildlife movement within these areas. Pathways were merged in a single map layer to represent composite movements for all species (Figure 3). There were differences in ways individuals represented and thought about wildlife movement pathways. Some thought in terms of roads and how species were forced to move either across or along them. Their notations would often indicate an area or section of road where species frequently moved along (n = 12) or across (n = 34), at times representing places where species would readily cross due to factors such as higher elevation (n = 16) (versus low-lying wetlands and coastal marshes) or tree cover on either side of the road. At other times, these represented their observations of wildlife crossing the road, wildlife tracks or high numbers of incidences of roadkill in the area. Of note was a 1-km road section along Highway (Hwy) 16 between Aulac and Port Elgin, NB, which is the sole area along that highway with remnant tree cover on both sides. Wildlife, both live and roadkill, were reported to be frequently seen in this location. The surrounding landscape has been cleared for agriculture, housing, and forestry.

Many participants noted that wildlife often travelled along 'paths of least resistance'. The most frequently mentioned was a natural gas pipeline right of way, which runs North-West to South-East across the NS-NB border and Hwy 16 near Hall's Hill, NB. The pipeline is cleared of brush along its entire route but remains forested on either side and is relatively less frequently bisected by fences and devoid of other human developments as compared with other potential routes. Several participants have observed wildlife and other evidence of travel along this corridor, such as moose and black bear sightings, tracks, and scat. Similar use of human-made routes was noted for moose and black bear in areas where logging roads and other forestry activities have permeated forested regions. Participants often reported that wildlife may be seen travelling along logging roads as they move through an area and often recorded observations of species sightings or signs (tracks and scat) along these routes when mapping out their spatial knowledge. Some participants reflected that there may be increased observations in these areas due to increased human presence facilitated by road or trail access, consistent with observational or sampling bias often reported in field studies. As one trapper, hunter and fisher said, "I'd see tracks all over where the cuts (clear cuts and logging roads) are. The only reason I would see them there is because those are the places where I have access, where I can get to" (P4).

Others described wildlife movement in a broader context in terms of how species move throughout the region, particularly across the NS-NB border and between suitable areas of habitat for specific species (Figure 3). At this broader scale, it was also noted by several participants that the region between Halls Hill and Uniacke Hill along Hwy 16 is the highest point of elevation when crossing between the two provinces and provides a natural funnel where terrestrial wildlife are "streamlined" (P3) across the Isthmus. When describing how wildlife move between NB and NS, some participants drew an hourglass shape which captured suitable habitat on either side of the border for terrestrial wildlife but was constricted through a pinch point in the border region, along this area of higher elevation.

Temporal, daily and seasonal, movement pathways were also indicated, particularly for deer and migratory birds. Wintering areas and deer yards were often delineated, along with areas where deer would frequently graze in agricultural fields and near salt marshes, and spring and fall movement pathways in and out of wintering areas. These pathways often included areas along and across roads where high frequencies of vehicle-deer collisions and deer crossings were reported. Temporal movements were also recorded for migratory birds such as the American Black Duck and Common Eider. In contrast to most patterns, migratory birds were shown as moving across the Isthmus from the Northumberland Strait to the Bay of Fundy (Figure 3). Human changes to the landscape were noted as interfering with these daily and migratory flightpaths, acting as barriers to movement. A couple of participants who are hunters and also work in the conservation field identified power lines that stretch across pastures near the High Marsh Road just west of the NS-NB border that birds would strike on their daily flight paths at dusk and dawn. The powerlines were described as so frequently deadly that eagles have begun to perch and wait there to scavenge dead, stunned or injured prey (P8, P9). The wind turbines located between Sackville NB and Amherst NS were also stressed as a deterrent to movement for bird species and associated fencing as a barrier to other species (P13).

3.2.2. Threats to Wildlife Habitat and Movement

Roadkill in general was frequently mapped during the interviews (Figure 4), primarily for deer, moose and black bear. Moose was noted as a hazard to drivers and most frequently hit in NB on Hwy 16 between Port Elgin and the bridge to Prince Edward Island. This stretch of Hwy 16 is notorious for vehicle-wildlife collisions and was highlighted 16 times as a hotspot for moose crossings and roadkill. Several participants indicated the surrounding area as moose habitat, supporting a healthy moose population (Figure 2b). Deer movements were also marked along the same highway, but south of the moose hotspot between Port Elgin and Halls Hill (Figure 4). Deer roadkill hotspots were also noted along the Tyndal road east of Hwy 16 in NS and at the Aulac, NB interchange at the start of Hwy 16. Black bear roadkill locations were noted along the Tyndal Road in NS; near cottages in Tidnish, NS along the Northumberland Shore; and along the Trans-Canada Highway east of Amherst. The hotspot on the Trans-Canada Highway separates two large black bear habitat areas and populations identified by participants (Figure 2a).

Increasing human-wildlife conflicts [134], especially pertaining to moose, can result in varying societal attitudes and values [135]. In NB where many rural routes and highways pass through moose habitat, there is the potential of increased risk of moose-vehicle collisions which could cause damage to vehicles or have the potential to injure and kill both wildlife and humans. Individual and social characteristics can influence one's risk perception; the evaluation of the probability and consequences of an unwanted outcome is heightened by experiencing the effects of danger [136,137]. Risk perception can be amplified by a mixture of individual, social, and environmental factors combined with perceptions and attitudes influenced by testimonials of extreme events [138]. This may well be the case with participants in our study. Collision data from NB Department of Energy and Resource Development show 13 records of dead moose on NB Routes 15 and 16 from 2013–2018 [49], and in an eight-week period in May–June 2017, vehicle-moose collisions averaged one per week [139]. Related media and other attention may have fostered a heightened sensitivity to moose-road interactions among our participants, resulting in its prevalence in their reports; however, it is also the case that high rates of moose-vehicle incidents do occur in this area.

Forestry was another predominant emerging theme that was often discussed and sometimes mapped during the interviews. Except for providing improved forage habitat for black bears, forestry was often discussed with a high level of frustration and concern for the 'devastation' it causes, resulting in a continuously changing landscape across the Chignecto Isthmus. Although some participants have worked in the industry and privately log wood from their land, there was overwhelming consensus that industrial silvicultural practices have rapidly shifted the landscape and negatively impacted habitat quality and quantity in the region.

> We can go for a drive today and drive up in this area and see moose tracks, but does it represent or have any remnants of what it was like 35 or 40 years ago? Not even close, and it never will. That piece of ground will never be the same. Those things in itself, to me, are changes that are irreversible and are going to represent some sort of adversity to wildlife" [referring to swaths of land currently being used for industrial forestry] (P10).

Referred to as "death by a thousand cuts" (P27), the impacts of forestry across the region have "devastated diverse ecology" (P27). What was once a mature, mixed Acadian forest is now young plantations of jack pine and balsam fir, creating monocultures which have stripped away wintering areas for deer and feed for moose (P17, P18, P28). Participants criticized such practices, calling the push toward monoculture as 'borealization' due to the focus on specific softwood species, disrupting the balance in Acadian forests (P27, P28).

3.3. Comparison with Modeled Wildlife Movement Pathways and Roadkill Hotspots

Local, tacit knowledge maps were overlaid with NCC's high-probability wildlife movement pathways [48]. This resulted in four additional maps being created and discussed at Workshop 2. Two maps overlaid participatory mapping for moose and bear with outputs from NCC's population patch, breeding patch and least-cost-path models for these species (Figure 5a,b). Two other maps overlaid NCC's modelled wildlife movement pathway with participatory mapping of roadkill, habitat, and species occurrence observations (Figure 6) and movement patterns for all species (Figure 7).

Spatial similarities were evident when participants' mapped data were compared to NCC's modelled outputs for both moose and bear (Figure 5a,b). The existing protected areas used as 'patches' to be linked in NCC's pathway modelling were also identified by participants as habitat areas for several species, including moose and bear. NCC's modeled suitable habitat and breeding patches[8] were also similar to areas captured by participants' location, habitat, and movement pathway data. Nonetheless, the participants also noted other wildlife movement patterns lying outside of the high-probability movement pathway and other areas for species that were not modelled by NCC.

Participants had identified three major hotspots of roadkill across the NS-NB border that also fall within the NCC's modelled high-probability wildlife movement pathway (Figure 6). These three major roadkill hotspots were along Hwys 940 and 16 for deer and the Tyndal Road (Hwy 366) for deer, porcupine, bear and coyote. These three major roads run parallel to each other and transect areas identified by both participants and the modelled data as areas of wildlife movement and habitat. Deer presence and abundance was noted to be concentrated along the NS-NB border in the agricultural belt along Hwy 16 between Point de Bute and Baie Verte as well as in another pocket East of Hwy 940. Deer movement was reported as heavy between habitat patches alongside Hwy 16, with increased roadkill occurring during spring movements from wintering areas. Roadkill hotspots identified through roadside field surveys conducted in the region in 2018 [49,50] revealed overlap with road sections that intersect with NCC's modelled high-probability wildlife movement pathway. Some of these overlapping areas are also consistent with movement and roadkill observations indicated by participants including areas highlighted along Hwy 366 and Hwy 16 (Figure 6). Most of the species movements mapped by participants converge into a major pinch point across the border, as in NCC's model (Figure 7). There was group consensus that their compiled spatial data bore strong similarities to the modelled outputs, with no outliers or glaring differences to address between the two sources of information. NCC's modelled pathways aimed to optimize landscape conditions and minimize movement costs for the suite of species considered, including bear and moose, which participants also mapped. The similarity in patterns seems to suggest that the participants and the modellers have consistent understandings of the conditions favourable to these species and where they occur on the landscape. It likely also reflects the somewhat limited options for wildlife in making their way through the region.

The conversation transitioned to possible factors as to why the observed trends were occurring, particularly pertaining to the types of landscape changes impacting wildlife movement. Once again, forestry impacts dominated the conversation (i.e., excessive clearcutting, use of herbicides and logging roads). Participants reported increasing human access into once remote spaces through the development of access roads without restrictions on recreational users. Concerns were also raised about increased highway and road traffic in general, which they attributed in part to increased tourism. Little regard for speed limits by many drivers on some of the highways was noted, with participants recommending better outreach and mitigation in terms of signage to raise awareness of high vehicle-wildlife collision risk. Overall, landscape changes were considered the major driver of wildlife locations and movement patterns, most often as direct limiting factors and barriers, but also including indirect effects such as those related to increased disease and ticks.

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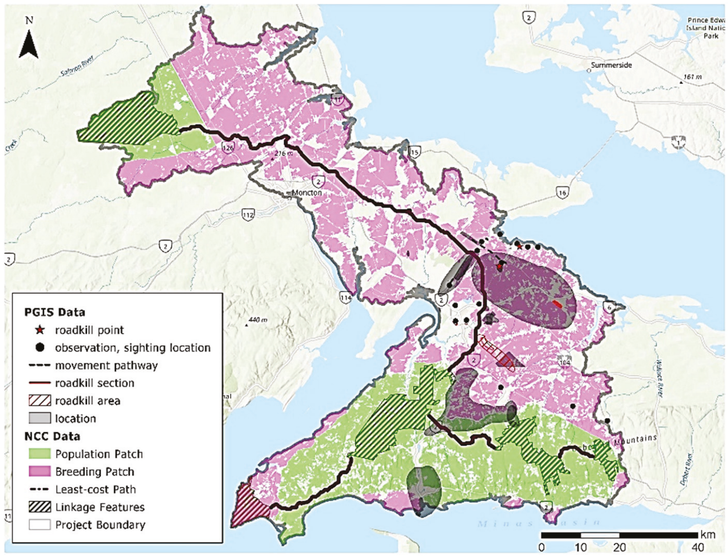
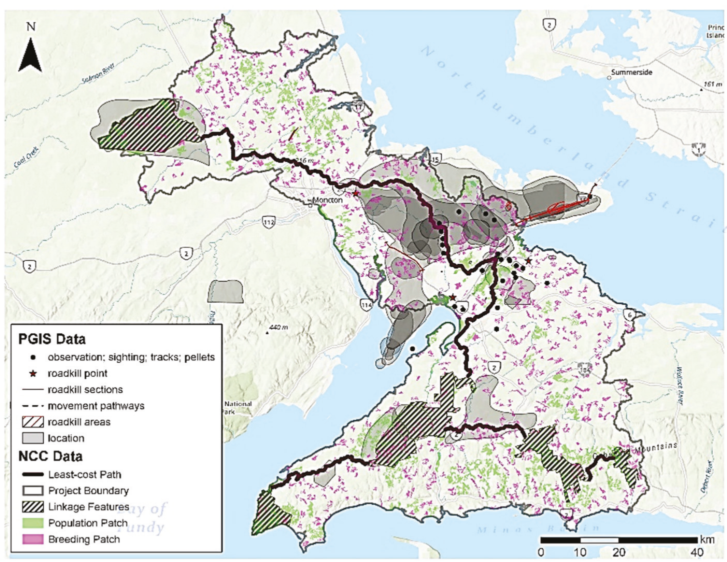
8 A population patch is the minimum area which can sustain a breeding pair for ten years and a breeding patch is the minimum area needed for a breeding pair [10,48].



(**a**)



(**b**)

Figure 5. NCC modelled connectivity data [48] overlaid with participatory GIS data for (**a**) black bear and (**b**) moose.

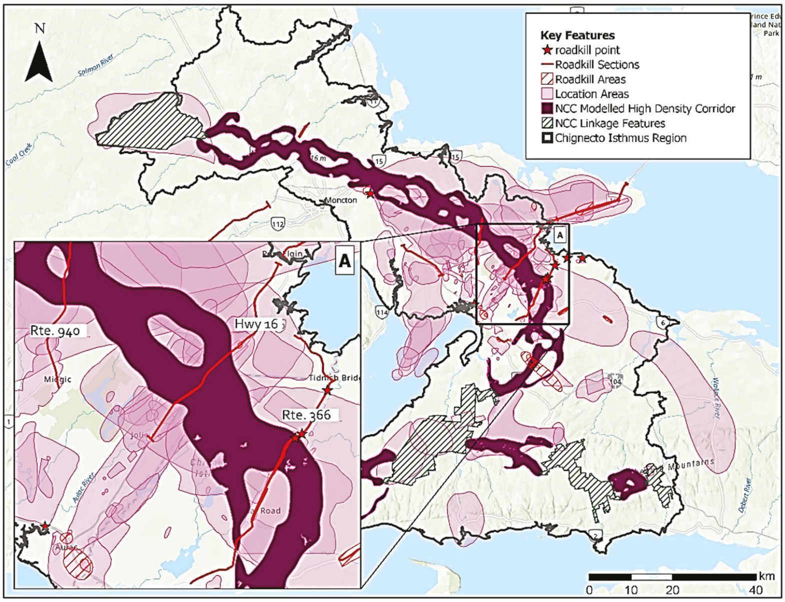


Figure 6. Species location and roadkill data for all species mapped and compiled from individual interviews (July and August 2019) overlaid with NCC's modelled high-probability wildlife movement pathway. Inset A highlights the 5-km wide pinch point along the NS-NB border identified in the NCC report [48].

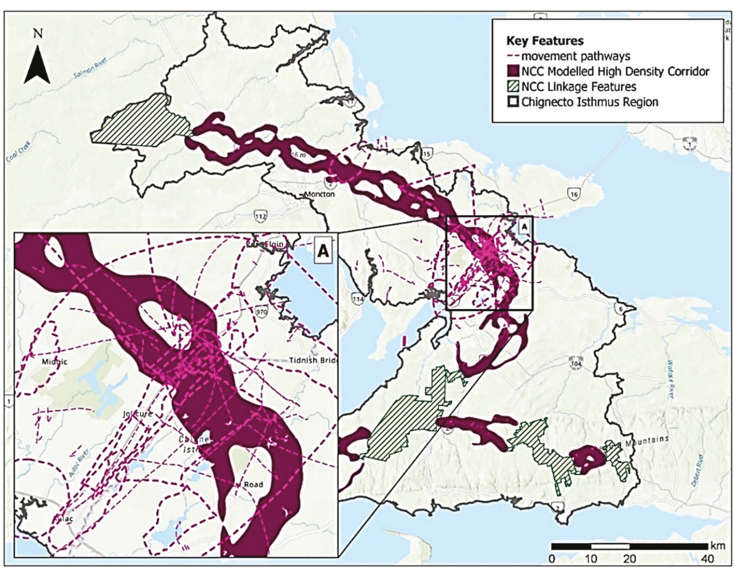


Figure 7. Movement pathway data for all species mapped and compiled from individual interviews (July and August 2019) overlaid with NCC's modelled high-probability wildlife movement pathway. Inset A highlights the 5-km wide pinch point along the NS-NB border identified by participants and in the NCC report [48].

3.4. Emergent Themes

3.4.1. Species of Conservation Concern

Participants agreed that moose are of conservation concern in NS, though plentiful in NB, and bear are increasing everywhere. They were relatively silent on conservation concern for other specific species, though concerned about general declines. Less clear, though a recurrent theme in conversations, was the question of whether deer are a nuisance or a species of conservation importance. A total of 126 points, lines and polygons were mapped during individual interviews to indicate habitat, locations, movement and roadkill for deer. While some viewed deer as pests who yard in their pastures and feed off their crops, in some cases these same participants also talked about deer in a positive light, indicating a complex relationship. Others simply enjoyed the sight of deer on their property and the opportunity to photograph them. Regardless, deer were talked about widely across all participants, who perceived the species as having the potential to shed light on key landscape changes and habitat fragmentation in the area. As noted by a local wildlife biologist, " ... not that deer are endangered. That is not to say they're not important ... It [deer] became a symbol of the corridor and the deer told that story. I don't know if you'd call it a keystone species, ... but I think it's a good indicator of why that corridor is important" (P15).

Participants also spoke to interactions between deer and moose, recognizing them as 'competing' species, and further, that they cannot inhabit the same space due to the detrimental impacts of a 'brain worm' on moose, which is a parasite (*P. tenuis*) carried by deer but deadly to moose (for a description, see [8]). They acknowledged that deer and moose have different habitat requirements and that landscape changes from agriculture, forestry, roads, and other activities have favoured deer and caused incursions into or overlaps with moose territory. At the same time, however, several noted that forestry activities also negatively impact deer, such as by interrupting their ability to move through areas or find suitable habitat and feed. As such, many saw deer as an indicator of the severity of the adverse impacts of landscape change and current forestry management practices for other, more sensitive species (P2, P4, P10, P20). These perceptions are consistent with those reported for these species more generally in NS and elsewhere (see, for example, [8,122,125,131,140]).

3.4.2. Species and Ecological Interrelationships

References to 'totality' and interconnections were prevalent among participants, who acknowledged that ecological systems are intricate and complex, and therefore you cannot focus on one component alone. For example, "So, in terms of the Isthmus—in terms of the ecological things you can think about—it is so important, eh? ... [J]ust the ... different species, and so on" (P3); and,

> [I]f you get anybody out and then try to have a connection—let them have a connection and see that—what connects to what, like that salamander connects to that—it doesn't matter how big a snake, ... anything. It all starts down here. You know, moss and the grass and then, you know, like, you gotta look at the whole picture (P27).

Participants recognized that wildlife, resource management systems and social interactions do not act independently and are intricately connected in the landscape. Such observations are reflective of systems thinking [141] and social-ecological systems frameworks [82,142], in which humans are intertwined with their environment. They situated the wildlife patterns within the complex social-ecological systems of the region, enriching existing data and models. During an interview, one participant, a wildlife rehabilitation technician, remarked, "[F]ew biologists will sit down and look at these issues in their totality, ... and that's what a project like this can do, is bring some clarity to those kinds of issues" (P29). Recognizing what the project can do—situating formal data within broader local tacit forms of knowledge to bring context, clarity and utility to decision making—is consistent with social-ecological-systems thinking, as is its representation through participatory mapping [81]. The value of the larger story and inclusive knowledge mobilization was acknowledged by participants, such as in stating that "the problem is we have a lot of environmental groups and activists out there that don't know what the story is . . . . So, what you're doing is telling the story" (P29).

Participants are not naïve about the social-ecological complexities of the situation, however, and noted challenges associated with the geographical extent of the Chignecto Isthmus, recognizing it encompasses multiple jurisdictions. Not only do ecosystems vary across the region, but so do institutional mandates, policies and social relations, creating problems for conservation governance, as pointed out by [143]. The scale of the challenge, especially when considering the role of human values and pragmatic factors inherent to decision making, is recognized by participants:

> I mean, it's a massive undertaking. It's so complex and distanced from the realities in nature. The arguments, like, should we stop spraying the forests to protect the deer, when in both instances they're both invasive issues? . . . We're no longer making choices of environmental stability; we're making choices of preferences over things that will make it (P29).

Adding to the complexity and urgency of the situation are uncertainties and measures needed to adapt to sea-level rise in this mostly low-lying, coastal region, both for wildlife and human infrastructure.

3.4.3. Sea-Level Rise

At the outset, our study assumed sea-level rise as a 'given', rather than as a research question. Accordingly, we did not ask participants specifically about the effects of sea-level rise. Regardless, several participants spoke about 'water' levels being an impediment to wildlife movements due to the large extent of wetlands and marshes and many streams and undulating coastline in the area. At least one participant fully recognized the effects of climate change and sea-level rise on movement pathways, associating it with the funneling effect on wildlife movement visible in Figure 3.

> And it's also the highest point of land on this size of the Isthmus. This is 350-foot elevation. And that's kind of important for looking at climate change and, you know, sea-level increases. Because, essentially, that elevation works like this: the elevations go from here, up through the top of this area here, which is the ridge—Jolicure. So, this is the highway and this is all, of course, relatively low compared to sea level, here. So, that kind of constitutes an important movement area, especially with the climate-change stuff happening (P27).

The ridge of higher elevation traversing the Isthmus was recognized as an important movement pathway for animals; participants recognized it as a safe passageway for animals who could not make their way through boggy or wet areas. Although not all participants linked it to sea-level rise, some went on to elaborate that part of the change on the Isthmus was associated with water levels and that these water levels affected not only human activity but also influenced animal movements and wildlife populations (influencing decline of some species while others became 'overpopulated'). The importance of the higher elevation area for movements was linked with seasonal effects on wet areas at lower elevations. Observations associated most wildlife movements with the higher ridge of elevation, while recognizing that wetter areas are used in the winter when the water and land is frozen, facilitating traverse over firmer terrain: " . . . [T]here's seasonal travel through this wet area, . . . Yeah, that would be of concern to some species. And once you get up to here [inland], I know there's a rise in elevation, there's more forest" (P12). Terrestrial ungulates (i.e., deer and moose) were reported to move through water on occasion but only in areas with adjacent habitat for landing and shelter. Participants widely noted the negative influences of forestry practices on cover habitat and associated this loss of habitat with influencing movement not only in the obvious ways (e.g., cutting out the forest, fragmenting the landscape) but also by no longer providing landing sites for possible movements through water, which may be further exacerbated by rising water levels in the region.

