DISSERTATION

A GUIDING MODEL FOR DECOLONIZING ENVIRONMENTAL SCIENCE RESEARCH

AND RESTORING RELATIONAL ACCOUNTABILITY

WITH INDIGENOUS COMMUNITIES

Submitted by

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ABSTRACT

A GUIDING MODEL FOR DECOLONIZING ENVIRONMENTAL SCIENCE RESEARCH

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In this body of work, I examine the process and methodologies applied in scientific research by, on, and with Indigenous communities with an emphasis on diverse ways of knowing in environmental sciences, natural resources, and climate research. Effectively addressing complex social-ecological issues faced within our current and future generations, such as extreme climate variability and environmental justice, will require *all* relevant sources of knowledge and data, including those held by historically marginalized communities who remain close to the land. Indigenous knowledge systems, informed through generations of careful observation of dynamics of environmental changes are recognized as critical resources for understanding and addressing social-ecological concerns, yet many institutions and researchers have yet to directly address colonial-rooted legacies, including centuries of oppression, ethical violations, and lack of accountability towards the communities who maintain these knowledge systems. My dissertation research draws from theoretical developments in Indigenous methodologies, community-based participatory research, participatory action research, and constructivist grounded theory to enhance our contextual understanding regarding factors inhibiting or supporting diverse knowledge exchange in the sciences.

Conceptual contributions include an evidence-based, practitioner-informed analytical framework that can be applied for guiding and evaluating responsible Indigenous community

engagement across a wide range of research fields. Using this framework, I provide data findings from the first global systematic review assessing Indigenous community engagement in climate research studies, improving understanding of how research design connects to broader social outcomes for Indigenous communities. In this work I also provide conceptual contributions in the form of a working model for decolonizing community-based science research with Indigenous communities through a cross-disciplinary synthesis of codes of ethics, principles and methodologies for supporting Indigenous sovereignty and self-determination in research. My dissertation explores this model through the values of *integrity*, *respect*, *humility*, and *reciprocity* to shape intentional commitments and actionable methods that can be applied to raise ethical standards and long-term relational accountability within Indigenous lands and communities

Empirical contributions within my dissertation include a case study field-testing and grounding the working model for decolonizing science research through an Indigenous community-based climate study led by youth and elders within two rural agricultural communities in the