> There's definitely a seasonal component, actually, to the animal movement through here, in my opinion. I hear—people would tell me stories when I was doing the wind farm bird

> surveys, they were telling me that—this is a long time ago, probably in the 1960s—they had this moose going out to the, to the water and swimming over here to this peninsula. And they, they saw it . . . . But I don't think it's happening today (P12).

Other participants also recognized that changing water levels, particularly deeper levels, pose movement challenges for particular species (i.e., deer, bear, coyote, small mammals). Deeper water is recognized as a direct barrier to movement: "They [deer] could cross over [but] it's pretty deep water, so they're not likely going across here because of that barrier" (P8). Some observed increases in siltation and how this has influenced water levels in the region, especially pertaining to rivers and the Bay of Fundy. Participants noted fish populations and movements as being affected by receding waterlines and muddied shorelines. Impediments to deer movements along shorelines of rivers to cool off and to access food and water were also noted as of concern, with muddied shorelines affecting their ability to walk.

> Into the Bay of Fundy. This is a tremendous change here, over the last 4 or 5 years. . . . I go down there every year . . . [W]e used to walk the shore. Can't walk the shore anymore. There's a tremendous influx of silt, here, and the only open water now is over by the fields on this side . . . . On this side, this is all silted in. There's a tremendous amount of silt here, and that's 4, 5 years.... We suspect—my friend and I—that it's come down the Petitcodiac River after they opened the causeway. Yeah, and there was a lot of silt accumulated there . . . . [T]here's a tremendous, tremendous change there. That's probably going to be good for the shorebirds but it's just muck. You can't walk. It [deer] would be a fool to walk on it. But, uh, it's changed tremendously. (P1)

One participant spoke directly to the tenuous circumstance provided by the prevalence of water, recognizing the importance of the land bridge and associated infrastructure such as dykes to maintain terrestrial connections through the Isthmus, for both social and ecological reasons.

> Yeah, without it, NS would become an island . . . . [T]here are big parts of the Isthmus that are protected by dykes; and, uh, if the dykes fail or the dykes are breached, NS will very quickly run out of what they consume and buy in the store. The railway, the rail line, is right across the Isthmus and all the roads go across the Isthmus . . . . So, the only connection NS would have to the rest of us in the case of breached dykes would be by air! But also, there's some very interesting wetlands up through the Isthmus. The Chignecto, . . . the Missaguash River and all the complex of lakes and so on. The Isthmus is—it's an interesting canoe ride, to go from . . . Point de Bute . . . to Hall's Hill. (P5)

Observations like this recognize that sea-level rise presents an important current and future context for wildlife in the region. They are consistent with studies showing that sea levels are rising, storm surges and flood events are increasing, and the land is subsiding due to post glaciation isostatic rebound [64,69,71,73]. As such, the already narrow land connection between NS and the remainder of North America is predicted to be much narrower and in instances of storm surges potentially severed completely, as has occurred at times in the past. Although our intention was not to address this issue explicitly, participants raised it nonetheless. It supports the rationale for generating local insights on current wildlife populations, locations, and movement pathways within the context of larger social-ecological contexts, to provide more inclusive knowledge systems as baseline data for various conservation and other planning responses to sea-level rise in the region.

4. Discussion

Knowledge creation such as in this study is important for conservation planning, particularly for connectivity conservation across broad landscapes of complex social-ecological systems. The use of local tacit knowledge and participatory mapping represents a rich contribution towards a unique and robust dataset for conservation planning, research and decision making. Using participatory research combined with geospatial technologies has provided a method to generate local tacit knowledge and represent its spatial components within a GIS, serving to enrich and address current gaps and limitations in formal-natural-science data and models. The contributed local knowledge provides insights into historical and current distributions, abundance and status of wildlife populations in the region, similar to findings elsewhere in NS [144]. The engagement of knowledgeable community members was effective for eliciting and incorporating social and ecological knowledge. As observed by a renowned farmer and naturalist in the region during the second workshop, the dataset that we have been able to create through the collaboration of a diverse group of local knowledge holders is probably "the best available data" for illustrating trends and patterns for this region (P5). There was overwhelming support and buy-in for the participatory process we used to collaborate with local knowledge holders. The process incorporated a bottom-up approach, allowing for local participation, consensus building and the inclusion of local knowledge in the research.

The multi-directional learning relationships facilitated through our approach has led to increased awareness among participants about wildlife locations, populations, habitats and movements and threats to their persistence within the region. It has fostered and enhanced participants' interest and investment in conservation priorities across the Isthmus, providing a spatial focus for conserving key areas. Each participant created spatially referenced maps representing their lived, individual experience by employing overlay drawing onto topographic maps. Together they identified areas of combined experiences, noting strong, validating consensus, and thereby gaining confidence in their knowledge and its potential use in decision-making processes. Not only did the methods serve to elicit spatial data, but the maps served as a method to facilitate conservation knowledge sharing throughout the interviews and workshops. Participatory mapping has been commonly used to create 'sketch maps' for such purposes [145–147]. Our use of maps increased participant involvement during the interviews and workshops by providing an anchor for the dialogue to revolve around, furthering conversations, and stimulating memories through the process, as was found by Boschmann and Cubbon [145]. Participatory GIS methods such as ours have been identified as serving to democratize research and planning processes [148–151] and build consensus between stakeholders and land use managers [152,153]. Knowledge exchange plays a key role in conservation management by facilitating the social, environmental and economic impacts of research [29,30]. Not only is knowledge exchange critical to research during knowledge production and disseminating phases, but also during mobilization and translation for policy planning and decision making.

Inclusive knowledge systems and participatory mapping approaches such as those applied in this study can help to guide knowledge production and contribute to novel solutions to conservation challenges at the intersection of human and natural systems, consistent with findings in environmental management in general [28,83–85,154]. Significant work has been done in the realm of PPGIS to operationalize concepts that bring social-ecological systems into spatial mapping frameworks [81] and our study contributes to the field. Conservation planning approaches recognize the need to embrace local knowledge along with formal science data and models and to utilize participatory methods to not only increase local participation, but to improve the validity of knowledge across spatial scales [56]. A critical step to overcoming barriers to knowledge exchange is improving access to information to allow the co-production of knowledge for use by decision makers [29]. Research such as ours facilitates local knowledge exchange and provides the opportunity to contribute to evidence-based decision making in the region, responding within a timeline that can directly impact conservation planning, as urged by Lemieux, Groulx, Bocking, & Beechey [155].

Local engagement and findings generated through our study are timely for supporting on-going work of NCC and partners in the NS-NB Community-Nominated Priority Place [59], national efforts through the Pathway to Canada Target 1 Connectivity Working Group [156], the New England

Governors and Eastern Canadian Premiers' Resolution 40-3[9] Working Group [157] and the joint NS-NB and federal feasibility study on infrastructural adaptations to climate change [74] among others. Opportunities to put this information into the hands of the decision makers and have the voices of key local people from across the region included within the decision-making process have been heightened through the research. The relationship between knowledge and decision making has become increasingly important in scientific literature recognizing that there needs to be a convergence of disciplines in order to properly address complex environmental management problems [29]. Several contributions of the conservation social sciences, as outlined by Bennet et al. [79], are highlighted throughout our research including facilitated learning of conservation challenges and the innovation of novel models for conservation through engagement of local knowledge holders. Our methods represent a generative effort to better enable and improve conservation data, models and planning. Such applications are vital to guiding processes with the best available and robust set of information [79].

Collaborative approaches have been recommended to help improve evidence-based decision making and this extends to conservation planning. Often, however, there is a disconnect between research and planning for conservation. To address the disconnect, research should match the evidence needs for conservation priorities [155]. Our research comes at a timely manner to address current concerns in the Chignecto Isthmus region surrounding climate change, biodiversity conservation and infrastructural adaptations such as those to be addressed in the feasibility study on the transportation corridor. Sea-level rise poses a heightened predicament for the tenuous land bridge provided through the Isthmus to people and wildlife. This threat highlights the need to think proactively about conserving and restoring wildlife habitat connectivity through this restricted land base, especially in light of current projects aimed at 'engineering solutions' to safeguard and adapt highways and other human infrastructure. Adaptations are likely to entail in-land relocation of some infrastructure to higher elevations and raised levels of others in place, such as for roads and dykes to remain above water in flood events and coastal inundation scenarios. Such adaptations are likely to further fragment habitat and restrict wildlife movement. On the other hand, engineered solutions, if planned with wildlife in mind, may provide heightened opportunities to mitigate barrier effects and other threats that infrastructure such as roads, railways and wind farms currently pose to wildlife populations, habitat, and movements.

Many known social and ecological issues intersect in human-wildlife systems. Within the Chignecto landscape it is important to identify key wildlife features (populations, habitat and movement patterns) so that they may be considered in conservation planning and infrastructural adaptation studies. Local knowledge has been shown to improve understanding of species distributions and the factors that influence them, especially where recent shifts in these trends have occurred that are not yet captured in scientific data [88,144,158]. Such up-to-date knowledge is critical in situations when timely conservation planning is required, such as in response to imminent threats (e.g., sea-level rise), sudden opportunities (e.g., infrastructure adaptation studies) and urgent priorities such as recovery of endangered species (e.g., NS Mainland moose) [144,158]. In our study and others [158,159], local tacit knowledge has proven successful in identifying species distributions, movement patterns and influencing features and processes within the study region, offering valuable information for planning and management.

While scientific data and models can reveal high-probability wildlife movement pathways or barriers to movement through the region, underlying factors as to what may be attributing to these spatial patterns can sometimes be left to speculation. Model outputs such as maps are limited by the accuracy, relevance and completeness of the data and are influenced by the optimization rules that drive the analysis. Such model outputs are powerful tools, yet they largely remain out of context of the complex social-ecological systems. Local tacit knowledge can help to explain the underlying

[9] Resolution on Ecological Connectivity, Adaptation to Climate Change and Biodiversity Conservation [157].

'why' of certain phenomenon in a region: what external and acting factors are directly impacting wildlife movement pathways, pinch-point locations, roadkill hotspots and other phenomena? The local knowledge generated through this study therefore not only contributes to a more robust dataset but provides additional explanatory context for the patterns and changes. In the Chignecto Isthmus, for example, NCC's model detected land-cover types and roads based on the best available georeferenced spatial data and projected habitat suitability and potential wildlife movement pathways based on these data. Local participants enriched and complemented these data, expanding upon the impacts of landscape changes on wildlife, such as due to forestry practices, road access and traffic, water levels and siltation, as well as human activities such as poaching and wildlife interactions, such as between moose and deer. Local knowledge also effectively reflected accelerated changes. One participant (P29) noted and another (P30) concurred that since moving to the Chignecto Isthmus,

> [W]e have really been recognizing just how important this area is because of animal movement, thinking how much small little sections of land are responsible for having to move so much land-based animals, and when you think of the type of traffic that's happening here . . . , the amount of change that we've seen in terms of development and car usage, it's insane (P29).

Our findings provide cross-validated information for delineating priority wildlife habitat and connecting corridors within the Chignecto Isthmus. The process has fostered a diverse base of local champions for wildlife conservation. The next step is to disseminate and mobilize the findings to inform future decision making for conservation planning and land and resource management in the region for a long-term outcome of enhanced human-wildlife co-existence.

4.1. Limitations

Some limitations exist when using local knowledge in this study [108,115,160]. There were moments when participants were hesitant to draw on the base maps in fear that the spatial data they would provide wouldn't be in the exact location or area or that they may be remembering certain events wrong. The 'shifting baseline syndrome', a concept coined to explain knowledge extinction, occurs when the knowledge of the past is lost and the human perception of biological systems changes [90]. As such the analysis may be limited by the accuracy and reliability of shared information. On the other hand, there was strong group consensus among the local participants and good agreement with NCC's formal science model and roadkill hotspots identified through roadside surveys [49]. Insights from the Mi'kmaq, if participants had been recruited, may have provided longer term insights, and most certainly would have enriched the diversity and inclusiveness of the knowledge emerging from such co-production.

As the livelihoods of many of the participants are linked to their knowledge of the land for hunting, trapping, farming and logging, the data could be seen as inherently biased. This may lead certain participants to talk more about one species than another. For example, a wildlife photographer enjoyed photographing black bears and much of the data represented areas where black bears may be spotted. As such, there is potential over-representation of certain species due to factors also recognized by Loftus & Anthony [90]: personal preferences for certain species, strategic choices in locations of travel and the ease of seeing or noticing a species. When interpreting results for wildlife conservation planning, it is important to acknowledge that the species and habitats are directly connected to the livelihoods and pastimes of participants.

There are some limitations to using participatory methods to gather local spatial data [108,115,160]. Fuzzy boundaries are prevalent throughout the data and it was sometimes difficult to discern class boundaries between mapped spatial phenomenon. Inaccuracies in the spatial data collected may result in inaccurate definitions of classes and assignments of phenomena to a class, which may raise uncertainties about the precision of the data and ultimately impact decision making [160,161]. How participatory data represents participants' and researchers' interpretations of certainty and ambiguity is important: fuzzy data should not be misrepresented as being precise and accurate [160]. Spatial reality in PPGIS is always fuzzy, and the accuracy and precision of data collected through participatory mapping methods when drawing on maps will also be impacted by factors such as scale and resolution [115]. How to represent and interpret fuzziness was an important concept to frame for this study. A series of decision-making steps and guidelines were followed consistently when choosing how to classify points, lines, and polygons of mapped data into their categorical bins for mapping and representing spatial knowledge. Of course, this interpretation is unique to the classifier of data, using their best ability to accurately represent each participant's individual data.

In studies such as ours that engage relatively small numbers of participants in in-depth and qualitative explorations, questions may be raised about the representativeness of the sample and the generalizability and validity of the results. In our study, 34 participants with deep long-term experience of the region's land and wildlife shared their knowledge through interviews and participatory mapping. Eight of these individuals participated in two subsequent half-day mapping workshops. These participants likely represent a relatively large proportion of our target population—those with deep experiential knowledge of the land and wildlife—in this rural area: nearing the end of our recruitment phase, no additional referrals were emerging from our purposive, snowball sampling method. Near the end of the interviews, no new data were being contributed, which suggests that data saturation was reached. As a qualitative study, we were not aiming for statistically significant results or findings that may be stratified or generalized to the broader public. As such we are confident that the number of participants was sufficient to generate consensus-based insights about local knowledge on the subject. Although the participants represent a relatively small portion of the general public, their voices could potentially be disproportionately influential due to their knowledge base and locally recognized expertise. Now that they are more aware and confident in their insights as a consequence of participating in our research process, they are likely better positioned to influence local people and communities and related planning around wildlife, habitat and connectivity conservation in the region.

4.2. Future Research

While our study did not focus on assessing landscape changes due to climate change and related sea-level rise, some participants spoke to 'water' levels and temperature increases as potential reasons for wildlife declines and impediments to movements. Comprehensive studies assessing changes in water levels, temperatures and associated impacts on habitats and ecological corridors in the region do not exist. Similarly, impacts of forest clearcutting and forest roads on wildlife presence and movement pathways have not been assessed in the region, though many participants highlighted such relationships as a central concern, as did an independent review of forestry practices in NS [131]. Quantitative data on landscape changes, irrespective of cause, similarly are not readily available nor to our knowledge have they been previously assessed at this scale. It is certain that the clearing of forests and construction of roads and dykes over the 400 or so years since Euro-American settlement have dramatically affected landscapes in ways that are important to wildlife, yet these have not been quantified in the region. In a petition to the colonial government in 1853, however, Mi'kmaw leaders expressed their concern with widespread changes throughout Mi'kma'ki:

> The woods have been cut down; the moose and the caribou, the beaver and the bear, and all other animals, have in most places nearly disappeared . . . . So that it is now utterly impossible for us to Obtain a livelihood in the way our creator trained us
>
> ([162] (n.p.) as cited in [141] (p. 9), citing [163] (p. 111)).

To our knowledge, roads and dykes have not often or recently been 'relocated', per se, as a result of sea-level rise. Such complex inter-relationships and impacts warrant further analyses and some may well comprise portions of the 'engineering solutions' study currently being conducted in the region. In the meantime, our findings serve to enrich the socio-ecological baseline data (while pointing out important gaps) so that future planning for road, dykes or other infrastructural relocation may avoid ecologically important lands, specifically those that are important to wildlife connectivity.

More proximately, the next steps in our study aim to further develop inclusive knowledge systems and their engagement in conservation efforts. To further understand the interrelationships and patterns in knowledge from diverse sources, future research will explore the local knowledge data in relation to element occurrence records for key wildlife species compiled by the Atlantic Canada Conservation Data Centre [164], forestry cover and roads, and model outputs of projected inundation due to sea-level rise. Forthcoming insights gained through our on-going qualitative, thematic text analyses of participant interview and workshop transcripts will be incorporated and shared. Improved understanding about how efforts such as ours that engage local knowledge can lead to local knowledge holders' support for conservation decisions that emerge from the knowledge sharing process would be beneficial. Important questions also remain about how efforts to engage local knowledge can lead those knowledge holders to further contribute to and participate in conservation efforts. In collaboration with participants, NCC and other partners, we will seek avenues for engaging, disseminating and mobilizing the knowledge gathered through these processes for conservation planning initiatives in the region. Importantly, we will explore opportunities to build relationships and work with the Mi'kmaq, who have lived, deeply immersed, within regional ecologies of reciprocal sharing interrelationships for 15,000 years [165,166]. Their title, rights, laws, governance systems, responsibilities, stories, and ceremonies need to be honoured and their insights would greatly benefit us all [95,96,165]. As signatories to the Treaties of Peace and Friendship (1725–1779) between the Mi'kmaq and Canada, we are all Treaty people [167].

5. Conclusions

The Chignecto Isthmus is a critical land bridge between NS and continental North America, providing connectivity for wildlife populations and human infrastructure. Coastal inundation and flooding due to rising sea level and storm-induced tidal surges threaten this already tenuous connection. Existing wildlife data from formal-science sources are limited and insufficient on their own to support regional conservation planning and on-going studies exploring 'engineering solutions' for safeguarding and adapting human infrastructure. Accordingly, our study aimed to generate complementary data based on local tacit knowledge, while enhancing local understanding and capacity for engagement in these local planning processes. To do so, we engaged local people with strong, long-term experiential knowledge of the land and wildlife to participate in map-based interviews and workshops. Thirty-four local people who hunt, trap, log, farm, enjoy nature and others participated in individual interviews with map-based spatial elicitation tools to identify key areas of wildlife habitat and movement pathways across the Chignecto Isthmus. Individual mapped data were digitised, analysed and compiled into a thematic series of maps, which were refined by subgroups of 8–10 of the participants through consensus-based workshop processes.

Locations of key populations and movement patterns for several species were mapped, consisting predominantly of terrestrial mammals, primarily moose, black bear and white-tailed deer, along with a group of other fur-bearing mammals and migratory birds. Strong consistency was observed among the mapped elements, resulting in group consensus despite some uncertainty expressed by individuals about their precision in noting the exact locations. When comparing local tacit-knowledge-based maps with those derived from formal natural science data and models, a strong overlap was apparent. Not only did the local participants verify the formal data and model, but they highlighted areas and concerns outside of the model and their explanations lent complex social-ecological context to its mapped outputs. Further, their engagement in the process resulted in knowledge transfer within the group and increased confidence in their experiential knowledge and its value for decision making. The process also increased their support and buy-in for mobilization of the results for wildlife conservation and connectivity planning, particularly for addressing revealed threats to connectivity from forestry practices (clearcutting and herbicide spraying), roads, power lines, wind-energy farms and increased water intrusion and flooding.

As such, our study has generated spatial and other wildlife data representative of consensus in local tacit knowledge relevant to wildlife connectivity and other conservation planning in the Isthmus region. The process represents a contribution to conservation planning methodologies, in which combinations of scientific data and local tacit knowledge are critically needed, both to provide reliable and locally-supported information for planning and to open up the research and planning process to different ways of knowing and to local communities, in the spirit of inclusive knowledge systems. The findings are relevant to on-going decision-making processes and represent important wildlife information for incorporation into local planning initiatives, addressing gaps in existing formal science data and lending validity to the outputs of computer-based modeling of wildlife habitat and movement pathways. The consistency of data obtained from these local people represents an important outcome that demonstrates and supports calls for greater generation and mobilizing of local knowledge in the scholarly fields of conservation planning and participatory mapping.

Our findings contribute to the growing yet nascent body of literature at the intersection of conservation planning and participatory mapping as means of co-production of knowledge and inclusive knowledge systems. Importantly, it also accesses, generates and makes available local tacit knowledge for conservation planning in practice, particularly for wildlife connectivity in a key linkage area identified as critical at local national and international scales. The findings enrich and complement data from formal natural science models, helping to address their gaps and limitations while providing important explanatory context. At the same time, our participatory mapping approach served to build local participants' confidence in their combined experiential knowledge and local support for conservation. It seems to have enhanced our participants capacity to serve as local champions for infusing local perspectives of wildlife and other ecological and social values that warrant consideration in conservation and other planning initiatives, such as for human infrastructural adaptations to climate change. Our study demonstrates a way to help build a more inclusive knowledge system grounded in the people and place. It illustrates an effective approach for representing differences and consensus among participants' spatial indications of wildlife and habitat. It presents a means of co-producing knowledge in participatory mapping for conservation planning. Engagement of local people and their tacit, experiential knowledge of the land and its wildlife provides important insights and means to enrich natural science and foster conservation action for connectivity and human-wildlife co-existence, both of which are key to addressing the twin crises of precipitous biodiversity loss and climate change.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-445X/9/9/332/s1, Interview Guide S1.

Author Contributions: Conceptualization, K.F.B. and J.L.N.; methodology, K.F.B., J.L.N. and V.P.P.; original draft preparation, J.L.N.; writing, reviewing, and editing, J.L.N., K.F.B. and V.P.P.; supervision, K.F.B.; funding acquisition, K.F.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Social Sciences and Humanities Research Council of Canada (Insight Development Grant #430-2018-00792) to K. F. Beazley and NCC collaborators, C. Smith and P. Noel, with in-kind support from NCC. Student funding was also provided by Faculty of Graduate Studies, Dalhousie University. Approval was received from Dalhousie University's Social Sciences Research Ethics Board (2019-4763).

Acknowledgments: The authors thank the 34 local participants who contributed their time and insights and our NCC collaborators, C. Smith and P. Noel.

Conflicts of Interest: The authors declare no conflict of interest.

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Beyond Calendars and Maps: Rethinking Time and Space for Effective Knowledge Governance in Protected Areas

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Received: 10 July 2020; Accepted: 22 August 2020; Published: 25 August 2020

Abstract: Protected area managers rely on relevant, credible, and legitimate knowledge. However, an increase in the rate, extent, severity, and magnitude of the impacts of drivers of change (e.g., climate change, altered land use, and demand for natural resources) is affecting the response capacity of managers and their agencies. We address temporal aspects of knowledge governance by exploring time-related characteristics of information and decision-making processes in protected areas. These areas represent artefacts where the past (e.g., geological periods and evolutionary processes), the present (e.g., biodiversity richness), and the future (e.g., protection of ecosystem services for future generations) are intimately connected and integrated. However, temporal horizons linked with spatial scales are often neglected or misinterpreted in environmental management plans and monitoring programs. In this paper, we present a framework to address multi-dimensional understandings of knowledge-based processes for managing protected areas to guide researchers, managers, and practitioners to consider temporal horizons, spatial scales, different knowledge systems, and future decisions. We propose that dealing with uncertain futures starts with understanding the knowledge governance context that shapes decision-making processes, explicitly embracing temporal dimensions of information in decision-making at different scales. We present examples from South Africa and Colombia to illustrate the concepts. This framework can help to enable a reflexive practice, identify pathways or transitions to enable actions and connect knowledge for effective conservation of protected areas.

Keywords: protected areas; knowledge governance; cross-scale management; knowledge systems; temporal dimensions; time

1. Introduction

Protected areas are artefacts where the past, present, and future are connected and integrated. As public assets, these designated conservation areas are boundary objects—spaces where multiple actors share information and interact [1], connecting diverse social-ecological elements, each with specific temporalities. Elements from the past are represented by landscapes, geological and ecological processes, refuges as sites and symbols of Pleistocene extinctions and historical climates [2], or the deep time evidence of the unfolding relationships between people and nature. Through time, human societies have evolved narratives that reflect different ways of conceptualizing, interpreting, and interacting with nature, justifying what is considered important or of value (including tangible and intangible values) and how to manage nature. In this context, protected areas represent the stage on which particular societal interpretations of nature are played out [3]. Human agency is expressed in conceiving and deciding what, why, and how nature in these protected areas needs to be conserved.

As complex social-ecological systems, protected areas comprise multiple temporal and spatial scales where human and non-human actors connect [4], although not necessarily at the same pace. Time-related characteristics in ecological systems include ecological and evolutionary processes including variables such as seasonality, frequency, and duration of interacting biotic and abiotic processes that are organized hierarchically [5,6]. For human societies, time provides the cues for specific practices, for instance, traditional local and Aboriginal communities organize their activities according to natural, seasonal tempos (i.e., harvesting, ceremonies, fishing), using customary and experiential knowledge that comes from memories and stories transmitted from one generation to the next. In this perspective, knowledge is active, rather than static and processed [7]; memories represent information from the environment that has been filtered and interpreted by human agents [8]. For modern human societies, time is entrained to deal with administrative issues, the creation of daily routines embedded in time-related metaphors like calendars, clocks, diaries, and time zones. In the case of protected areas, time is related with management and operational plans to meet conservation goals, with specific timeframes for implementation measured in months or years.

Managing and planning biodiversity conservation is complex, with inherent uncertainties and contested interests affecting decision-making [9]. In managing for environmental sustainability—including protected areas—practitioners rely on relevant, credible, and legitimate information for their decision-making processes [10]. Although advances have been made to better integrate information for managing natural resources, two issues are still evident: the constant call for better, more effective science indicates a persistent frustration and perceived lag between science and action [11], and there remain many cultural and institutional barriers to effectively use scientific information [12,13].

Unpredictable change is inherent to managing protected areas as complex systems and managers often are prepared to deal with it [14]. However, the increase in frequency and severity of impacts of drivers of change [15] affects institutional and individual capacity to respond to such events and use information for decision-making; in part, because of the inherent tensions managers face in reconciling management timescales and ecological timescales. For example, the speed and rate of extreme climate events and their impacts can extend beyond both the timeframe of a management plan and boundaries of a protected area or a country; its effects overlapping different temporal and spatial scales and cascading across biophysical systems [16]. Such events limit the ability of managers to identify and use climate information for decision-making processes [17,18], design monitoring systems, and comprehend ecological transformations and how people and nature respond to climate change [19,20]. In short, the additional complexity of climate variability limits the capacity of managers to design conservation strategies that effectively address adaptation to climate change.

What does time mean for managing protected areas under uncertain changing conditions, and how can people plan for, and select the best information to deal with unexpected changes? To help answer these questions, we propose that careful consideration of temporal and spatial aspects could provide benefits for knowledge creation and its application for managing natural resources in times of high uncertainty and rapid change. We argue that the linear conceptualization of temporal dimensions, implemented and reinforced through the use of modern calendars and clocks (as well as timetables, diaries and agendas), might be constraining our capacity to understand complex interactions in social-ecological systems at multiple spatial and temporal scales. Land managers operate in at least two spatio-temporal scales: the here and now and day-to-day of their responsibilities, as well as the scale at which social-ecological processes play out in the longer term at a landscape or regional scale [21,22]. However, managers are often constrained by the need to respond to specific timeframes mandated by the tools for management or urgent responses to meet administrative or political objectives, rather than operating at more extensive spatio-temporal scales beyond administrative constraints and maps [23].

To facilitate a multi-dimensional understanding of knowledge-based processes, we propose that dealing with uncertain futures starts with a better understanding of the knowledge governance context and decision-making processes involved in adapting protected areas management to climate change. Drawing primarily from civic epistemologies studies [24], the manuscript is divided in four sections. In the first section we present concepts related to time, presenting the idea of the "eternally unfolding present" [25,26] to enable actionable knowledge and practice under uncertain futures. The second section focuses on knowledge governance, and the implications for decision-making in the context of protected areas management. In the third section we propose a framework that can help understand time-related issues in relation to identifying, accessing, and using knowledge in ways that reflect the multi-dimensional scales within which protected areas operate. In the fourth section we illustrate our concepts with practical examples from the South African National Parks (SANParks) experience with Strategic Adaptive Management, and interviews performed during a study of knowledge governance under climate change in Colombia [18]. In the concluding section, we highlight the importance of understanding time related processes in planning and practice, to facilitate addressing multidimensional processes where protected areas managers operate.

2. Timescapes and Time Perspective

2.1. Understanding Time: Connecting Past, Present, and Future

Time helps human societies, individuals, and institutions to plan and organize activities, connect with specific moments in history, and, in separating the past from the future, it facilitates the making of prospective decisions [27,28]. In every society, different conceptions and perceptions of time coexist. A key assumption in planning for the future is that time is "continuous, linear, unidirectional and irreversible" [28] (p. 140); time is continuous in that it keeps moving on and does not comprise discrete units, unidirectional in that one event follows the other, even if repeated in cycles, and irreversible in that it cannot go backwards. The perception of time as linear or circular is not only a subjective construction but also a cultural one [28].

In modern industrial societies, and the management of natural resources, time is the " … disciplining coordination metrics of modern clocks and calendar … by which modern society measures and responds to change and categorically distinguishes the 'past' from the 'future'" [27] (p. 3). Ecological processes and ecological responses to external variables (including human disturbances) operate in longer spatial and temporal scales. This inherent mismatch between human planning and the rhythms of nature constrains the capacity to recognize, access, and use alternative tempos from Indigenous and Local Knowledge (ILK); such knowledge comprises individual and collective memories, their relation to and interpretation of territory, and environmental change [29].

From a temporal perspective, the duality of nature and society that is inherent in natural resource management does not exist in Indigenous societies [27,30]. For example, a landscape represents both abstract and physical aspects, where time and space are intrinsically related and evident (i.e., in geological eras, evolutionary processes, and human habitation). A landscape is created in the eyes and mind of the observer, so its boundaries depend, in part, on the observer's capability for interpretation and imagination [30] and represent both tangible and intangible elements of cultural relationships between people and nature. From landscapes, we can move to the idea of *timescapes* as described by Adam [30], to acknowledge complex environmental phenomena and inherent temporalities relevant to social-ecological systems. Timescapes encompass time-related characteristics (seasons, rhythms, pace, cycles, environmental change, memories) linked to the natural environment. The concept acknowledges change and how past events and memories influence the present while offering options for the future: "A timescape perspective enables us to integrate scientific and everyday knowledge and the constitutive cultural Self with the workings of nature" [30] (p. 55).

In protected areas and in the context of climate change, timescapes can help integrate diverse forms of knowledge to understand how climate change-related impacts cascade across scales [16] and levels of governance, including different temporal and spatial scales that go beyond the boundaries of protected areas. A timescape includes the complex responses to changes in social-ecological systems, the different interpretations of risk, and the urgency to act. It implies active learning from past events and diverse actors, crafting new knowledge in the present, and envisioning future scenarios under climate change.

2.2. Temporal Dynamics and Conservation Goals

This interaction of different timelines (past, present, future) is common in biodiversity conservation and climate adaptation studies. However, sometimes knowledge-related work does not explicitly consider temporalities. Knowledge baselines for managing protected areas are often based on species inventories, which are limited to a specific location and time. Long-term monitoring can address temporal coverage from single inventories [31]. Defining indicators of the conservation goals, alongside Thresholds of Potential Concern (TPC) can help managers and scientists to identify levels of unacceptable change in the system under management [32,33]. Ecological responses have specific temporal hierarchies, representing long-term system variability [6]. Understanding the differences between individual ecological responses (events) and processes can facilitate the identification of information needs and the design of monitoring systems. Monitoring ecological processes and responses—not just particular biotic groups—can provide a better understanding of the complex, non-linear processes of ecological responses through time, and help to understand patterns and trajectories across scales (see e.g., [5] for a watershed case covering multiple protected areas, and [34] for long term elephant and fire savannah management in Kruger National Park).

As drivers of change and their impacts operate at multiple scales, monitoring systems might consider units beyond the protected area boundaries to facilitate an understanding of the complex dynamics of social-ecological systems. Tools for forecasting and prediction can help to visualize scenarios for the future and identify information needs for conservation goals [35,36]. These prediction tools have an important temporal basis enabling time perspective: being aware of how events follow each other over time, and the role of past events in shaping the choices made today for the future [37]. It emphasizes the role of everyday practice, experience and learning, placing an actor (individuals and institutions) in an "eternally unfolding present" [25,26].

Memory is an important element of time-related perspectives. In "The importance of a certain slowness", Cilliers [8] describes the relevance of knowledge and memory, and its role to help anticipation of what is to come as complex systems unfold over time. He points out that memory is the "persistence of certain states of the system, of carrying something from the past over into the future". This does not mean to glorify the past, but allowing past events to linger in the present is how we can process information, interpret new events to help inform anticipation of the future, and counter the illusion that "if we live quickly and efficiently in the present we are somehow closer to reality" [8] (p. 108). Knowledge creation is a social process that requires learning, reflection, and dialogue, all of which take time. Integrating diverse forms of knowledge and memories provide a means to interpret the changes and evaluate the rhythm, impacts, and extent of drivers of change.

As different stakeholders in protected areas usually hold a diversity of beliefs, values, and knowledge, and different interpretations of time and change, exploring knowledge governance arrangements can help to identify potential political, cultural or customary tensions when selecting and applying knowledge for planning [38]. In the next section, we discuss how these temporal dimensions connect with knowledge-based processes.

3. Knowledge Governance: Accessing, Using, and Sharing Information

3.1. Creating Meaning, Crafting Knowledge

Words and stories shared by a group shape its identity and create meaning for mutual ideas and concepts. Meaning is produced through interactions with the world and reinforced by the selected choice of words, language, and metaphors used in everyday interactions [39]. This collective creation of meaning is closely connected with knowledge creation. Knowledge-based processes are context-dependent: institutions, rules, geographies, as well as individual and collective preferences, shape how knowledge is created, shared, and applied. A variety of cultural and political settings frame how people perceive, understand, and respond to natural phenomena and processes, including the 'how', 'what', and 'whose' of knowledge and its use [40].

Acknowledging the complexity and varied forms of knowledge, in this paper we consider two domains: scientific knowledge, and ILK [41]; ILK evokes the strong, long-standing linkages of Indigenous people, but also of more 'recent' communities (e.g., pastoralists or farmers) to their natural environments, and their specific interpretations of environmental change. Protected areas provide a good example of the interplay (or lack thereof) between knowledge and action produced by different actors operating at different spatial and temporal scales. As a 'community of practice' [39], protected area managers reinforce meaning through maps, regulations, and management plans, the implementation of which is measured in calendar time. In contrast, Indigenous communities create meaning and make sense of their world through dreams, stories, ceremonies, and traditional practices, where calendars and clocks are less relevant [42]. As explained by Cuvi [43] (p. 81), ILK[1] is created through practice, learning, and openness to experiment. These individual and collective interpretations of the world, with different understandings of risk and future climates, can lead to different environmental rules and standards, which can then enable or constrain adaptation options [29]. In managing complex social-ecological systems, it is important to acknowledge the plurality of visions and human dimensions shaping science-policy relationships [44].

In doing their work, protected area managers are expected to find, produce, and use information to connect management objectives with specific time horizons for their implementation, monitoring and evaluation [45]. In deciding what knowledge to use for planning and making decisions to deal with changing environments, protected area managers are conditioned by their decision contexts. Gorddard et al. [46] explain the decision-context as a societal construction whereby held human values (such as the motivation to conserve nature), societal and institutional rules (formal and informal actions, norms and practices for managing and planning), and knowledge (the diverse ways used by people to make sense and understand the world) influence how people make decisions. When certain values or rules predominate it affects how certain forms of knowledge are included or excluded, depending on what values, rules and knowledge the decision makers consider credible, legitimate and important (see examples of values, rules, and knowledge interactions from Australia in [46,47]; for Colombian examples, see [48]). In the next section, we provide details of this knowledge-practice interaction.

3.2. Producing, Co-producing and Governing Knowledge

In linking science with management decisions, there is a trend to move from the knowledge deficit model [11] to co-production as a way to promote actionable science while considering the complexity of challenges in managing natural resources under climate change [49]. Although co-production has different definitions, we follow Wyborn et al. [50] (p, 3.2): "processes that iteratively unite ways of knowing and acting—including ideas, norms, practices, and discourses leading to mutual reinforcement and reciprocal transformation of societal outcomes". This definition addresses context-related aspects of producing and applying knowledge and the governance of knowledge-based processes in situations where there are different interpretations and ways of creating meaning in the setting of goals, as is the case for protected areas.

Knowledge exchange, understood as processes of creating, sharing, interpreting, accessing and using knowledge, is one way of understanding the interplay that is required for co-production, and is not straightforward [13]. Understanding contexts and barriers can facilitate the identification of options to enable knowledge exchange for more efficient decision-making and management. Such an approach requires an understanding of the governance of knowledge: the overarching rules of how

[1] Here ILK is inferred by the authors; in Cuvi (2019) Indigenous knowledge is mentioned, but does not refer explicitly to ILK.

societies engage in knowledge creation (including the preferred types of knowledge for making decisions) and how to share, protect, use, or access that knowledge [38]. Knowledge governance "can help to understand the role of knowledge and learning in the governance of complex societal issues" [51], including knowledge-based arrangements (formal and informal rules) for decision making, and facilitate more effective interactions between knowledge and practice. Knowledge governance is often confused with knowledge management, however the latter involves the day-to-day practice of organization along with accessing and using information and is not considered here.

Understanding knowledge governance can help to address temporal mismatches when deciding how to address conflicts of interests, identify ways to move beyond traditional practices and embrace innovative options for managing natural resources. A first step is to identify existing knowledge governance systems, for example the so-called 'loading dock' model [50,52], as well as institutional arrangements in use, for example boundary organizations, knowledge exchange, and embedded researchers [13,53]. These models are often framed by high-level processes and complex arrangements that shape the way society governs knowledge-based processes (known as civic epistemology), which therefore influence knowledge systems (such as institutional arrangements for science-policy interaction), as well as interventions and knowledge management responses for the application and translation of knowledge into action [38].

Knowledge-based processes (including co-production) might benefit from explicitly embracing different temporal dimensions. In collaborative interdisciplinary research, different perceptions of the urgency to solve problems, and the different paces to create knowledge by different disciplines and communities of practice, influence how we define timeframes for action [54]. In the next section, we present alternatives to explicitly explore the diverse conceptions of time, how it is conveyed in knowledge-based processes, to open opportunities for productive collaboration and dialogue with multiple stakeholders in and around the protected area, rather than mismatched understandings based on preconceptions or assumptions of time.

4. Framework for Multidimensional Knowledge-based Processes

> "*Some years ago, we started reflecting on fragile ecosystems and climate change, and we realized, what are we going to do with the glaciers? Who is working on that? What management actions are needed?*"
>
> Manager, Colombian National Parks, 2016

In its conception and implementation, management of natural assets often neglects or misinterprets temporal horizons when designing environmental monitoring programs and decision-making processes. To facilitate an understanding of time in relation to knowledge processes and decision making, we propose a framework to evaluate current knowledge-based processes in protected areas management and planning, as a guide to understanding the timescapes in which managers operate. Acknowledging that management of conservation goals operates within spatial and temporal limits, the framework is a guide to addressing the complex interactions of multidimensional management in a practical way while identifying options to move beyond constrained and utilitarian concepts of time (such as calendars) in relation to knowledge selection, usage, and the implementation of policies. Each protected area context is different, and it is likely that some managers are already applying some of these ideas. The framework aims to enable managers to navigate options for integrating practice (e.g., management effectiveness), applying science and technical knowledge (e.g., monitoring systems), and connecting diverse knowledge systems and memories to understand social-ecological processes and responses to drivers of change. For example, ILK can provide a richer vision of social-ecological processes, based on multigenerational observations and practice [55].

The framework is based on the idea of ecological reflexivity [56], involving *recognition* (monitoring impacts and system changes while anticipating future conditions), *reflection* (learning from past events, rethinking values and practices and envisioning), and *response* (reviewing objectives and values and reconfiguration of processes and practices). We integrate these elements into a simplified version of protected areas decision making (Figure 1). The framework includes the idea of the here-and-now that protected area managers face every day in their jobs. The present represents the living memory (including previous learning) gained by practice, anticipation of what is going to happen, and careful observation of the outcomes. We present some guidance questions (Figure 2 and Appendix A) intended to facilitate the reflexive process, guide discussions, and help managers exploring multidimensional knowledge-based processes in their current practice. These questions can happen as part of a deliberative process to update management plans or monitoring systems and can guide managers navigate and understand how current knowledge systems address time across scales. The framework and suggested options are not prescriptive, but aim to guide the discussion to identify what information is useful, whose knowledge is relevant, and elements to consider in designing monitoring systems that allow managers to capture systems dynamics in space and time.

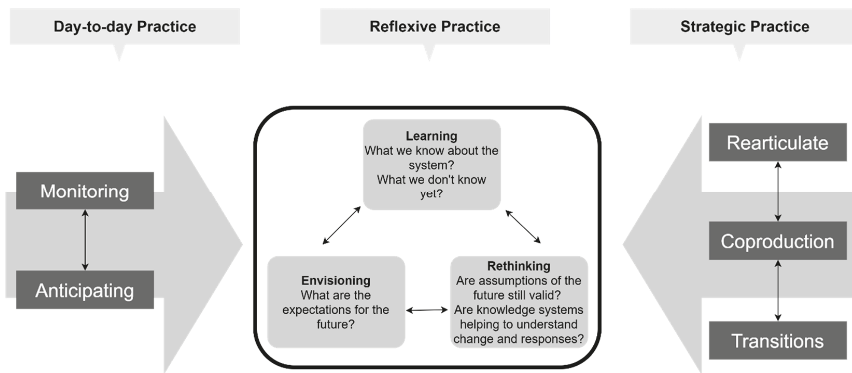

Figure 1. A framework to address multi-dimensional knowledge-based processes for management of protected areas. The day-to-day practice on the left focuses on monitoring social-ecological processes and anticipating or thinking about future conditions of the system. The reflexive practice (center) emphasizes learning from previous knowledge-based processes, rethinking assumptions and knowledge systems, and envisioning expectations. To the right, the strategic practice level focuses on how to rearticulate or transition to alternative forms of knowledge and management. Modified from Dryzek and Pickering [56].

The first category is the *day-to-day practice*, or operational level, which represents the activities to meet the strategic objectives, including anticipating changes and monitoring current conditions. This level is critical to provide feedback to strategic decisions and update planning. Then, an intermediate level of *reflexive practice*, to allow learning about past projects, planning and activities, rethinking the effectiveness of knowledge systems used to understand change, and envisioning expectations for the future. Finally, the *strategic level* corresponds with decisions related to broad, overarching, long-term goals that span geographical and temporal scales. These can include setting collective visions for a protected area and surrounding landscapes, align management plans with Indigenous Plans of Life (a participatory planning instrument to reimagine Indigenous futures), developing and managing a network of protected areas, or complying with international conventions.

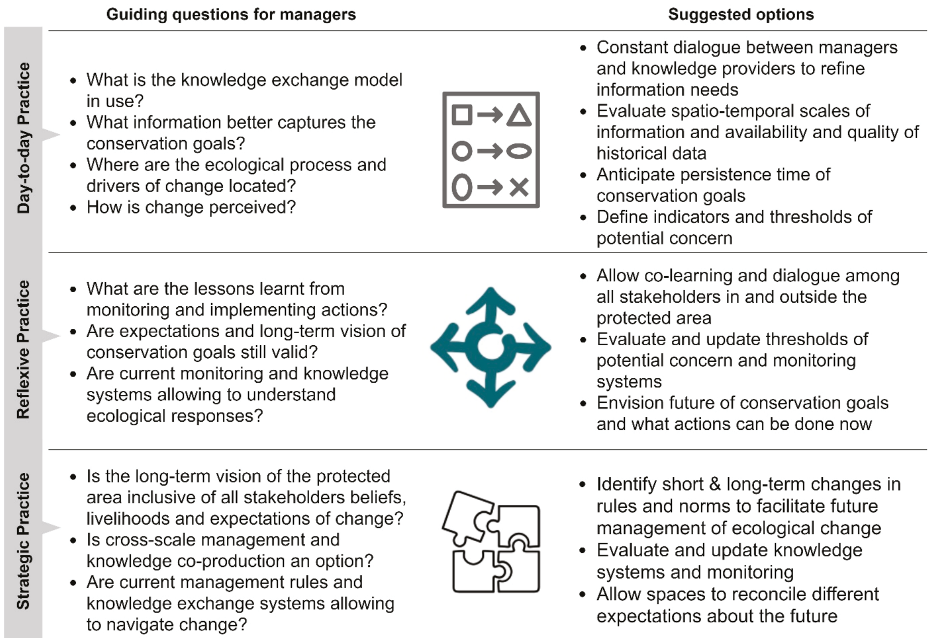

Figure 2. Illustrative example of the guiding questions and options for managers, to guide the discussion about multidimensional knowledge-based processes. Tables A1–A3 expand the questions at each level.

The information required to understand changes in ecological functions and the cascade effects of disturbances across scales require more than data collected over narrow temporal and spatial scales [57]. The relationship between information needs and decision-making timeframes might have different interpretations in management and planning [18] (p. 45), affecting how information is produced, selected, and used. Moreover, our lack of clear knowledge about the type, speed, and extent of ecosystem transformation as consequence of climate change challenges how we make decisions, our interpretation of time, affecting knowledge-based processes for managing protected areas. For example, when designing monitoring systems, scientists and managers often omit the response timeframes of ecological processes, or use incomplete datasets that do not reflect the interconnectedness of ecosystem processes at different spatial and temporal scales [5] or the underlying complexity of ecosystem services and the processes that provide them. In this sense, we understand ecosystem services as biophysically and socially co-created; their use and interpretation evolve over time according to societal preferences [58]. As ecosystems, biodiversity and social processes are structured hierarchically across temporal and spatial scales, protected area managers can benefit from explicitly addressing temporal scales, territorial dynamics and ecological processes when using knowledge and information.

Careful linking of management effectiveness times, with long-term monitoring results can help visualize changes and responses while allowing learning, testing of management options, the effectiveness of information collected and evaluation of thresholds of change. At the strategic level, the rethinking of information and knowledge needs involves a process of collective reflexivity on how to adjust knowledge systems for managing change and understanding that management of future ecological transformation requires dynamic management, learning and eventually rethinking and changing practices, structures and conservation approaches consistent with what has been learnt and observed. Although this re-articulation is not straightforward, it can occur as small transitions in current approaches that facilitate reframing knowledge governance processes and incorporating other forms of knowledge (e.g., see four conceptual transitions to enable future adaptation in [48]).

The example illustrated in Figure 3 shows how ecological processes and information needs on conservation goals distribute across spatio-temporal scales to support predictions of ecological responses and change over the longer term. Anticipatory processes can benefit in setting TPCs, and reflecting on the observed responses of biota to climate and other drivers of change, managers and researchers will be able to better understand the mechanisms of climate impacts, the sensitivity of natural systems and implications for transformation in the protected area. Human needs and their dependence on ecosystem services play an important role in defining conservation goals, but also as underlying drivers of environmental change. Social TPCs can complement ecological ones to allow an integral understanding of processes and responses of the social-ecological system [59].

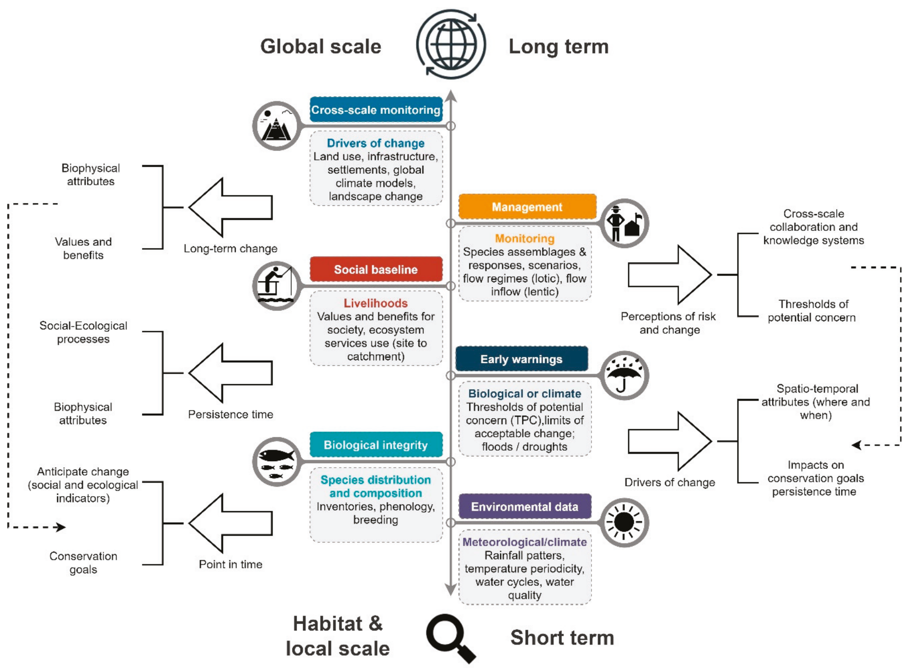

Figure 3. Overview of social-ecological processes and information needs on conservation goals for managing protected areas across spatio-temporal scales, from the short-term and local scale (bottom) to the long-term, large scale (top). Information from local level can help to understand conservation goals and social-ecological responses across scales, and the overall performance of ecological processes and functions. Data collected at the local scale (e.g., inventories) are limited to a moment in time and space; long-term monitoring can address temporal coverage from single inventories. Identifying early warnings like Thresholds of Potential Concern (TPC) facilitates an understanding of systems responses to drivers of change. Drivers of change can be events at local level/small temporal scales, or located at larger spatiotemporal scales, even outside the protected area, their impacts cascading across biophysical systems.

Human responses to environmental change play an important role in the dynamic nature of knowledge production. These responses can include changes in agricultural practices, reforestation and restoration efforts, human migrations or shifts in use of natural resources [20]. Observing and recognizing these responses within and outside the protected area can facilitate learning and experiential management, which is essential to enabling adaptive practices, while adjusting information needs, timeframes, and planning, which is essential for moving into the strategic practice level.

Finally, it is important to recognize the knowledge governance and decision-making context in the protected area. Each case is different and human perceptions and interpretations of the conservation values influence the creation of knowledge for managing these areas. An open dialogue with relevant stakeholders might allow agreement about objectives and desired future goals as well as identify the most relevant socio-ecological processes that require monitoring and management, while defining the thresholds of potential concern and limits of acceptable change [9,59]. In understanding the type of information available, including the timeframes for which climate information exists, managers can reflect on current practices and management questions, update planning tools, and improve decision making processes.

5. Reconciling Calendar Time with Reflexive Practice

So far, we have considered a framework for multidimensional knowledge-based processes for protected areas management. We emphasize that recognizing temporal dynamics related to production of knowledge is essential to support decision making and planning of social-ecological systems. It can help in understanding complex temporal patterns, the interaction at different geographical scales, and biotic responses to different drivers of change [6]. However, some questions remain outstanding. Environmental managers in the Anthropocene need to be more aware of driver-response dynamics through time and rethink temporal horizons and spatial scales, given the complex context under which multiple actors interact and make decisions [4]. We suggest this framework can help reconcile the different motivations for protecting natural assets when defining and implementing management and adaptation options under uncertain and changing conditions.

Calendar timeframes are useful when dealing with administrative issues, assessing changes in the conditions and guiding future management [60]. Independent on the knowledge model in use, applying a reflexivity process for the management of protected areas can facilitate a time perspective approach and identify relevant information from past events, while observing, documenting, and learning from previous practices, and investing that knowledge in new meaning in the present and into the future. This approach includes thinking about what information is available now or what information might be relevant to understand socio-ecological processes and responses in relation to the conservation goals, while reflecting on the biophysical characteristics that span through space and time and can support an understanding of ecological responses to climate change. In this context, the time perspective can help design monitoring systems with a more systemic vision and facilitate adaptation to a changing climate.

We present examples from South Africa and Colombia to illustrate how calendar times can be reconciled with reflexive practice. An ongoing collaboration between the authors helped to infer how this is happening in each country. The different governance models and knowledge systems of these countries allowed the authors to explore—through an inductive process—the assumptions for the framework. The example from South Africa comes from SANParks extensive experience with adaptive management; for Colombia, we used data collected through a co-production and knowledge governance study [18].

5.1. South African Approach: Strategic Adaptive Management and Reflexivity

How different is the framework presented here (Figure 1) from adaptive management? Adaptive management has become a foundation of effective environmental management in contexts characterized by high levels of ecological uncertainty [61]. It stems from acknowledging that ecological (and social-ecological) systems are complex, that understanding of such systems is imperfect and partial, and that the responsible way to proceed with management in these contexts is to learn by doing, and to adapt actions as new understanding emerges. It achieves this by integrating research, planning, management, and monitoring in repeated cycles of learning [62]. Adaptive management is a systematic approach to improving the management process by purposefully learning from the outcomes of management actions.

Strategic Adaptive Management (SAM) is a version of adaptive management that has been iteratively developed and implemented by SANParks for more than 20 years [9,63]. SAM has been applied to a variety of social-ecological challenges, from relatively narrow (e.g., management of elephant populations [64]) to extremely broad (e.g., management of a national park; for more information, see Roux et al. in review) application contexts. Regardless of the context, SAM consists of four interlinked and dynamic sub-processes [65]: adaptive governance (co-producing the 'rules of the game' at a range of levels, from national legislation to park policy to local rules shaped by stakeholder norms and values); adaptive planning (co-creating a vision and management objectives for addressing a specific social-ecological challenge); adaptive implementation (designing and implementing management measures, research experiments and monitoring programs to action the above objectives and enable learning from their outcomes); and adaptive evaluation (assessing and reflecting on the outcomes of implementation against the vision and objectives, to inform ongoing learning and adaptation).

During adaptive planning, diverse stakeholders participate in face-to-face dialogues during which they deliberate the social values, changing contexts (social, technological, economic, environmental, and political) and vital attributes (special or unique features) of the social-ecological system of concern that should guide future decision making. These dialogues provide the basis for jointly articulating a vision and setting management objectives. The tacit knowledge of participants, which reflects past experiences, converges into an explicit vision statement and objectives for directing management in the future.

During adaptive implementation, ongoing engagement between agency scientists, park management, and stakeholder groups enables the consideration of multiple knowledge sources, including experiential and tacit understanding as well as science-based information, to inform decision options. Selected management actions are implemented in conjunction with complementary research projects and monitoring programs, to enable purposeful learning by doing. Monitoring of key indicators, and setting TPCs for these indicators, serve as forms of feedback to stimulate reflection, especially when thresholds are being approached or exceeded.

Adaptive evaluation refers to formal and informal assessment of and reflection on progress towards achieving the vision and set objectives, in line with the reflexive level. Lessons learned through these processes provide forms of feedback to, at least in theory, update or adapt the rules of the game (adaptive governance), the vision and objectives (adaptive planning) and management actions, research agendas, and monitoring programs (adaptive implementation). The SAM process incorporates memories and prior knowledge of stakeholders to anticipate and articulate a desired future state, which in turn guides sense-making in the present through combined actions, monitoring, learning, and research.

The SAM approach aligns to some degree with the framework. However, even SAM, with its strong emphasis on getting "consensus on a desired future state across a range of value systems" [62], has shortcomings. Park management plans are embedded in national legislation, which render their planning, implementation, and evaluation processes less flexible, responsive, and adaptive to natural social-ecological cycles than ideal [62] (e.g., policy determines when a plan gets revised, and not necessarily readiness of the social-ecological system; compliance culture stifles experimentation; and resource constraints limits dialogue with stakeholders). However, there are opportunities to rearticulate the rules. For example, where management plans include a program on climate change, ongoing learning about, and improved understanding of, climate as a driver of social and ecological change will help to update the normative rules of the game, to better understand information needs for climate adaptation, update monitoring systems, facilitate envisioning options, and rethinking assumptions.

5.2. Colombian Protected Areas: Linking Knowledge and Management Beyond the Calendar

The Colombian protected areas national agency has been actively working to understand the hazards and impacts related to climate change and their implications for managing protected areas. The Future-proofing Conservation project worked with protected area managers to rethink management options in the context of climate change and uncertainty about future socio-ecological transformation [48]. Using semi-structured interviews, the quotes below were documented by C.M. during the project to identify the different forms of knowledge related to climate and ecosystem services that are used for long-term planning and management, and how knowledge governance can be enhanced for strategic thinking and decision making. Full details on the methodological approach and methods are presented in Munera and van Kerkhoff [18]. The quotes in this manuscript have not been published previously.

Knowledge creation is an evolving process of past experiences and everyday interaction with the world, in which reflection is encouraged and learning is incorporated into practice. In Colombia, managers recognize these attributes, and are in the process of implementing reflexive practice: "we have [scientific] information; [now] is a moment to stop, review and analyse what we have, looking at the future, to identify gaps, reflect on other issues we would need to cover and to develop a long-term vision for managing protected areas" (Int. 3). This quote demonstrates the relevance of practices of learning, collaboration, and openness to change. In applying long-term thinking, it is important to consider choices and decisions made today, while being open to accepting and using alternative knowledges to understand territorial processes to support implementation of conservation strategies and connect with different concepts of time and knowledge.

For Colombian protected areas the learning process is allowing reflection on current practices to integrate risk into management and better connect with territory: "we are working on understanding if restoration is an adaptation action or not, what criteria we need to consider and how to apply it in practice to decide if we need to update zoning in the management plan. Managing risk is helping to better understand the territory and identify places where landslides can affect indigenous communities or farmers" (Int. 4). This process is facilitating managers to integrate other forms of knowledge alongside scientific information, enabling the strategic thinking necessary to manage uncertain futures and planning for climate adaptation [18].

Climate change and uncertainty of climate-related information have been reported as a major barrier for making decisions [66], so is the poor understanding of climate change impacts and mechanisms of climate sensitivity for species and ecological processes [17]. These limitations, plus a sense of urgency in trying to avoid ecological change, might prevent managers from fully considering social-ecological dynamics and potential mismatches in the information available to them. Climate change is opening the door to update current practice: "climate change is forcing us to look beyond the boundaries of the protected area and have more integral planning" (Int. 12). Although this openness to incorporating new knowledge was in response to a technical deficit (a lack of instruments for monitoring climate variables), it demonstrates that it is possible to rethink practice [18]. Instead of a reactive use of information, when a climate event triggers a response [66], managers can benefit from careful consideration of how past events have shaped present-day ecosystems, and cross-scale ecological responses of the conservation goals. Such considerations include the identification of conditions that may trigger other responses and can give managers agency to identify the most relevant information to act as the future unfolds.

A diversity of worldviews in a context of managing protected areas and knowledge-based processes can facilitate the reconfiguration and rethinking of managing multidimensional protected areas systems. Indigenous communities have specific timescapes, intrinsically linked with their interpretation of the environment across temporal and spatial scales. In their view, life and nature are not seen as discrete units, but as processes that have specific cycles linked with belief systems and cosmology. For Indigenous groups, decisions on their land requires revisiting their ancestral history [42,55], a view that demonstrates a deep time perspective and connectedness with the territory. Some Colombian protected areas that are co-managed by indigenous groups are in the process of adjusting modern administrative timeframes to local tempos, set by nature and people's connection with it [42,67], and, when setting meetings, managers need to consider environmental rhythms (e.g., river flows), customs (e.g., funerals, wakes, and dreams) and their timing with nature. Although these parks are managed under State rules, local practices have been influencing the way the National Protected Areas agency interprets their role and governance in areas inhabited by Indigenous communities [42].

5.3. Implications for Future Management

As we started developing the ideas for this manuscript, an unprecedented bushfire season ravaged parts of Australia. Although bushfires are expected every summer, their severity and extent had enormous impacts on National Parks, wildlife, and livelihoods, challenging the response capacity to deal with them and questioning how to integrate Aboriginal customary practices of fire management. Fire regimes in Australia are well documented, especially in relation with the human practices and Aboriginal knowledge [68]. Aboriginal customary practices to manage the land using fire have been proven to reduce the density of shrubby understory plants and fuel loads, thereby reducing the intensity of bushfires [69,70]. Incorporating Indigenous fire management into Australian protected areas can be regarded as a direct adaptation measure to manage dynamic ecosystems under a changing climate or as an indirect adaptation measure, which aims to maintain ecosystems in their current configuration, depending on context and perspective [71]. Integrating ILK with modern technology and science can be beneficial, but requires changes in knowledge governance hierarchies, reflection on future expectations of conservation goals, and defining how much change managers and local communities are willing to accept to facilitate system monitoring, management, and action [72].

Understanding and accepting change (ecological change, change in practice, change in knowledge, and change in the territory) is a first step to rethink management of biodiversity under changing environmental conditions and climate. This perspective constitutes a shift in the way we conceptualize nature and management, and therefore the epistemic context and responses. In documenting dynamics of change and adaptation in epistemic communities (specifically practitioners and researchers working in ecological restoration), Hirsch and Long [73] found that when practitioners move their expectations from stable climates and ecological models to recognize the possibility that historic conditions and preconceived assumptions of nature might no longer exist, they were able to reorient practice and goals. This shift in thinking and practice might bring new paradigms, concepts, perspectives, and ideas, enabling the integration of new information and knowledge for strategic adaptive management.

Through a reflexive practice, managers, local communities, and other relevant stakeholders (information providers included) can discuss and identify TPCs and limits of acceptable change and identify management responses in relation to change, while adapting information needs. This shift in the science-practice paradigm is reported in Kruger National Park [9], where SAM was a response from managers who realized that instead of avoiding change, it would be better to understand and anticipate it, while working to identify conservation goals and thresholds of potential concern. This re-framing allows a transition from business-as-usual management to an approach where the complexity of social-ecological dynamics is recognized. Rapid change is embraced to allow room for co-learning, to understand change and the multiple values, knowledge, and interpretations of nature.

The interaction between different epistemic communities can help to update knowledge-based processes, as reported for Colombian protected areas [18]. This interaction demonstrates that biodiversity conservation planning processes can accommodate a range of different outcomes and worldviews, while recognizing how environmental decisions connect or impact other sectors. Anticipating the future is not about speculating, but being able to consider future consequences of decisions made today, having agency and willingness to change and take action, question current alternatives, being able to connect with other forms of knowledge, disciplines, and stakeholders, and being aware of others (nature or society) when making decisions [37].

6. Conclusions

The framework we present provides some guidance to connect multiple dimensions where knowledge and decision-making interact in the management of protected areas. We consider it is adaptable to specific context and circumstances, considering the knowledge governance model in use, and taking advantage of managers' experience and daily interaction with social-ecological systems to facilitate learning and co-production. Also, the framework incorporates a recognition that social-ecological processes and drivers of change have different time horizons and operate at different spatial scales. Rethinking and changing knowledge systems in use can take advantage of the diverse ways people make sense of the present and envision the future.

The custodianship of the present for future generations is augmented by an appreciation of the past and the acknowledgement of the plurality of knowledge systems. Use of diverse knowledge systems takes advantage of a richer set of memories, facilitating the process of anticipation and adaptation to new conditions, dealing with surprises, and reconciling collective agendas and expectations [8,74]. In a context of climate change, governance determines how we respond to new and uncertain climate impacts, and influences whether and how strategies are implemented [75]. Considering the challenges posed by climate change, and other drivers, we need more flexible management of biodiversity and ecosystem services while incorporating multiple visions, temporalities, processes, and interpretations of the world. The concept of timescapes [30], can help managers to understand time related processes in their areas, rethink assumptions, and explicitly consider and integrate multidimensional knowledge-based processes in mental models and practice. For example, because timescapes encompass seasons, natural rhythms and cycles, and memories of natural events, they can be used in TPC thinking and SAM by paying greater attention to changes in the return interval and seasonal shifts in events related to drivers of change, such as bushfires, floods, droughts, and cyclones. The effects of such changes on the integrity of protected areas and surrounding landscapes, and the consequences for achievability of management objectives then form a basis for a more reflexive approach to management.

Reconciling calendar management times with reflexive practice is possible, as we have presented here. South Africa National Parks is working on it, while Colombian protected areas have been accommodating diverse knowledge systems to complement technical knowledge and transitioning to adjust practices and rules. Although we probably will not find an ultimate suitable and cost-effective solution to deal with complex problems in a rapidly changing world, as Fernández [11] (p. 172) points out, we need to remember "new circumstances and context, including past solutions, require ongoing work because we are dealing with co-evolving systems". Accepting this challenge requires for us to stop, contemplate, and understand the moment, as well as to be conscious about how our actions and knowledge are connected and can impact future social, political, and ecological outcomes. Embracing a bit of slowness is important to better identify, evaluate, and deploy the knowledge required to deal with future changes, beyond just responding to "efficient" calendar times. We finish quoting an old Italian proverb: *chi va piano, va sano e va lontano* (whoever goes slowly, goes safely and goes far).

Author Contributions: Conceptualization, C.M.-R., M.J.C., D.J.R., L.v.K.; investigation C.M.-R., D.J.R., L.v.K.; formal analysis: C.M.-R.; writing, review and editing, C.M.-R., D.J.R, M.J.C, L.v.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Some of the information presented here was collected during the Future-Proofing Conservation project where C.M. and L.v.K. where involved, funded by Luc Hoffmann Institute and with collaboration from Parques Nacionales Naturales de Colombia-PNN and WWF Colombia. C.M has a scholarship from the Endeavour Leadership Program. We thank Carina Wyborn (Luc Hoffmann Institute) for reviewing the manuscript and her valuable comments.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Guiding questions for protected area managers to facilitate the reflexivity process in multidimensional knowledge-based processes, and options to consider for the *day-to-day practice* level. **Words highlighted in bold** represent some key ideas and issues to consider.

Guiding Questions	Options	References
What is the current model of knowledge governance in use?	**Constant dialogue** between managers, practitioners and scientists to follow up system responses and 'novelties. Even under a loading dock knowledge transfer model, managers can have a dialogue with scientists to refine information needs. **Co-production**, interdisciplinarity and socio-cultural diversity to integrate local knowledge can facilitate understanding of different needs, expectations, and social-ecological responses. Evaluate **costs and needs** for data collection, including where to host the data, funding, and capacity to analyse and interpret it in the long term	[12,13,50,52,53]
What is the main conservation goal (e.g., biophysical attributes, ecosystems services, ecological processes) and what information better capture conservation goals responses to drivers of change?	**Inventories** and surveys provide a first glimpse of conservation goals status but are limited to **narrow spatio-temporal scales**. Evaluate survey characteristics, frequency of data collected, and applicability of results. Historical data can be useful to understand the system and anticipate responses, important to **evaluate availability and quality** (e.g., gaps in time or space) of datasets. Identify indicators that can help understand climate change as a factor influencing **ecological integrity** (e.g., early warnings systems-floods and droughts)	[5,31,76,77]
Where are the ecological processes and drivers of change located?	**Conservation objectives** can have a narrow or broad **spatio-temporal scale**; drivers of change can be inside, or outside the protected area. Evaluate which **methods** for data collection best captures processes and drivers of change at **different scales**. Identify the **quality and origin** of the drivers of change (e.g., endogenous change, exogenous-agriculture, anthropogenic climate change-related)	[5,31,78,79]
What temporal and spatial scales are more relevant to monitor conservation goals and social-ecological processes?	Information about social-ecological responses at **smaller spatial scales** (and over short periods) can help, over time, to **connect to broader scales** (even if this is not the original objective) but requires **consistency to avoid information gaps**. Consider establishing **long-term monitoring** systems of ecological processes and **monitoring impacts of external drivers of change**. Understand **persistence time** of conservation goals to improve design of monitoring systems and observe **responses and trends to anticipate future changes**	[5,78]
How much change are managers and stakeholders willing to accept in relation of social-ecological systems?	Define indicators and **thresholds of potential concern** of these indicators, co-produced with managers, scientists, and communities to track social-ecological responses, define future expectations, **limits of acceptable change** and decide when to intervene. Complementary to quantitative tools, **qualitative tools** can help predict **system responses and cascade effects** of disturbances	[32,57,59,80,81]

Table A2. Guiding questions for protected area managers to facilitate the reflexivity process in multidimensional knowledge-based processes at the *reflexive practice* level. **Words highlighted in bold** represent some key ideas and issues to consider.

Guiding Questions	Options	References
Are managers and scientists understanding response times and social-ecological systems responses?	**Evaluate if current information** systems and **data quality** allow managers and other relevant stakeholders to understand ecological processes, functions, and responses to disturbances. **Conceptual models** and mental maps can help design monitoring, understand system dynamics, **connect knowledge systems**, and identify management options	[9,31,82–84]
What was learnt from the previous practice and monitoring?	Allow time for **co-learning and evaluate social-ecological responses** in deciding if, and when to intervene, including understanding and learning from human responses to ecological transformation through time	[48,85]
Are current monitoring systems and management effectiveness processes adequately capturing responses and changes of socio-ecological systems across temporal and spatial scales?	**Review and update** monitoring systems to capture knowledge and learning from different actors and facilitate future decisions. Evaluate if **monitoring system timeframes** are adequate to follow social-ecological responses, inform decision-making processes, communicate risks, and facilitate stakeholder engagement. Evaluate if management effectiveness results can help to understand changes in social-ecological systems	[78,86]
Can observations from stakeholders outside the protected area and local knowledge, help to understand human and nature responses to drivers of change?	Evaluate and **update thresholds of potential concern** to ensure monitoring systems are capturing ecological responses across scales and enabling action. **Identify potential collaborators** for monitoring ecological processes outside the protected area	[18,59]
Are future expectations for the conservation goals in the still valid and relevant?	Under conditions of uncertainty and complex systems, **envisioning and futures thinking** approaches can help visualize future scenarios and identify actions that can be done in the present	[35,36,48]

Table A3. Guiding questions for protected area managers to facilitate the reflexivity process in multidimensional knowledge-based processes at the *strategic planning* level. **Words highlighted in bold** represent some key ideas and issues to consider.

Guiding Questions	Options	References
Under scenarios of ecological change, is the long-term vision of the protected area inclusive of the beliefs, livelihoods, and expectations of different stakeholder groups?	Identify **complementary management and adaptation options** (e.g., stewardship programs, corridors, community conservation). Evaluate if conservations goals are still relevant or need to be reframed to address stakeholder visions while addressing future climate change. Participatory workshops, face-to-face **dialogues**, or **co-production** to reconcile different expectations about the future. Evaluate **changes in perception of values** about the protected area and identify how to allow access to conservation benefits without compromising ecological integrity.	[48,78]
How do we improve and update monitoring systems and knowledge governance models to facilitate strategic planning in a context of high uncertainty?	**Update standards and rules** (including funding) to improve monitoring systems and enable action; evaluate adequacy of **funding**. Co-design strategies for knowledge co-production can help identify options to **rearticulate knowledge governance models** to deal with uncertain futures. Evaluate management options, identify new alternatives and barriers that constrain adaptive management	[12,48,87]
Are there options for cross-scale management and knowledge co-production in and outside protected area boundaries?	Consider the **voices and expertise** from diverse **stakeholders in and outside the protected area** to enable a dialogue and participatory strategic planning. This can help evaluate responses and **rethink current practices** while finding a balance between the requirement of protected area management and the social-ecological context.	[48]
Are decision-making processes and knowledge systems still valid to deal with new conditions and navigate ecological change?	Evaluate **strategic alliances** between different groups for collecting, analysing, and sharing information (e.g., private sector, academia, local communities). Identify which **rules and norms** might need to change to facilitate integrating diverse knowledge systems to facilitate adaptation in the short and long-term	[46]

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Article

Pastoral Stone Enclosures as Biological Cultural Heritage: Galician and Cornish Examples of Community Conservation

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Received: 25 November 2019; Accepted: 23 December 2019; Published: 2 January 2020

Abstract: The role and importance of a built structure are closely related to the surrounding area, with interest in a given area having a concomitant effect on the relevance given to the constructions it may hold. Heritage interest in landscape areas has grown in recent times leading to a sound valorisation process. This connects with the recent concept of biological cultural heritage (BCH), or biocultural heritage (definition still in process), that can be understood as domesticated landscapes resulting from long-term biological and social relationships. Although pastoral enclosures (in large part dry-stone walling, whose construction has been recognised by UNESCO as Intangible Cultural Heritage of Humanity since 2018) arise as traditional rural constructions linked with a way of life already disappearing, engaged local communities are recovering their biocultural value in terms of identity and positive conservation outcomes. In this sense, this article focuses on valuing traditional stone-built pastoral enclosures in two locations on the Atlantic coast of western Europe: Frojám (NW Iberian Peninsula) and Ladydown Moor (SW England). Findings concerning plant communities related to current or ancient pastoralism, and artefacts of built heritage are described, and an emphasis is placed on community engagement as a mechanism for conservation. The resilience of species-rich grassland communities is identified as a manifestation of biocultural heritage and an opportunity for habitat restoration. Finally, current trends and improvements in understanding of biological heritage and community conservation are addressed.

Keywords: pastoral enclosures; vernacular architecture; minor rural buildings; art of dry-stone walling; indigenous and community conserved areas; Galicia; Cornwall; forestry heritage; heathland and grassland conservation; plant biodiversity

1. Introduction

This study examines two areas where long-established land management practices have been disrupted during the last century as a result of technological or demographic change, bringing to an end, long histories of pastoralism. These changes are typified by agricultural mechanisation and its associated rural depopulation in Cornwall, and by a population shift to urbanised industrial employment in Frojám (Galicia), following government-led land seizures, and a fast rise and decline of mining in the area. However, the 'flight to the city' has recently reversed with increasing movement to a rural lifestyle under the guise of sustainability and quality of life, thus imposing renewed changes on abandoned landscapes [1]. In this sense, there is an increasing recognition of cultural values when discussing wellbeing in rural areas [2].

The concept of biological cultural heritage (or biocultural heritage), sometimes shortened to BCH, is a very recent development. Ove Eriksson [3] raised a tentative definition of it in 2018 as the "biological manifestations of culture, reflecting indirect or intentional effects, or domesticated landscapes, resulting from historical human niche construction". In 2019, Lindholm and Ekblom [4] framed the concept as one that allows new approaches to heritage, nature conservation, landscape planning and management, thus defined as "an understanding of cultural landscapes as the result of long-term biological and social relationships, shaping the biological and material features of the landscape and also memory, experience, and knowledge". In practice, this can manifest in a variety of landscape features and ecological systems; each with distinct indicator species, archaeological deposits, and cultural associations.

The BCH concept is a relatively new and developing framework, where the biological makeup of the heritage site exists as a cultural indicator in its own right, in addition to the structures and deposits of archaeology and heritage. It originated from human intervention and endures beyond the life and preservation of any structures and activities linked to their origin. In this way, BCH represents a heritage perspective that specifically and uniquely attests to living artefacts as a complex system.

This article introduces a type of BCH overlooked so far, viz. stone-built pastoral enclosures, and introduces case studies in two territories on the Atlantic coast of western Europe (Figure 1) currently involved in endogenous processes of biological conservation and investigates parallels between the two. Using historical parallels of mixed pastoralism as a starting point, the study focuses on two zones of archaeological interest, assessing the establishment of functional stone-built livestock enclosures as indicators of local tradition. The paper goes on to look at how long-established and recently abandoned pastoral activities in these enclosures have manifested specific changes in local plant communities, leaving an adapted and indicative biological culture in their place. The first site, Frojám (or Froxán, Figure 1) is an Indigenous and Community Conserved Area (ICCA) in Galicia (Spain, NW Iberian Peninsula). In contrast with state-driven protected areas that often marginalised human communities living and interacting with rural spaces in traditional forms, ICCAs have emphasised the relevance of indigenous communities in the management and conservation of biodiversity [5] and biocultural heritage. Thus, this represents a paradigm shift from conventional approaches to the conservation of protected areas by recognising customary practices in the conservation of biological and cultural diversity [6]. The second case study, Ladydown Moor, St. Breward (or St. Bruwerd, Figure 1), in Cornwall (SW England), is also conserved by community and voluntary groups under the provisions of the Commons Act (2006) and the Countryside Rights of Way Act (2000), though ownership of parts of the area are now unclear [7]. Under this joint legislative protection, locals are granted rights of grazing and access to the traditional land holdings on the moor and are encouraged to be part of the decision-making process for aesthetic and management changes via local government-led initiatives [8]. Frojám and Ladydown areas share relatively similar ecological conditions, which make them comparable systems from the environmental perspective. The geological substrate in both cases is granite, over which siliceous acidic soils have developed [9,10]. Coastal Galicia and Cornwall belong to the same biogeographical unit, the European Atlantic province [11]; a wide region including the western European regions from northern Portugal to southern Norway and encompassing the entire British Isles.

More apposite however, the temperate hyperoceanic bioclimate existing in the areas of study has a reduced distribution in Europe, restricted to Ireland and narrow Atlantic fringes in north-western Iberian Peninsula, Brittany, and Great Britain [12]. This bioclimate is characterized by constant moisture and mild temperature, with a short annual thermic interval (<11 °C) [13,14]. In the case of Galicia, the hyperoceanic climate is represented by a Submediterranean variant, with a perceptible fall in precipitation during the summer. The area of the Frojám enclosure lies in the Barbança mountain range at 500 m AOD (above ordnance datum), and summer drought is mitigated due to altitudinal compensation of water inputs [15]. This pattern of dry summers is historically reflected in Cornwall, although in recent years there has been a noticeable increase in summer rainfall, leading to a disruption in traditional farming practices on the peninsula [16].

In addition to historic cultural practices, the combination of climate and soil is a key determining factor for vegetation, being similar in lowland and submontane areas of the north-western Iberian Peninsula and south-western Great Britain. Forests are dominated by Oak woodlands (*Quercus robur*) with birch (*Betula alba*) and other acidophile species [17,18]. Interestingly, the grassland vegetation of pastureland in submontane-montane coastal Galicia (mesotemperate and lower supratemperate belts) and Cornwall have been grouped in the *Violion caninae* phytosociological alliance [19]. It is classified in the Class Nardetea, and so it is considered a priority for conservation European habitat (European code *6230) [20], in spite of the reduced occurrence of *Nardus stricta* in both areas [19]. This community was named *Agrostis curtisii* grasslands by Rodwell [21] and is dominated by *Agrostis capillaris*, *Agrostis curtisii*, *Danthonia decumbens*, and *Avenula sulcata.*

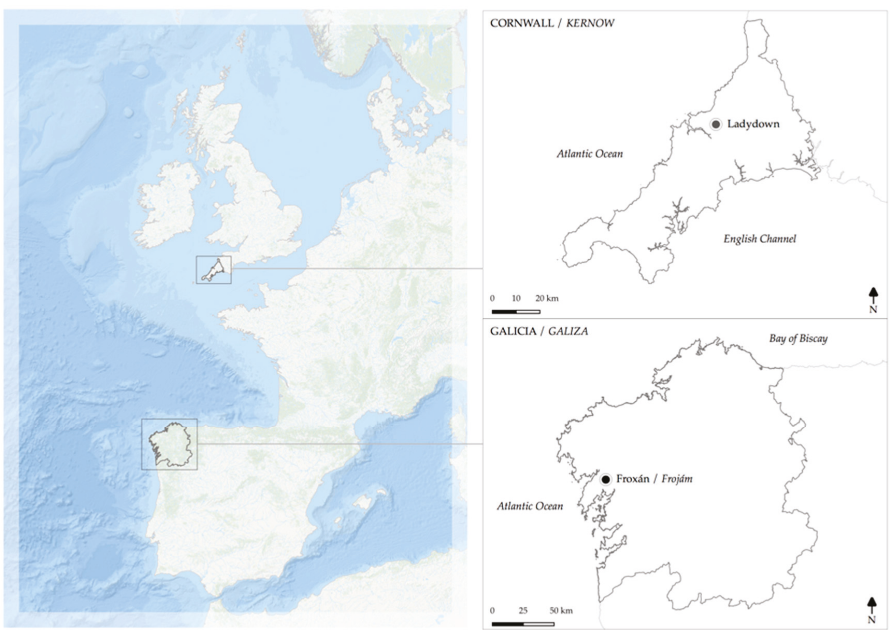

Figure 1. Location of the case-study areas.

In moist, acidic peaty soils in both regions, vegetation originally developed as wet heaths and bogs with *Calluna vulgaris*, *Erica tetralix*, and *Erica ciliaris*, in a mosaic with *Sphagnum* and Cyperaceae/Poaceae wet grassland communities. This type of mixed formation has been reconstructed through the Holocene with pollen data and plant macrofossils in peatlands of north-western Iberia and south-western Great Britain [22,23]. Plant macrofossils allow a good reconstruction of the local vegetation at different temporal layers, and when this information is combined with information from charcoal remains the prevailing communities can be identified in relation to putatively anthropic burning [24]. Although the resulting vegetation is a product of complex interactions dependent on local historic processes, continued grazing in enclosures should have led to the replacement of healthy vegetation and the expansion of pre-existing grassland communities, dominated by *Molinia caerulea* in the wettest parts [25].

Nevertheless, the process of vegetation turnover in heathlands is complex and can differ significantly between regions. Whereas in Galicia, *Molinia caerulea*, and *Agrostis curstisii* grassland have been historically a relevant constituent of peatland and wet heath systems [23], vegetation reconstruction in some British moors do not follow this pattern and peatlands have revealed a late relevance of *Molinia caerulea*, with a clear prevalence only after the industrial revolution [26]. Therefore, agents other than traditional grazing and burning have to be invoked as responsible, like increased atmospheric input and/or changes in grazing pressure [25]. However, vegetation in historical pastoral enclosures is inferred to have arisen from the effects of routine domestic herbivory over centuries, coupled with practices historically associated with pastures, moorland, and heathlands to maintain these ecosystems, such as burning [27]. Species turnover due to customary grazing and mechanisms of the new dominant species to endure after grazing abandonment has been described in the acidic grassland species *Brachypodium pinnatum* in Western Pyrenees [28]. In the same way, an analysis of British grasslands showed that the seed bank was dominated by propagules of species associated with eutrophic grasslands, so vegetation change would prove difficult to reverse [29]; however, this pasture endurance through seed bank dominance seems more related to improved grasslands than to unimproved grasslands. These descriptions of historical and environmental processes affecting the Ladydown and Frojám enclosures, as well as the composition of plant communities currently occurring, therefore allows for the determination of biocultural heritage artefacts within these zones as indicators of traditional activity in their own right. The further impact of community engagement as a mechanism for conservation of these rural assets in Galicia and Cornwall was analysed and compared in this study.

The main purpose of this article is to value the stone-built pastoral enclosures, analysing dimensions, materials, and construction technologies, and their influence in the current habitats and plant biodiversity, and the image of landscape, this analysis will occur within a framework of nature conservation, landscape planning, and management and heritage preservation on the basis of long-term biological and cultural relationships between people and their surroundings.

2. Pastoral Stone Enclosures: A Biological Cultural Heritage

Pastoral stone enclosures in Atlantic Europe were already common in the Bronze Age. Although many such enclosures served the immediate agropastoral needs of a given community, others likely had additional functions as central facilities for surrounding communities both for tending and controlling livestock (e.g., culling, marking, shearing, and safeguarding from predators) and as places of ritualized gatherings, public hearings common ceremonies, and trade [30]. Being coeval with Bronze and Iron Age hilltop enclosures in Galicia and Britain, some early enclosures possibly served simultaneous or shifting agropastoral-defensive functions while other were obviously too large (i.e., >40 ha) to perform military functions [31] but occasionally included hillfort features such as ditches and present evidence of human occupation such as small huts or *chouços* (where shepherds or cattle could shelter) or permanent settlements as in the 'banjo' type enclosures of the British Middle Iron Age [32,33].

In Cornwall and neighbouring Devon, Iron Age pastoral enclosures are exemplified by those of the Dartmoor area (30U 436281 5602042, datum WGS84) concentrated on the south side of the moor, usually on south-facing slopes above river valleys close to a water supply, according to Cunliffe [34]. In this area, Shaugh Moor (30U 426212 5588925, datum WGS84) is an interesting example that includes pastoral enclosures, burial cairns, and stone-walled huts, with evidence of continuous use from the second millennium BCE to the 9th century CE [35].

In more general terms, the settlement and enclosure of the Cornish peninsula are in contrast to the counties of Devon, Dorset, and Somerset. The pattern of grouped field systems with scattered farmsteads has endured in this region to a greater extent, where inland (in more intensively farmed and populated areas) the village became the de-facto settlement type [36]. Post-medieval enclosure in Cornwall can also have been said to progress at a reduced rate and lesser extent to other areas of England and Wales, with a significant percentage of tillable land structured and enclosed by the 17th

Century [37] with the retention of these forms to a greater extent than counties to the east, where later parliamentary enclosure is the dominant driver of extant agricultural landscape formation.

In Galicia, although agropastoral structures (e.g., enclosures, walls, and huts) have received little archaeological attention, recent finds in the Barbança mountain range [38–40], in the proximities of the Frojám site, have revealed not only their abundance but also their continued use over millennia. As in Cornwall, the spatial distribution of these structures is often conditioned by existing sources of fresh water and adequate orography [40]. Erected through dry stone gathered in the surroundings, enclosures often feature remains of huts or other types of shelters within their perimeter or built into the outer walls, built to the height of a person [39].

2.1. The Frojám Enclosure as a Case Study in Galicia

Located in the proximity of the Barbança mountain range where similar structures have already been documented [38–40], the Frojám enclosure stands out for its large dimensions. The granite dry-stone walls (whose construction is UNESCO Intangible Cultural Heritage of Humanity since 2018) are at the top of the Gironha mountain (29T 515908 4733504, datum WGS84) at altitudes ranging between 450 and 500 m, and have two discernible sections (Figure 2). The first and larger section has a perimeter of approximately 1 km enclosing 5 ha of land while a second smaller enclosure is formed through an additional 500 m stretch of wall encircles an additional 2.5 ha. The enclosure lies within the customary lands of the Frojám Commons (‘*monte vizinhal em mão comum*’) that currently stretch over 100 ha, not serving as a boundary demarcation of any kind, with only the southern tip of the perimeter touching the community boundary at a vertex.

The larger and perhaps older enclosure has a slightly triangular shape with rounded edges, following the natural orography, with a spring (‘*Fonte de Ramo Curvo’)* at its northern tip that was likely modified to serve as a watering hole for livestock (Figure 2). The smaller enclosed area to the south (Figure 2) surrounds a peat wetland called ‘*Campo de Lamas*’ (literally, ‘mud field’). Although signs of collapse and buried sections indicate a greater original height, most sections currently above ground do not exceed 0.5 m from the surrounding ground surface, making it difficult to discern from the taller scrub. Compared to its immediate surroundings abundant in granite outcrops, the enclosed area presents deeper soils which, together with access to water supply, seems to be the rationale behind the choice of the perimeter. This could relate to the availability of pastures during the drier seasons but perhaps also to the use of the area as a ‘*seara*’ (communal open field, used for the cultivation of rye or wheat in winter and spring) which kept livestock *out* of the enclosed area.

Several hypotheses have been raised [15] to account for the enclosure’s unusually large dimensions compared to other known Galician examples. Placed at the watershed divide between the Ulha and Tambre river basins, the site could have hosted a seasonal inter-community livestock fair, a possibility hinted by existing oral lore that identifies Gironha as a place of annual assembly for supernatural beings. Alternatively, as suggested, the enclosure could have served to keep the community flock concentrated *in* the area with the most abundant pastures during the summer while keeping them *out* during the period of cultivation of winter grains.

Figure 2. Orthoimage highlighting visible and probable sections of the Frojám enclosure. Based on IGN PNOA (*Plan Nacional de Ortofotografía Aérea*) 2008 images taken after the 2006 forest fires.

In spite of its dimensions, it was only during mechanical clearance made prior to a tree plantation in 2016 that a section of the enclosure was first noticed by community members (Figure 3). Although the local community is intimately familiar with its ancestral lands in which pastoralism endured until forced common land seizures in the 1940s, the structure had gone unnoticed. Orthoimages taken in 2008 (after forest fires in 2006) revealed the extent of the enclosure (Figure 2) and in 2017, after a preliminary archaeological field visit, a request was made for listing the site as protected heritage. Since its discovery, the local community has remained committed to preserving the site as part of its larger conservation efforts. This commitment has materialized through the natural beaconing of cleared wall sections and the incorporation of the enclosure in a conservation plan issued to restore the adjacent peat wetland [15]. While the ongoing wetland restoration process serves both biodiversity targets and community adaptation to climate change (by regulating water supply), the recovery of the enclosure is part of the community's reconnection with its pastoralist past.

Although the village itself is certainly older, Frojám appears for the first time in written records in a 1409 manorial agreement that set a rent to be paid in bread. The importance of pastoralism is evidenced in a 1527 manorial deed, were the annual collective rent to be paid to the feudal lord includes 'a good ram and two goat kids' ("*un buen carnero et dos cabritos*"), in addition to a rent to be paid in rye. Two centuries later, a renovated 1709 manorial deed established the obligation to serve two rams and three goat kids to the Marquises of Mos together with other goods that continued to be delivered annually by the commoners in Pedra d'Ouro, Noia. This deed also described the precise perimeter of the community's territory through various landmarks, including the '*Lage da Pedra Vigia*', a large granite outcrop by the '*Campo de Lamas*' peat area that also serves as a southern vertex for the enclosure. This microtoponym (literally 'Watchers Stone') at a place that would allow for the control of the enclosed area perhaps refers to its ancestral pastoral use.

As presented in Table 1, in the 1753 Marquis of Ensenada census, conducted across the Crown of Castille, Frojám appears with eight households, all of which kept livestock that included sheep, rams, goats, bucks, cows (2 or 3 per household and a similar number of calves), mares, mules, and pigs (either exclusively owned or in a form of joint ownership called '*parceria*'). A total of 1753 livestock (188 heads, excluding stabled cattle and mules) are reflected illustrating the community's pastoral load at a time in which the enclosure may have still been in use; lack of living memory and state of conservation indicate abandonment prior to the 20th century.

Table 1. Livestock per household in Frojám according to the 1753 census [1].

Commoner	Sheep	Rams	Goats	Bucks	Mares	Total
Domingo Devesa	7	7	20	2	1	37
Esteban da Costa	10	1	14	1	-	26
Francisco de Albagueira	5	2	-	-	-	7
Joseph San Lois	5	2	13	-	-	20
Lázaro Romero	19	7	-	-	1	27
Lucas da Costa	14	4	2	-	-	20
Manuel Romero	6	3	5	-	-	14
Thomas Cao	22	9	-	4	2	37
TOTAL	88	35	54	7	4	188

[1] Arquivo do Reino de Galicia 2881 and 2882 Expediente do Catastro de Ensenada de Santa Eulalia de Vilacoba.

Manorial obligations (codified through '*foros*') were sustained in Frojám until 1928 when villagers extinguished feudal ties with the Viscounts of São Alberto in exchange for a monetary payment of 6049 pesetas [41]. This meant that for the first time in centuries, villagers fully owned their smallholdings and common lands, but for the latter, ownership would prove to be short-lived. In fact, traditional pastoralist practices ended abruptly in Frojám in the 1940s with the usurpation of the village's common lands by the State forest services (*Patrimonio Forestal del Estado*), a phenomenon occurring throughout Galicia at the time.

The oldest villagers, now almost in their 100s, recall how before land seizures each of the village's households (four at the time) had a flock of 30 to 60 sheep and goats—mostly sheep—that were taken up to graze year-round in the commons. In 1940, the joint flock numbers essentially match the recorded 18th century load, perhaps indicating an ecological equilibrium. Oral memory matches existing 20th century records, as in the 1905 partition deed of Pedro Cau Boullón (a descendant of Thomas Cao) that left 15 sheep (valued 60 pesetas) and 20 goats (valued 100 pesetas) to his heir, the exact same number of heads his ancestor had in 1753.

The flock was shepherded up in the mornings and brought back at night—a task usually undertaken by children and adolescents—but remained to its own avail during the day as wolves and other predators did not appear to represent a significant threat. As the joint flock of roughly 200 head would stay together, and every village house had its own earmark that served to identify ownership of individual animals in case of doubt—although sheep are said to have headed back to their respective 'homes' without guidance.

Franco's regime forcibly turned the Galician village commons into productive forest monocultures, ending this age-old agropastoral system [42]. The first pine plantations were carried out in Frojám and neighbouring commons in 1947 in spite of fierce opposition and contestation—a total 389 ha of Maritime Pine (*Pinus pinaster*) and Monterey Pine (*Pinus radiata*) were planted in the late 1940s. Heavy fines were levied to those caught taking their flock to mountain pastures now riddled with newly planted pine trees. Although forest services designated a steep and poor area in the Eastern mountain slope as '*zona de pastoreo*' ('grazing area') villagers were forced to sell their flocks lacking their indispensable land base.

Sheep and goats were the main source of meat for year-round consumption and also generated monetary revenue by periodical sales in markets, particularly to pay '*foros*' and land taxes ('*contribuição*'). Usurpation represented a severe blow for the community during the famine brought by the 1936–1939 Civil War. From the 1950s onward, each house kept no more than five sheep (vs. 30–60), in addition to six cows and oxen, a few feral horses ('*bestas*' or '*garranos*', a breed similar to the Cornish Dartmoor

Pony) and other house animals such as pigs or donkeys. Today only two of the now five commoner houses still keep sheep for self-consumption. Although cows and feral horses were taken to fields and nearby common land areas that were not planted, the almost total suppression of herbivore pressure in the old mountain pastures together with the introduction of pine monocultures and other measures such as wetland drainage represented a significant change in landscape and a disturbance of existing habitats.

In 1975 villagers initiated the process to reclaim ownership of the commons in spite of strong opposition from the municipality, and legally achieved recognition as a '*monte vizinhal em mão comum*' in 1977. State management of communal lands continued until the last ties with the administration were broken in 2002, signalling full community control and self-management. However, the landscape handed over in 2002 had little in common with the one seized by the state 60 years earlier. Pastoralism had virtually stopped with the exception of some feral horses that still roamed around and the land presented deep scars left by tin and tungsten mining, forced drainage of peatlands, introduction of pyrophyte tree species (*Eucalyptus* sp., *Acacia* sp., and *Pinus* sp.), and subsequent waves of forest fires.

In spite of the daunting scenario, Frojám, with just 20 inhabitants, has become an example of how community-based projects can make a difference in restoring biocultural heritage [43–45] and even reformulating hegemonic top-down conservation projects in Western societies [46]. A management plan drafted in 2018 to restore the '*Campo de Lamas*' wetland within the enclosed area was selected as one of four pilot case studies in Spain of climate change adaptation of natural management initiatives [15]. Lack of resources to implement restoration work has been met through volunteer initiatives (such as the '*Brigadas deseucaliptizadoras*') mobilizing hundreds of individuals to remove invasive exotic tree species and restore native habitats. This has led to swift changes in the landscape moving away from the previously dominant Eucalyptus plantations to a mosaic of recovering natural habitats. Besides being among the first UN acknowledged Indigenous and Community Conserved Areas in Europe, Frojám is also within a Special Landscape Interest Site (LEIP) and has been designated as a Natural Site of Educational Interest. It is also one of the first self-declared 'No-go areas' for mining as part of the community's struggle to end environmentally degrading activities [47].

While the community sustains the return of mountain pastoralism as an aspirational goal that would see the area of the enclosure back to its ancestral use, the '*Campo de Lamas*' management plan incorporated a solution conceived by the community itself: 'natural beaconing' or 'biobeaconing'. When the first section of wall (Figure 3) was noticed in 2016 during scrub clearing works, the community decided to place a 3 metre strip at each side of the enclosure followed by a row of *Castanea sativa* that, being a relatively fast-growing species, would function as a 'barricade tape' to avoid future damage due to mechanical clearing. Chestnut trees (*Castanea sativa*) also provide cover to control undergrowth that would eventually allow the appreciation of the structure with little or no maintenance. For '*Campo de Lamas*', the management plan suggested using *Salix atrocinerea* and other hydrophilic species already present.

Natural habitats in Frojám have suffered dramatic alterations since the forced abandonment of pastoralist practices in the 1940s. The potential vegetation would be a silicicolous deciduous broad-leaved oak (*Quercus robur*) forest, with birch (*Betula alba*), alder buckthorn (*Frangula alnus*), and willow (*Salix atrocinerea*) as pre-climax stages. The vegetal formation is in the altitudinal interface of two Galician-North Portuguese oak woodland types, defined by the submontane/montane *Vaccinio-Quercetum roboris* and the lowland *Rusco-Quercetum roboris* associations [48]. However, current vegetation is composed of gorse-heath shrubland, degraded pine, and eucalyptus plantations and grassland in a few areas.

Figure 3. Dry stone sections of the Froján enclosure (Photographs: Joám Evans Pim).

The whole zone has suffered repeated burns during the last decades (1975, 1993, 2000, 2006, and 2016), affecting the productivity of pine and eucalyptus forest plantations. Interestingly, the deeper soils of the enclosure have allowed faster recovery of plantations compared with the more degraded soils in surrounding areas.

Ulex europaeus, *Calluna vulgaris*, and *Erica cinerea* are the dominant species in the shrubland, with significant coverage of *Erica umbellata* in areas with shallower soils. This shrubland vegetation is classified in Annex I of the 92/43/CEE European Habitats Directive [20] as 'European dry heaths', habitat of community interest (code 4030). Other gorse-heath formations occur in the Froján enclosure, yet restricted to '*Campo de Lamas*' peatland, dominated by a different gorse species, the Western gorse (*Ulex gallii*) and two hygrophilous heath species (*Erica ciliaris* and *Erica tetralix*), although *Calluna vularis* is also abundant. Two subtypes can be identified, with the Western gorse-wet heath community occupying the external parts of the wetland, and purer ericoid formations in the areas with a higher water table. This habitat is classified in Annex I of the 92/43/CEE European Habitats Directive [20] as a priority habitat under the name 'Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*' (code *4020).

Grassland should have occupied the main part of the Froján enclosure when pastoral practices were active, as images from the 1945–1946 American Series A Photogrammetric flight seem to suggest. As a serial formation, grasslands tend to be replaced by scrub plant communities once grazing and trampling have finished. These practices have been mostly absent in Froján during the last 70 years, so we expect grassland to be decreasing in the area.

However, two hygrophilous grassland types are currently inside the Froján enclosure. The most abundant is represented by wet meadows dominated by *Molinia caerulea*, accompanied by tall-growing herbs, mostly *Deschampsia flexuosa* and *Agrostis hesperica* and some rushes and sedges and smaller herbs, and *Sphagnum subsecundum*. This habitat could be included in the habitat of community interest '*Molinia* meadows on calcareous, peaty, or clayey-silt-laden soils (*Molinion caeruleae*) (code 6410)' in Annex I of the 92/43/CEE European Habitats Directive [20]. Although species-poor *Molinia* grasslands on acidic soils are generally excluded from the 6410 habitat definition of Annex I, analyses of organic carbon content in the soil of '*Campo de Lamas*' identify this wetland as a minerogenic bog with peat accumulation (Serrano et al., unpublished data).

The other community is a hygrophilous species-rich caespitose acidophilous grassland dominated by *Agrostis* species, including grasses and herbs as *Agrostis capillaris*, *Agrostis curtisii*, *Agrostis hesperica*, *Avenula sulcata*, *Potentilla erecta*, *Carum verticillatum*, *Danthonia decumbens*, *Pseudarrenatherum longifolium*, *Gentiana pneumonanthe*, *Serratula tinctorea*, *Carex binervis*, and *Galium saxatile*, with some presence of *Molinia caerulea* and *Agrostis stolonifera*, among others. This type of community has been included in the association *Galio-Danthonietum decumbentis* [19] in the *Violion caninae* alliance of pasturelands in extremely oceanic environments in the European Atlantic Arc. Thus, the so-called '*Agrostis curtisii* grasslands' community [21] from the south-west has been considered ascribable to this alliance [19]. Despite the scarcity of *Nardus stricta* in these communities, they belong to the *Nardetea* phytosociological class and consequently have been classified under the priority habitat 'Species-rich *Nardus* grasslands on siliceous substrates' (*6230 code) [19].

Wet heaths and *Molinia* grassland communities appear intermingled in '*Campo de Lamas*' in the areas with a higher water table, with the *Agrostis* hygrophilous grassland occupying some parts of the outer rim of the wetland. Under Froján environmental conditions, the wet heath vegetal community should prevail in the wetland; however, it covers only 17% of the area, while *Molinia* grassland covers 70% of the area, having the peripheral *Agrostis* hygrophilous grassland the lesser extent, with 13% coverage of the wetland remnant.

2.2. The Ladydown Moor Common as a Case Study in Cornwall

Situated 9 km south-east of the north Cornwall coast at Port Isaac Bay, and 5 km south-west of the regional high point on Bodmin Moor, Ladydown Common (sometimes 'Lady Down', Figure 4) is an area of mixed heathland and 'in-bye' grassland at 233 m above sea level (30U 381192 5601778, datum WGS84). The area falls within the Cornwall Area of Outstanding Natural Beauty, and comprises approximately 49 ha of common grazing land. It is listed in the national register of Common Lands—entry 124—as part of a larger grouping totalling 162 ha, of which Ladydown forms the south-western tip [49]. The immediate area features a minimum of six stone cairns; some of which appear to be clearance cairns, though at least two are likely to have been sepulchral [50,51]. There are further partially buried remains of a settlement including hut circles and associated field systems, most likely to be late Iron Age in establishment [50].

To the immediate west of the survey area is the village of St. Breward ('St. Bruwerd' in Cornish), which comprises three adjoining linear settlement zones known as Row, Churchtown, and St. Breward; each situated on the upper slope of the Camel river valley, which runs NE–SW to the west of both the village and the moorland zone. St. Breward itself is not listed in the Domesday Book, though the nearby settlements of Blisland and Hamatethy are, indicating continued settlement in the region of the moor. The 2011 national census recorded 919 residents within the parish, which also includes the Hamlet of Fentonadle, which lies around 1 km to the north-west of Churchtown, within the valley.

Granite extraction has formed the major economic activity in the area for much of the history of the settlement, with the high-quality building stone being exported nationally (including for the construction of London's Tower Bridge and Thames Embankment) [52]. More generally, the area comprised small groups of farmsteads (typically between 5 and 20 ha) of stone-enclosed mixed grazing and arable land with shared commons. The local economy also supported other extraction operations (some predating the industrial period), China Clay quarrying, and coastal fishing.

Population and settlement fluctuations within the area are linked to the operation of these extraction operations and are evidenced by the partially-buried settlement remains on and around the common, and by the patterns of enclosed 'in-bye' field systems without attendant homesteads. Earlier habitation and land use are indicated by the hut circles and megalithic monuments that are found across the area, which include the Fenacre stone circle, five standing marker stones, and a stone cross, of which only the base now remains in place [53]. Further prehistoric features have been recorded at nearby Stannon Quarry, most notably burials dating to the Bronze Age [54].

Significant demographic change took place across the region during the mid-part of the 20th century, driven by international conflict and the mechanization of agriculture and extraction operations. Farming became economically unviable on the traditional small scale and resulted in many landholdings becoming conglomerated into the larger commercial operations more recognisable today. This led to the near abandonment of unproductive or difficult to manage areas in upland zones such as Bodmin Moor, including the adjoining commons of Ladydown (Figure 4) and Emblance Down.

Whilst industrialised agriculture now envelops the area with post-medieval enclosures of sub-rectangular fields and centralized farmsteads, the isolated nature of the common and proximity to both mineral extraction zones and archaeological features have meant that full encroachment of grassland 'improvement' has been limited. Ladydown Common is therefore a representative area of the at-risk heritage of the characteristic Cornish Killas landscape zone, comprising areas of unimproved grassland and traditional vernacular stone-built livestock and land management structures [55]. It is formed of upland heath (also known as moorland) plant communities, a semi-natural habitat with long histories of seasonal land management with livestock and mixed cropping.

Bodmin Moor as a whole constitutes the most south-westerly upland zone in England and is a key component of both the Cornwall Area of Outstanding Natural Beauty (AONB). The region is included in the Cornish County Conservation Area on account of the mix of cultural and natural heritage preserved within it and is a designated Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act of 1981. Ladydown forms a component of this landscape joined to the local peak of Brownwilly Tor (Cornish: *Bronn Ewhella*) through a series of linear common land links which include the neighbouring Emblance and Treswallock Downs. The grouping falls under the joint protection of the Commons Act (2006), and the Countryside Rights of Way Act (2000) through the mechanism of the Area of Outstanding Natural Beauty designation. In practice this designation enables locals to access grazing areas for livestock in traditional open field management practices despite much of the land now being in private ownership, and also places land management and planning decision-making in the hands of local stakeholders (not exclusively landowners). This dual-level of protection ensures heritage, aesthetic, and habitat conservation measures are given due consideration within any application to build, demolish, or change land-use patterns.

Habitats related to the heritage land use of the Common are reliant on the continued management of landscapes, as the natural climax communities are a mix of Oak–Birch woodland and blanket bog. Within the common itself there are two distinct plant communities linked to former livestock enclosures and land management within the common. Adjacent to the modern stone-walled field enclosures there are the recognizable mix of Bent (*Agrostis capillaris*) and Rye (*Lolium perenne*) grasses, with a deep Moss thatch. Away from the recognizable grazing zone, onto the greater area of the Moor, the Grass sward includes Common Cotton (*Eriophorum augustifolium*) with a predominant coverage of Bent species (*Agrostis curtisii*, *Agrostis capillaris*), with Sheep's Fescue (*Festuca ovina*) and Purple Moor Grass (*Molina caerulea*) also present. This so-called species-rich '*Agrostis curtisii* grasslands' community [21] from south-west Great Britain has been considered ascribable to the *Violion caninae* phytosociological alliance [19] and therefore to the *Nardetea* class, what leads to its classification in the priority habitat *6230 [56]. Herbaceous hygrophilous species of the Moor are typical of the upland moorland habitat and include *Molinia caerulea*, Tormentil (*Potentilla erecta*), and Heather (*Calluna vulgaris*), with Common Bramble (*Rubus ulmifolius*), Hawthorn (*Crataegus monogyna*), and Blackthorn (*Prunus spinosa*) at the margins, principally as plant populations on and adjacent to the dry stone walls (whose construction is UNESCO Intangible Cultural Heritage of Humanity since 2018, Figure 5); forming the common 'Cornish Hedge'. This formation dominated by Purple Moor Grass can be included in the *Molinia caerulea-Potentilla erecta* association [21]. This is a species-poor community that develops on acidic substrates under intensely oceanic climates, and it is not included in Annex I of the Habitat Directive, corresponding to the British National Vegetation Classification (NVC) M25 *Molinia caerulea-Pontetilla erecta* mire.

The stone enclosures of the study zone are multi-phase in construction and differ in condition and preservation today (Figure 4). The area contains a section of a mixed Cornish hedge and a dry-stone wall (Figure 5) along its north-west edge, forming the boundary to the adjoining modern field systems. This is the best-preserved feature of the area, in excess of 2 metres in height, made of alternating lodged stone in a herringbone pattern, with soil infill and a combination of grasses, moss, and herbaceous plants along its length, including Hawthorn (*Crataegus monogyna*) and Bramble (*Rubus* ssp.). Immediately adjacent to the hedge, to the south-eastern side, runs a grassed ditch almost a metre deep in places. The lack of terminal outlets for this ditch suggests it is generated by sheltering animals moving along the boundary, and not as a drainage feature.

Within the area of the moor to the south-east of this boundary, there lies partially buried remains of enclosure wall (Figure 6), adjacent to the similarly buried remains of a former settlement [57]. In addition, approximately 200 m to the north-east of these features are the earthwork remains of a further livestock enclosure of indeterminate age. The extent and nature of these features have not been investigated through excavation, though habitual close grazing has resulted in some areas of both these features becoming exposed. The southernmost linear enclosure feature measures 1 to 1.5 m in width, but is almost entirely buried, apparent for the most part as a result of the different vegetation that grows over the feature. At no point along its length is the structure any greater than 0.5 m higher than the ground surface around it. This form is echoed in the adjacent cairns (both clearance and funerary), and the archaeological remains of the former settlement. The northernmost enclosure features are more prominent in the landscape, possibly as a result of its proximity to a modern gateway, where the collection and feeding of cattle take place at times of the year, causing increased erosion of soil around the features. The buried linear feature here is in excess of 2 m in width near to its NE terminal end and is in excess of 1 m in height for much of its length. The feature effectively merges with the landform after a length of around 20 m (running NE–W).

Figure 4. Orthoimage highlighting Ladydown Moor and its introduced structures. Source: ESRI World Imagery (Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community).

Figure 5. Dry stone sections of the Ladydown Common enclosures, in the form of a traditional Cornish Hedge. Scale 50 cm (Photograph: Richard Grove).

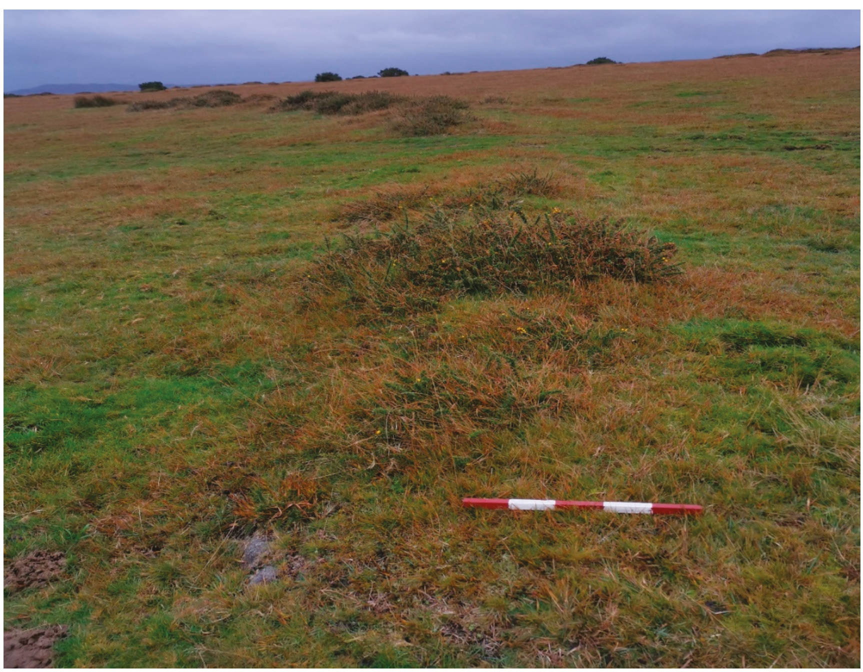

Figure 6. Partially buried stone sections of the Ladydown Common enclosures. Scale 50 cm (Photograph: Richard Grove).

3. Discussion: Biocultural Heritage Manifestations and the Role of Community-Based Conservation

Frojám and Ladydown enclosure areas share comparable environmental conditions in terms of climatic and edaphic variables. However, they represent different stages regarding the traditional pastoral activities that justified their ancient construction. While Ladydown is still open to grazing, Frojám has suffered a severe process of disturbance of the traditional biocultural environment by drainage and forestry plantations of pyrophyte tree species [15]. Thus, Ladydown has an important coverage of grassland habitats evidencing the long-term continuity of pastoral uses, with a hygrophilous species-rich *Agrostis curtissi* grassland as a predominant community, in a mosaic with *Molinia* acid grassland and other hygrophilous formations in the wettest places. The *Agrostis curtissi* grassland is a hyperoceanic community only occurring in Great Britain in Cornwall, SW England and far South Wales [25], being classified under the priority for European conservation 6320* grassland habitat type [19].

Conversely, the absence of pastoralism would have made Frojám unsuitable for the development of grassland habitats, which should have existed in the past. Serial gorse-heath shrubland is expected to predominate under current conditions, with climatic wet heaths of *Erica ciliaris*, *Erica tetralix*, and *Calluna vulgaris* (4020* Habitat directive code) in mosaic with *Sphagnum* bog in the peaty wetland. Although the grassland representation in Frojám is quite inferior in land coverage than in Ladydown, it is greater than would be expected. The *Molinia* peaty grassland (6410 Habitat directive code) and Agrostis grassland (*6320 Habitat directive code) are still found in Frojám, albeit confined to the peaty wetland of '*Campo de Lamas*', where the former is overwhelmingly dominant.

This endurance of grassland after decades of grazing interruption can be interpreted as a marker of past traditional practises and, therefore, a manifestation of biocultural heritage [3,4]. *Molinia* grassland predominance over *Erica ciliaris* and *Erica tetralix* wet heaths on acidic/oligotrophic wet environments are interpreted as the result of historical processes, including traditional practices, which increase the soil nutrient content and promote vegetation replacement. Traditional pastoralism produces eutrophication by combining recurrent burning and grazing [58,59]. The Atlantic wet heath habitat is extremely dependant on oligotrophic conditions, and organic matter and nutrient changes in soil derived from burning result in substitution by *Molinia* grassland [60]. The concentration of grazing livestock is a driving factor for increasing soil nitrogen content, eventually leading to the predominance of *Molinia* grassland over wet heath communities [61]. Once established under conditions of increased nitrogen availability, the competitiveness of *Molinia* will be kept through efficient mechanisms of nitrogen sequestration [62] that could result in a durable vegetation shift.

In Ladydown, the wet heath community is currently absent, as would be expected under the long-term active pastoral practises. This habitat occurs in nearby areas of Bodmin Moor, although the community is impoverished since *Erica ciliaris*, an endangered species in Great Britain, shows a gap in its distribution range in the region [17]. In Frojám, the wet heath community shows some recovery, intermingled with the relatively species-poor *Molinia* grassland. Interestingly, in Frojám remnants of the hyperoceanic hygrophilous species-rich *Agrostis* grassland of the Nardetea class (habitat directive code *6230) can still be found. This interesting vegetal community is well distributed in other areas with strong grazing pressure in the Barbança mountain range. Under hyperoceanic climate conditions, this community covers the pasture uplands that otherwise would be covered for more dry grasslands [19].

The peaty wetland associated with the Frojám enclosure has worked as an unexpected refuge for this hygrophilous community in the absence of grazing, preserving both the grassland as a biocultural heritage marker and a reservoir for species recovery. In fact, since the activities of environmental restoration initiated in Frojám, this habitat, previously confined to a rim bordering '*Campo de Lamas*' wetland, has expanded to cover the surroundings forestall trails. The reasons why the grassland community was not ousted by gorse scrub formation since the abrupt stop in the traditional practices remain unclear, although annual water level oscillations and possible herbivory from wild animals could have had some role favouring grassland habitat resilience. Remnants of habitat heterogeneity still existing both in Ladydown and Frojám enclosures represent an opportunity for conservation in the context of reactivating common land practices.

The designation of Frojám as an ICCA has implied, besides the international recognition of such territory and their custodian people, a significant shift in the management of hegemonic protected areas in Europe. Whereas state-driven parks have often marginalised human communities traditionally living and interacting with such spaces [46], the Frojám Commons has reversed this paradigm [47,63] by internally defining restoration projects and conservation goals [6] and thus facilitating the identification and restoration of one stone-built pastoral enclosure among other elements of biocultural heritage. This change links to the idea of non-institutional governance [64] and the higher engagement of local stakeholders in restoration projects in rural areas, which often imply the long-term involvement that is required to effectively address the challenge of certain invasive exotic species (in this case, Eucalyptus and Acacia) and integral landscape restoration.

Around $\frac{1}{4}$ of Galicia's total landmass (29,574 km^2) is officially classified as Common Land that belongs to 3300 Common Land Communities (*Comunidades de Montes Vecinhais*) like Frojám. Commons vary in size from a few to several thousand hectares—the average being around 200 ha—and village commons communities being anywhere from just one or two 'open houses ('*casa aberta*')—with people living in them—to hundreds or even thousands, the average being around 40 houses. All in all, approximately 15% of the Galician population lives in commons 'open houses'. While many of these commons are still managed directly by the government that has historically prioritized forest monocultures disregarding conservation and traditional uses, a growing number of self-managed commons in Galicia are giving greater emphasis to the preservation and restoration of biocultural heritage. Five such communities have already been acknowledged as ICCAs by the UN Environmental programme (Frojám, Covelo, Teis, Vilar, and Couso) while many others would likely qualify. In all these cases, communities have implicitly or explicitly assumed a biocultural approach to conservation and have become the main actors in the preservation, restoration and protection of closely interconnected elements natural and cultural heritage (e.g., burial mounds, petroglyphs, water mills, enclosures, and trails).

In England, common land formed a central part of the collectively farmed open field tradition of the medieval period. The rise of absentee landlordism in the immediate post-medieval and reformation years saw large areas enclosed for private grazing, and then relatively few common lands survived the process of 18–19th century land reforms as typified by the parliamentary Enclosure Acts. Today registered Commons (under the 1965 Commons Act) cover approximately 3% of the landmass in England (some 4000 km^2). These are often areas of high conservation value, including 40% of all existing heathland [65,66]. The same percentage applies to Cornwall that currently holds approximately 100 km^2 of common lands divided across almost 300 units. Most Cornish commons, however, are of relatively small size (40% are under 1 ha) with only 10 Commons larger than 200 ha [67]. As early as 1956, the Natural Conservancy stressed in a report to the Royal Commission on Common Land that commons were "wildlife sanctuaries", "reservoirs for species", "islands of semi-natural vegetation", and "disproportionately rich in examples of plant and animal communities which have largely been eliminated from surrounding localities" [68]. While the separation of formal land ownership and 'rights of common', in contrast with common land communities in Galicia, has sometimes lead to conflict, local communities continue to display "an impressive level of initiative and activity (...) in working to establish and maintain wildlife-rich green spaces in their local environment" [64]. An example of this proactive community conservation can be seen in the Cornwall AONB Peatland Restoration Project, a collaboration between local owners and interest groups with a private water supply company and government agencies, with the aim of halting the loss of biodiversity and habitat within the moor [5,8].

In spite of growing evidence of how indigenous peoples and local communities, through their knowledge and traditional management practices, play an active and effective role in ecosystem restoration, carbon sequestration, and prevention of environmental degradation [67], such groups continue to be considered mostly as passive recipients of restoration work while their cultural practices remain ignored in spite of being crucial to the preservation of biocultural heritage [69,70]. The findings presented in this article stress the leadership and engagement potential of local communities in bringing about effective conservation initiatives that bridge nature conservation, landscape planning and management, and heritage preservation on the basis of long-term biological and cultural relationships between people and their surroundings. From this point on, it is crucial that these relationships—both historical and contemporary—are studied and understood as drivers for both conservation and change.

4. Conclusions

As is shown in these case studies, there is a direct link between historic cultural activities and the establishment and survival of habitats and ecosystems within stone-built heritage structures. Several hygrophilous hyperoceanic grassland habitats, related to current grazing in Ladydown and historical grazing in Frojám, have been identified in both enclosures despite the cessation of pastoral practices in the latter for more than seven decades. Not only do these areas demonstrate the anthropogenic origins for what are often seen as natural habitats by the layperson, but the complex ecosystems within them are also the result of long histories of symbiotic human–livestock–landscape interrelationships. Their conservation relies upon the continuation of these long-established practices.

Taking the example of the Cornish type-site at Ladydown, the chronology for habitation and management extends back to the Iron Age at least, with archaeological deposits demonstrating local activity back to the Bronze Age. The immediate surroundings of Frojám are also home to numerous Neolithic burial mounds—including a tumulus in Frojám itself called '*Casa Velha*', 'old house', destroyed during open cast mining operations in the 1940s—similarly indicate continuous habitation for millennia. In both cases, as woodland and mire represent the potential natural successional climax for the zone, early activity must have taken the form of clearance, first of vegetation, then of surface stone, resulting in the creation of cairns that remain in situ today (in Frojám these cairns are called '*meroças*', akin to Portuguese '*maroiços*'). The unique orography of the enclosed areas in both sites relative to lowland farmlands, coupled with demographic, political, and economic changes in the area over time, led to the preservation of Ladydown Moor and certain parts of the Frojám Commons as outliers of historic habitats in areas of encroaching modernization related to mining, forestry, and industrial agriculture.

Whilst sharing a range of characteristics, the stone enclosures Ladydown and Frojám are divergent in some key aspects with regard to their conservation and management today. The moorland site in Cornwall presents some areas of exceptionally well-preserved stonework in the Cornish Hedge forming the western boundary of the moor, as well as a range of buried and partially-buried ruins within the moor itself. In contrast, Frojám presents a more uniformly ruinous structure, resulting from the woodland plantation and its management. Whilst these differences prevent direct comparison regarding the conservation management and use of the areas discussed here, the link between historic use and existing heritage endures in both the stone structures and their associated habitats, as evidenced by both the built and biological cultural heritage extant today. Whilst this study has sought to draw on a range of source materials to create this study, questions inevitably arise from the drawing of conclusions from incomplete datasets. In addressing these, a more comprehensive study would be advisable which would include palynological assessment of soil cores and geophysical survey. The addition of these tasks would provide a detailed chronology of the plant communities specific to the area, and potentially a record of cultural activity related to the creation and development of stone enclosures.

Author Contributions: First idealization, J.E.P. and P.S.; conceptualization, R.G., J.E.P., M.S., and P.S.; writing—original draft preparation, R.G. and J.E.P.; preparation of maps and images, D.C.; writing—review, R.G., J.E.P., M.S., D.C., H.V., and P.S.; editing, H.V.; supervision, P.S. All authors have read and agreed to the published version of the manuscript.

Funding: Fieldwork in Frojám is being supported by Fundação Montescola and the Frojám Community Conserved Area which in turn are grateful for support received from the European Outdoor Conservation Association. In this framework, this work was partially financial supported by a research contract with Fundação Montescola, entitled: *Estudo para o restauro da zona húmida de Campo de Lamas (Frojám, Lousame)* (2018-CL065). M.S. and P.S.

thank the financial support of Xunta de Galicia grants ED431B 2018/36 and ED431C 2018/32. D.C. acknowledges receipt of the PhD scholarship "Programa de axudas á etapa predoutoral" (ref. ED481A-2018/263) financed by the Xunta de Galicia.

Acknowledgments: The authors thank Fundação Montescola and the Frojám Community Conserved Area for their interest in the project, collaboration, and valuable assistance, and Javier Amigo (Universidade de Santiago de Compostela, Spain) for a fruitful discussion regarding habitats.

Conflicts of Interest: The authors declare no conflict of interest.

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Review

Fostering Evidence-Informed Decision-Making for Protected Areas through the Alberta Parks Social Science Working Group

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Abstract: Since 2012, the Alberta Parks division in the Province of Alberta, Canada has been engaged in a process of building scientific, research, and evidence-informed capacity and practices across the parks system. Following a series of priority-setting workshops and agreements with the research, Parks management, and local communities, Alberta Parks has adopted a working group approach and subsequent framework, to support the research and decision-making goals of parks and protected areas management, and the research communities. This Social Science Framework is an innovative way to support evidence-informed decision-making in the public sphere by explicitly linking data-specific needs (benchmark data in social, natural, and applied sciences) with both established and emerging policy and research priorities. It is also a way to situate those needs within a broader goal of inter-organizational collaboration. This paper presents the background and developmental context to the framework, and its structure and desired functionality. The paper concludes with an assessment of the anticipated benefits and potential liabilities of this direction for linking academic and policy agents and organizations in a more formalized structure for environmental policy.

Keywords: decision-making; evidence-informed policy; social science; protected areas; Alberta Parks; research

Citation: Hallstrom, L.K.; Hvenegaard, G.T. Fostering Evidence-Informed Decision-Making for Protected Areas through the Alberta Parks Social Science Working Group. *Land* **2021**, *10*, 224. https://doi.org/10.3390/land10020224

Academic Editor: Andrew Millington

Received: 25 September 2020
Accepted: 20 February 2021
Published: 23 February 2021

1. Introduction

Aichi Biodiversity Target 19 [1] calls for states to improve, share, transfer, and apply knowledge, science, and technologies to provide more and better information to support decision-making. In the realm of parks, such evidence-informed decision-making can help to improve areas such as management effectiveness, planning, and visitor experiences [2]. Commonly understood as grounded in scientifically valid and reliable research, evidence for decision-making includes not just the use of data, but also aggregation, synthesis, assessment, and analyses of those data (and their individual or collective analyses) to identify potential solutions to a broader question of "What should be done" and the complementary "How should it be done?" The choice of when, how, and how much to access evidence in management decisions is, therefore, influenced by individual judgments, an organization's culture, and an organization's rules, structures, and procedures [2,3]. Our study focuses on one agency, Alberta Parks (the provincial agency responsible for parks), to explore a process and framework developed to promote evidence-informed decision-making focused upon socially-based, and derived problems, and thus calling upon knowledge and evidence from the social sciences. For the purposes of this paper, we differentiate natural science (primarily concerned with natural events in the natural world) from social science (concerned with people and their behaviors, impacts, attitudes, and uses of parks and protected areas [4]).

Recently, Alberta Parks sought to enhance community engagement, scientific collaboration, and longer-term mechanisms to build upon its existing Plan for Parks and Alberta Parks Science Strategy (see below). Similarly, the results of an earlier prioritization process [5] illustrated that while the visitor experience is indeed important to Alberta Parks, visitor-based methodologies required a complement to support a response to the range of questions identified. These goals were countered by concerns about the scientific literacy and interest of the provincial public and elected officials, the viability of evidence-informed policy-making at different levels of the bureaucracy, and the low availability of data and or synthesis work to inform decision-making. This tension demonstrated the need to develop and validate a multi-faceted and multi-functional structure, and process, to support evidence-informed decision-making [6] within the Province. In 2016, a framework was developed for Alberta Parks to facilitate the generation of knowledge through collaborative and applied research (in the natural, social, or health sciences), and to identify mechanisms that support and facilitate the translation, synthesis, and exchange of knowledge between scientific and decision-making communities.

Principles of evidence-informed practice and decision-making originated in the sphere of public health [6–11] beginning in the early 2000s. Discussions of evidence-informed decision-making have also occurred in the spheres of social services [12,13] and education [14,15]. In general terms, evidence-informed practices and decisions hinge upon the intention to "make well-informed decisions about policies, programs, and projects by putting the best available evidence from research at the heart of policy development and implementation. This approach stands in contrast to opinion-based policy-making, which relies heavily on either the selective use of evidence (for example, on single studies irrespective of quality) or on the untested views of individuals or groups, often inspired by ideological standpoints, prejudices, or speculative conjecture" (p. 3 in [16]). Evidence-informed perspectives are not grounded upon simply the provision or use of data—rather, they are focused upon the use of data, knowledge synthesis methodologies, experiential expertise, and the inclusion of contextual factors to determine solutions to specific issues or problems. However, evidence-informed decision-making models are often more difficult to conceptualize in the fields of social and applied sciences due to the context-dependent nature of social science data. Nonetheless, the use of evidence decision-making is critical in a variety of social and applied sciences, including protected area management, the focus of this study [1,17,18].

This paper presents the framework as an innovative synthesis of models in a way that resonates with the provincial context and shifting mandate for Alberta Parks. The ensuing discussion of the structure and functionality of this framework makes the following contributions: (1) it resulted from a formal collaboration between academic and management practitioners with a specific eye to research, knowledge mobilization of that research, and decision-support for Parks management; (2) it expands the stakeholder base for such work from park visitation to a broader context of both potential participants and audiences for evidence-informed decisions; (3) it was developed in response to not only academic and management needs, but a participatory and validated research and policy prioritization process; (4) it presents a relatively generic template that is (by definition) both adaptive and responsive to local/regionalized and stakeholder contexts; and (5) it seeks to counter common assumptions about the uptake of evidence [19] by the scientific community. To do so, we position the functionality of the framework within a 'policy design' approach [20], as well as an examination of some of the limitations and challenges faced in adoption and implementation. Our broader goal is to facilitate the use of evidence in Parks and similar management environment, provide insights for other park agencies across the country and around the world to enhance their evidence-informed decision-making efforts, and to support Aichi Biodiversity Target 19 that emphasizes improvements in knowledge and science to support biodiversity [2].

2. Alberta Parks—Linking Parks, Research, and Decisions

2.1. Creating a Framework for Knowledge Mobilization in Social Science

Many models and frameworks have outlined procedures for evidence-informed decision-making, including Impact Assessments [6], the ROAMEF model (Rationale, objectives, appraisal, monitoring, evaluation, feedback) [6], Evidence-informed Medicine [10], Realist Synthesis [21], and the Evidence-Informed Policy and Practice Model [15]. Other models explicitly incorporate the unique social context of an area into management actions and decisions. However, the models describing the processes of evidence-informed policy-making commonly fail to address how individuals and organizations generate evidence and conduct research that connects to policy actors. Evidence-informed practice and decisions (which call upon, but are not synonymous with research, nor "just" data—see Carnwell [22]) and research often remain separate from policy generation and governance (see for example [1,23–25]). The literature also fails to illustrate a methodology for how interactions between key stakeholders would be structured or the roles and responsibilities that each actor would hold (methods such as appreciative inquiry or participatory policy analysis tend to be more evaluative or research-oriented, rather than being focused upon supporting decision-making). There is, therefore, both academic and practical demand for increased engagement between decision-makers, practitioners, and researchers [26], particularly for knowledge transfer and capacity-building [6]. The Social Science Framework presented here is intended to fill this gap by explicitly linking researchers and decision-makers throughout the entire process of prioritization, research, knowledge transfer, and networking.

The two key models for the framework are derived from public health and health promotion: (1) the PRECEDE-PROCEED Model, first presented by Green and Kreuter in the 1970s with the most recent edition presented in 2005 [27]; and (2) the AMESH Model (Adaptive Methodology for Ecosystem Sustainability and Health), presented by Waltner-Toews [28]. While neither model was designed to support the specific challenges identified by Alberta Parks, the synthesis of different elements derived from: (a) the identification of both evidence-informed diagnostics (current state) phase as well as both proximal and distal factors influencing successful implementation; and (b) hypothesis-testing embedded in complex social, ecological, and economic systems, leads to a combination of structure and process well-suited to the Parks' context.

The PRECEDE-PROCEED framework was first designed and applied in health promotion in the 1970s to provide a structure for applying theories and concepts in a systematic way to plan and evaluate programs [29,30]. The initial stages of the model are designed to develop a deeper understanding of a community and to better design interventions that strategically and accurately address needs. AMESH is a more recent decision-making model (brought forward in the early 2000s) and focuses on a broader, more ecosystem-based form of health that integrates the well-being of people, plants, animals, and the physical integrity of the earth. Historically, the model has been applied to sustainable development and ecosystem management [31] (pp. 317–349) and has been tested in Nepal, Kenya, Canada, and Peru [32]. AMESH acknowledges the high levels of complexity within social systems and seeks to use narratives and other social science-based information as evidence that can inform leaders and policy-makers.

Given some of the challenges for Parks noted above (reluctance to incorporate or draw upon evidence, regional differentiation, changing provincial research priorities, lack of institutional research capacity, and tenuous linkages/funding with the research community), the Parks framework is driven by an explicit demand for research AND knowledge synthesis, translation, and exchange, as well as a need to incorporate multiple stakeholders (including those outside the research process) within the broader function of the model.

The decision-making model for Alberta Parks incorporates the following aspects of the PRECEDE-PROCEED model:

- Active Participation
- Measurable Objectives
- Data-driven decisions
- Community-focus

The model also incorporates the following aspects of the AMESH model:

- Holons as a management unit (elements that are both whole, but also parts of a whole (e.g., within a network—Koestler [33])
- Use of multiple perspectives in decision-making
- Incorporating narratives (a.k.a. storytelling) into the process
- Both scholars and local citizens are equal stakeholders
- Links are identified across scales and perspectives
- Social understanding holds a focus

2.2. The Alberta Parks Social Science Framework

The final framework (Figure 1) combines both models into an integrated and iterative system of decision-making and story-sharing to enhance both research and knowledge mobilization. The model allows managers and planners of Alberta Parks to incorporate both the rigor of the scientific method with the local and contextual creativity of stories and dialogue into their management decisions. Elements derived from PRECEDE-PROCEED provide a strong focus on data, evidence, and measurable goals. In addition, AMESH focuses on the importance of social factors within a system and allows for local citizens, park visitors, and park staff to share their own evidence through stories and narratives. This framework, therefore, provides a structured method for connecting academics, government officials, and community members at every stage of park management. The principles of integration, diverse perspectives, accountability, and adaptive management are explicitly articulated to maintain a strong culture of respect for the scientific process, and as part of a strong sense of community and shared narratives. Research, knowledge synthesis, translation, exchange, and networking are brought together as concurrent and necessary steps for capacity-building and development of best practices and policy. By clearly linking the scientific process with decision-makers and stakeholder groups, the Social Science Framework offers a unique and innovative methodology for supporting evidence-informed decision-making in the public sector.

As can be seen in Figure 1, the synthesis of these two models and processes is broadly consistent with the policy process but more nuanced and linear in function. This framework takes a systems-oriented approach to link research to both the local community and population context, as well as the systemic structures. Specifically, the identification of pre-disposing, enabling, and reinforcing factors (that shape not only the definition and scale of issue identification but also the likelihood of successful interventions) is a key addition to supporting parks' management with evidence and engagement—a key element is an emphasis on the active participation of local stakeholders at different points of both research and knowledge mobilization. In fact, the conception of this framework as a participatory and iterative series of interactions between researchers, decision-makers, and stakeholders is also a key element. While exogenous factors may trigger priorities, the inclusion of an a priori prioritization process means that a range of stakeholders (parks' staff, researchers, and community members) are invited to identify their own priorities, problems, goals, and solutions—such stakeholders are not merely consulted, but actively invited into the process. At the same time, it is important to note that this is not necessarily a community-focused or participatory action research process (although it can be)—the framework is intended to link and support research, engagement, and implementation, but with a particular emphasis upon parks' management. Steps 1–3 of this process, therefore, hinge upon building dialogue from issue or research priority, to local and contextual understanding, to systems-based qualitative and quantitative assessments and interpretations of those issues. This process, given the importance of social and integrative questions for parks' management, helps create shared foundations for solutions, decisions, and implementation.

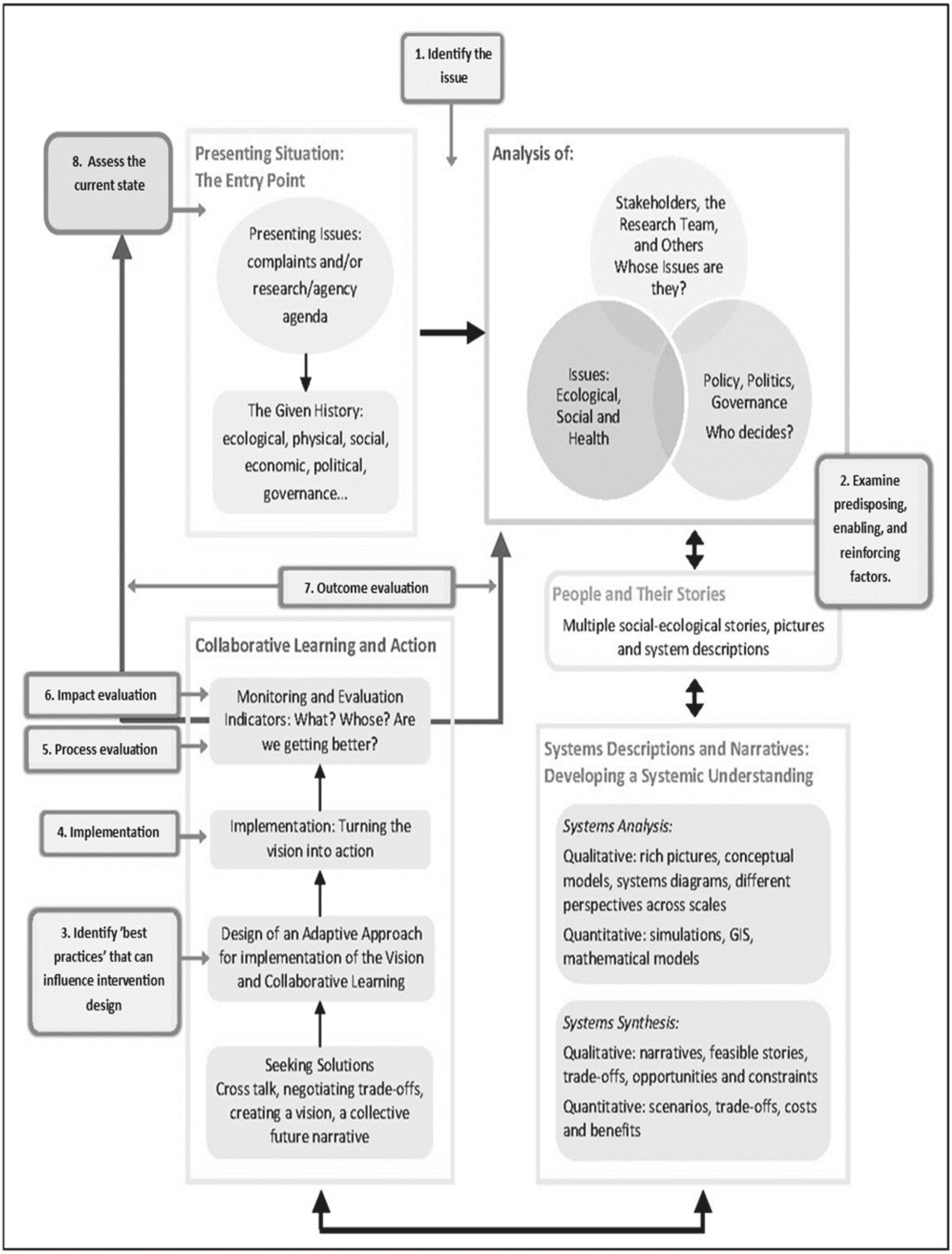

Figure 1. An adaptive framework for evidence-informed parks management and policy.

Having established the contextual and systemic narratives that surround the issue in question, the secondary phase of this framework is oriented toward linking evidence with stakeholder vision, future scenarios, planning, and design. This combination of collaboration, negotiation, design, and evidence "flow" is an important response to the common "uptake" challenge for evidence. As Lawton [19] noted, just because evidence exists does not mean it gains usage or traction in decision-making. As a result, Steps 3–6 are not only based on the foundation of dialogue and interaction but are particularly oriented to acknowledging evidence, setting that evidence within the local or place-based context of the issue. As part of moving from the current state (diagnostic), causal, and contextual factors, the latter stages of this framework recognize that complex eco-social systems are understood best when diverse and different perspectives are brought together. The methodology, therefore, makes explicit the participation of local people and the use of 'nonexperts' to shape a community's understanding of their ecosystem. Drawing explicitly from AMESH, the key elements in this process include:

- Local stakeholders and researchers come together to identify alternative courses of action (looking at multiple scales and from various perspectives)
- Stakeholders choose, develop, and implement a plan that incorporates governing, monitoring, and management actions.
- Outside investigators try to understand the system, the process, and how interactions may influence our understanding.

As might be expected, the conclusion of this process (steps 7–8) is, in fact, not an ending. Instead, the assumption is that the combination of engagement, monitoring, indicators, and co-design leads to an on-going process of issue identification, clarification, systems analyses, and adaptation across and within multiple pillars of action (environment, social, economic, cultural, and governance). Not only is this process consistent with the realities of adaptive management and dynamics of change within both ecological and social systems, but it also has the potential to address, or mitigate, a common response from community members and organizations. Rather than situating stakeholders as a source from which solutions or input can be "extracted" or as a subject of study, this process situates engagement, action, and evidence as three pillars of an on-going and long-term framework.

2.3. The Alberta Parks Social Science Working Group

The call for socially-oriented research and the principles outlined in the Plan for Parks [34] and the Science Strategy [35], sparked the creation of the Alberta Parks Social Science Working Group (SSWG). This group consists of representatives from multiple post-secondary institutions across the province alongside park managers, Alberta Parks executives, and other members of the broader ministry of Environment and Parks. The purpose of the SSWG is to increase the capacity for social science research within Alberta Parks for the benefit of park management. Such groups are not uncommon (e.g., the Conservation Biology Social Science Working Group is one international example), but a scan of comparable efforts conducted in 2014 identified a tendency toward either natural science frameworks (e.g., Ontario, the USA, and Greece) or "integrated" scientific frameworks (such as those identified at the local and provincial levels in Canada, and local, regional and state-level frameworks in the USA, Australia, and South Africa). Socio-cultural aspects can be brought into these conversations but are rarely the sole focus of an initiative [36].

In addition to these frameworks, significant attention has been placed (particularly in the USA) on developing frameworks to measure and manage the scope and impact of the visitor experience [37]. Presented by Manning [38], the Visitor Experience and Resource Protection (VERP) framework is a 9-step process intended to link public engagement, resource use, and key assets within management zones, and identifying quality indicators and standards in order to generate long-term monitoring, as well as management strategies. This approach draws from, and aligns with, the Limits to Acceptable Change framework (as used in New Zealand [39] and the USA [40]), as well as frameworks and methods (e.g., Visitor Impact Management (VIM) and Visitor Activities Management Process (VAMP)) created to inform management, identify recreation and tourism opportunities, and assess the effects of (typically increasing) human use in order to reach desired outcomes [41].

Based on the need to incorporate existing social science research in the decision-making process, the need for *new* social science research, and the need to operationalize social science processes and initiatives, the SSWG was the collaborative venue tasked with providing a clear structure for integrating science-based evidence with Park management. Specifically, the projected outcomes of the Social Science Framework incorporate objectives identified by the working group and derived from the Alberta Parks Science Strategy, and the Alberta Plan for Parks. The full list of outcomes includes:

- Supporting an increase in the amount, quality, availability, and use of social and applied science in, on, and relevant to parks and protected areas;
- Creating a 'Community of Practice' between government, academia, and communities for carrying out social science research and implementing effective parks management;
- Supporting knowledge synthesis, translation, and exchange (KSTE), building upon previous research, prioritization, and data collection to support and expand operational capacity and linkages to the scientific community;
- Increasing capacity to make informed decisions that positively affect parks and their users, enhancing the ability of managers and staff to integrate social science into management and operational approaches. This extends to increasing capacity for both researchers and decision-makers to execute and integrate social science; and
- Implementing an adaptive management process that works to carry out evidence-informed action.

3. From Recreation to Evidence and Community Informed Management

3.1. Historical Overview

Alberta's first provincial park legislation—the *Provincial Parks and Protected Areas Act*—was enacted in 1930 [42], resulting in Alberta's first provincial park at Aspen Beach in 1932. The original purpose of provincial parks was to provide small recreation sites for Albertans to swim, picnic, and relax. In the subsequent years, the purposes of parks have evolved, reflecting not only public and collective values, but also new perspectives on recreation, tourism, conservation, and the natural world. The Alberta Provincial Parks system is now comprised of a network of protected areas distributed across the province, each with varying levels of visitor facilities and park programming managed by Alberta Parks staff. Alberta now manages 473 provincial parks and other protected areas [43], covering 27,666 km^2 [44]. Provincial legislation and regulations provide varying classifications for each park and also provide direction for management of the areas, *including* preserving critical wildlife habitat, recognizing wilderness areas (most strictly protected areas; no development permitted) and natural areas (preserve sites of local significance; allow low-impact recreation) [45].

3.2. Parks and Protected Areas: Planning Documents

Released in 2009, Alberta's *Plan for Parks* outlined a 10-year strategic plan to "ensure Alberta's parks and recreation areas remain protected yet accessible to Alberta's growing population" [34] (p. iii). The plan recognizes the increasing tension between a growing population with its resulting demands for accessibility and the need to manage our parks for environmental conservation. To address both needs effectively, the plan outlines priority actions and strategies to enable these actions. To achieve the desired outcomes of people-friendly communities, healthy ecosystems, and sustainable prosperity, the plan promoted "knowledge-based decision-making - Decision-making is informed by natural and social science, evidence and experience, which includes traditional knowledge of Aboriginal peoples." [34] (p. 4). Recognizing the importance of evidence in decision-making, the *Plan for Parks* provided a foundation for other initiatives, including the Science Strategy, the development of research priorities, and the nascent Social Science Framework.

The 2010 *Alberta Parks Science Strategy* was born from the Plan for Parks as a key action to fostering evidence-informed decision-making [35]. The Science Strategy's outcomes include increasing scientific information about parks and their visitors, increasing capacity to make informed management decisions, and creating a culture of respect for the value of science in park management. As Lemieux et al. [1] note, the potential benefits of evidence-informed approaches are not maximized in Canadian protected areas management, even though managers may value and incorporate different forms of evidence in their decision-making, information produced by staff, and from within their organizations are given priority. Other forms of evidence, such as Indigenous knowledge and peer-reviewed information, are valued and used less and can reflect a disconnect between managers and the research community.

In order to create a successful platform for incorporating science into park planning, the Strategy outlines specific objectives, including: (1) improving communication with the research community, (2) improving dissemination of information, (3) establishing partnerships, (4) establishing research centers, (5) involving staff in science, and (6) ensuring support for science. In response to the objectives of the Science Strategy—specifically objectives (1) and (3)—the Province and the University of Alberta, Augustana Faculty signed a Memorandum of Understanding (MOU) in 2009 that promoted shared objectives while maximizing the value and effectiveness of each organization. Ultimately, these objectives formed the core of the framework's intended functionality but were operationalized by the results of a province-wide research and policy prioritization process.

3.3. Research Priorities

One priority action identified in the Science Strategy was to set research priorities for Alberta's provincial parks. Research priority-setting processes have been in use at the international, national, and regional levels [46] to link researchers, the public, managers, and policy-makers in a variety of settings. Some research priority processes are based on assessments by individuals (e.g., Eagles) [47], but our study used a community-of-practice-based process originating with Sutherland et al. [48–50], and later adapted by Rudd [51,52], Fleischman et al. [53], and Hallstrom et al. [5]. Such work can have both instrumental effects (by directly influencing policy objectives, language, or even policy tools), but also conceptual effects by gradually "infiltrating" public policy and shifting the values, audiences, and contexts that inform policy design [20,52].

The research priority-setting process for Alberta Parks occurred in 2012 and 2013, with the results first disseminated within the agency, and then published in the *Journal of Park and Recreation Administration* (for full details regarding project methodology and results, please see Volume 37, No. 3 [5]). After reviewing the list of top 20 research questions for both regional and provincial parks management, some themes emerged [5]. First, the questions emphasized the struggle between maintaining a balance between conservation and recreation in a province pushing economic growth. Second, 56% of the priority research questions were grounded in the social sciences. The need for social science is supported by recent reviews of research priorities for other park and resource management systems [47,54,55]. These two observations highlighted the need to incorporate both existing and new social science research into park management, and to extend the scope of research for parks management beyond conservation biology to include a broader range of issues that extended across all five pillars of sustainability. Specifically, the prioritized research themes for Alberta Parks include understanding demographic and social changes; visitor experience expectations; benefits of parks and protected areas in the eyes of the populace; understanding the contribution of parks to well-being; how to effectively collaborate (particularly rural and Indigenous partners); and expectations around Parks' role in conservation and recreation.

4. The Alberta Parks Social Science Framework as an Exercise of Policy Design

Although the framework was the result of a collective process of response (to research and decision-support needs), engagement, and deliberation, it is possible to analyze the emergence of the framework as a result of a design-oriented process. More specifically, using the concept of 'policy design' [6], it is possible to articulate the higher-level factors that shape good design (audience, values, and context). Doing so offers insight into the guiding and driving forces that influence how policy, politics, and practice may intersect (see [5,46]).

4.1. Audience—The Organizational Dimensions

Several actors are involved in the process of the framework (Figure 2). Working groups operate closest to management actions by identifying knowledge gaps, coordinating research activities, and connecting on-the-ground researchers and decision-makers. A Research Group—comprised of representatives of working groups and chaired by an Alberta Parks Science Coordinator—works on a broader scale to develop research questions, allocate funding, operationalize research priorities, and initiate and support processes of research, knowledge transfer, and networking. Still broader yet, a Research Advisory Group consisting of the Science-Coordinators, Alberta Parks executives, and high-level members of academic institutions provides broad level strategies and linkages on a provincial scale. Various working groups provide focused research efforts on specific topic areas in natural science, social science, and health science.

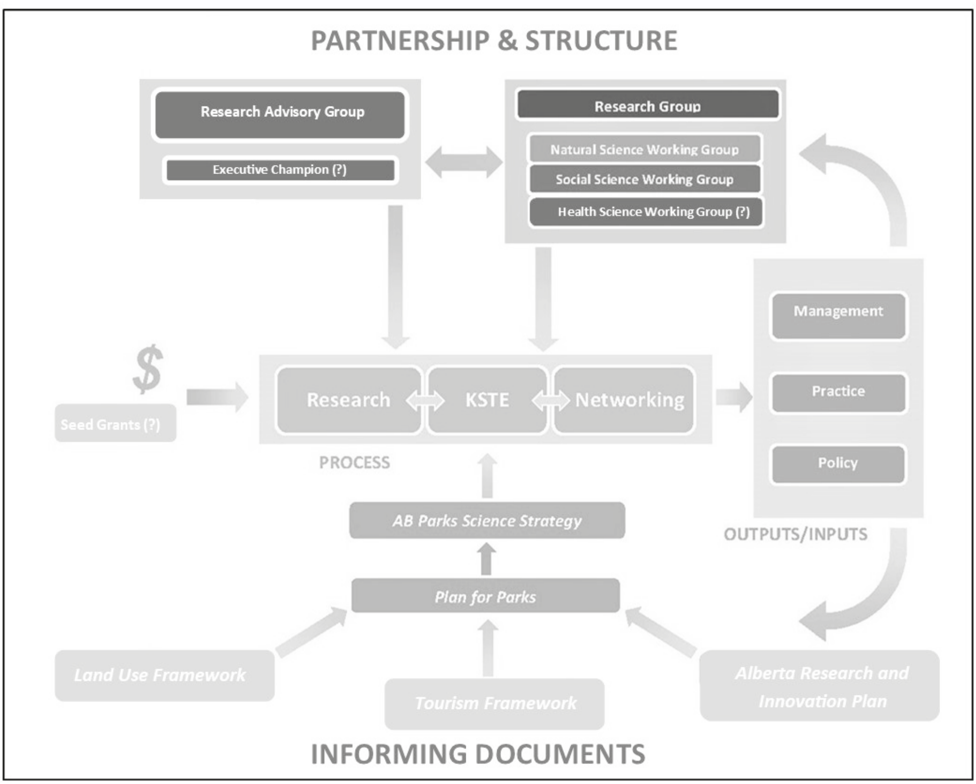

Figure 2. The organizational dimensions and process of the Social Science Framework.

All of these actors engage in a process of KSTE and Networking. Research allows data to be gathered, then KSTE transforms data into useable information and translates it into relevant messages for each stakeholder. Finally, networking allows stakeholders to engage in dialogue and pursue solutions alongside one another. These processes are not a linear progression of steps; rather, social science initiatives may include any combination of research, KSTE, and networking activities. It is crucial for individuals and organizations from all three groups of stakeholders (government, communities, and academia) to engage in these activities, as they embody the principle of partnership and diversity outlined in the framework's conditions for success.

Through the activities of research, KSTE, and networking, social science knowledge and information will increase. This evidence can then be incorporated into management decisions, help create adaptive policies and plans, and support the implementation of on-the-ground best management practices. Once they have been implemented and/or enacted, policies, practices, and management actions become inputs that inform the direction of future initiatives.

4.2. Values—The Conditions for Success

In order for any of the outcomes listed above to be realized, several conditions must first be in place. These conditions include structural aspects of governance within Alberta Parks as well as relational conditions between stakeholders.

- **Executive Support**—The Social Science Framework must be championed by a member of the AB Parks Division executive to increase its credibility and allow for high-level support and oversight.
- **Accountability**—Both researchers and decision-makers have to be held accountable to one another and to the objectives of the framework.
- **Culture of Respect**—The use of scientific information for the purpose of evidence-informed decision-making must be recognized and valued within the Government of Alberta.
- **Integration**—Horizontal and vertical integration must occur across every level of decision-making.
- **Partnerships**—No single group will be responsible for carrying out the work of the Social Science Framework. Governments, academics, and communities (which include citizens, NGOs, companies, etc.) must work together to accomplish the objectives of the framework.
- **Diversity**—Individuals participating in the Social Science Framework process should represent broad and diverse perspectives.

Like many governmental initiatives, such frameworks do not stand alone. In this case, the Parks' framework is complemented by three other relevant frameworks: The Land Use Framework (2008), the Tourism Framework (2013-20), and the Alberta Research and Innovation Platform (2012). As a result, beyond the higher-order values noted above, Alberta Parks and this framework are also embedded in a series of policy and political values identified for land use more generally, including striving for a balance between local investment, economic development, and sustainability of ecological and social assets. The Parks' framework, therefore, provides evidence and engagement across all 3 initiatives, while also speaking explicitly to three Land Use Framework outcomes of:

- People-friendly communities with recreational and cultural opportunities
- Healthy ecosystems and environment
- Healthy economy supported by our land and natural resources.

4.3. Context—Balancing Evidence with Demand in Alberta Parks

While fields such as medicine, public health, engineering, and planning consistently look to emergent, better, and best practices to inform the decisions, actions, and evaluations conducted as part of their practices, the context for Alberta Parks presents some challenges.

In particular, as this framework is intended to reach out to regional offices and supports more centralized provincial decisions, it entails organizational, practitioner, and cultural change at both levels. Particularly in the regional offices, one challenge is the broader limitation of scientific literacy within Parks staff. In many cases, the staff has moved up through the ranks from a time when only a high school diploma was required. While they may have extensive experience in Parks management, conservation, or interpretation, they may not have been organizationally or educationally conditioned to factor research, knowledge synthesis, or the work (applied or theoretical) of the research community to their jobs. This is particularly pronounced within the common characterization of regional parks management, which is a balance between annual cycles and crisis management. This complication presents a common set of challenges for the inclusion of evidence in decision-making. Such challenges include effectively connecting researchers with those in positions of authority, and addressing the common (mis)perception by policy-makers that social science is less rigorous, reliable, or valid than the natural or health sciences.

As Carnwell [22] and others [1,56–58] point out, there is a complex array of barriers to the use of evidence, with most literature pointing to organizational and political barriers as more prevalent, versus issues of personal capacity or ability. In essence, and as Lemieux [1] and Cvitanovic [57] emphasize, organizational and institutional norms of practice, poor alignment between research questions (and methods) and the needs of decision-making, and cultural factors (such as inter-departmental or inter-organizational difference) can be significant.

A similar challenge exists in the perceptions that decision-makers (in Parks and in other jurisdictions—see for example [59]) have regarding research and its desired role in public management, decision-making, and policy-making. As noted above, there is no clear distinction drawn (conceptually or in practice) between social science, applied research, and business analysis, but there is also a broader sense of uncertainty about the implications and obligations of evidence-informed decision-making. Specifically, some participants have noted that decisions need to take place even if there is no evidence and (as was not uncommon under previous governments both nationally and provincially) even if the evidence contradicts the policy (see for example [60–62]).

5. Conclusions

Along with increasing public pressure to provide parks as purely recreational spaces, Alberta Parks has also seen significant environmental events such as flooding, droughts, fires, and similar naturally occurring events that are exacerbated or even accelerated by human actions. As a result, there is a broader realization and growing openness to linking park management to research, data, and evaluation. At the same time, there is also a realization that, to date, there has been no structure or mechanism beyond personal connections to develop those relationships in practice.

There are significant benefits and opportunities presented by the implementation of the Social Science Framework for government bodies such as Alberta Parks. Specifically, this initiative not only operationalizes earlier and higher-level planning and strategic directions for Alberta Parks, but procedurally it provides an opportunity to link natural and social sciences with both community and management perspectives. The combination of models and processes is intended to foster evidence-informed decision-making and to embed the realities, meanings, and applications of that evidence into local and place-based contexts. Doing so provides regional or eco-systemic variability and is functionally a step toward adaptive decision-making. That form of decision-making is intended to balance the rigor and validity of scientifically derived knowledge within local and regional narratives, experiences, and priorities. Making these links should in turn balance the objectivity of data with the variation of the local and lived experience.

At the same time, there are also exogenous factors that influence the successful implementation of the framework. Political factors (including the reorganization of ministries, changing political, fiscal, and electoral priorities, re-assignments of both ministerial and operational staff) can have profound (and typically negative) impacts upon uptake. In this case, having both a historical record of collaboration and a process that supported the initiation and creation of the working group and framework were critical conditions that facilitated the role of champions within Alberta Parks at both central and regional levels. This combination also facilitated a clear sense of direction and alignment from earlier planning documents, through to establishing research and knowledge mobilization priorities, to the adoption of the framework itself.

While such champions were clearly major factors in the development of the framework, their presence is also a vulnerability. Personal events, illness, job changes, and shifting leadership can all directly affect the ability of any such champion to advocate for, or use, a framework such as this. Implementing such processes may appear counter-intuitive or inefficient to new leadership, and when combined with some of the cultural and organizational dynamics noted above, may result in the decision to proceed as usual (without evidence or collaboration) in order to accelerate the decision-making process.

Similarly, the reality of this (and any policy-making process) is that evidence cannot be the sole input. Beyond the details of the Alberta Parks case, it has long been established that there are significant political dimensions to public policy, and park management is no different. In addition to broader issues of public opinion, attitudes, and behaviors, both party-specific and bureaucratic rationalities also influence uptake, alternatives, and implementation [63,64]. This creates an additional challenge, but also a benefit, for the framework. As Marleau and Girling [18] note, such a process is very much intended and was designed to not only keep science "at the table" but to spark and support cultural shifts toward evidence-informed management and decision-making. However, in the absence of formal institutionalization and adoption, keeping science more generally, but particularly social science, within Parks, decision-making will continue to be faced with political, experiential, and attitudinal barriers.

In conclusion, while the development of the working group and framework are important steps forward for evidence-informed decision-making and collaborative research within Alberta Parks, the real test remains in the implementation and funding of the process. While other provinces in Canada have identified the need for comparable frameworks and approaches, the work undertaken in Alberta is (thus far) largely unique in parks management in Canada, and particularly as a result of its emphasis (and inclusion) of social and applied sciences. As a result, being able to engage not only in a prioritization exercise that demonstrated the validity and importance of social science research to park managers was critical, but so too (we expect) was the capacity to engage a broad spectrum of park staff, administration, and research staff from post-secondary institutions in the formulation and review of the framework. Furthermore, being able to draw from multi- and even transdisciplinary work such as PRECEDE-PROCEED and AMESH were also critical attributes for this project—an earlier scan for comparable initiatives in Canada showed an emphasis upon research or KSTE, but limited evidence of structures or approaches that had any potential to link the two. In the same vein, this framework may provide a set of unanticipated (yet positive) consequences, largely through the potential to engage and collaborate with community-based stakeholders. Given the increasing public and political interest in citizen science, as well as a series of already established relationships with stakeholders, such as conservation and recreational non-governmental organizations, a significant opportunity may lie in the development of scientific capacity and engagement across both parks and stakeholder groups, not only as inputs into research or policy, but also as active participants in both science and parks management and policy (through implementation, enforcement, public engagement, pilot studies, and assessment).

Author Contributions: Conceptualization, L.K.H.; Methodology, L.K.H. and G.T.H.; Formal analysis, L.K.H. and G.T.H.; Investigation, L.K.H. and G.T.H.; Writing-original draft preparation, L.K.H. and G.T.H.; Writing-review and editing, L.K.H. and G.T.H.; Supervision, L.K.H.; Project administration, L.K.H.; Funding acquisition, L.K.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by Alberta Parks.

Data Availability Statement: Not applicable.

Acknowledgments: We are grateful for the engagement and support of Alberta Parks' staff, along with the administration, leadership, and the faculty members at the University of Alberta, University of Calgary, and Mount Royal University. We thank E. Specht and D. Patriquin for valuable research assistance and K. Corrigan and C. Cook for editing. An earlier version of this paper was presented at the 2016 Annual Meeting of the Southwestern Social Science Association (Las Vegas, NV, USA, 23–26 March).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study, the collection, analyses, interpretation of data, the writing of the manuscript, or in the decision to publish the results.

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ISBN 978-3-0365-1073-6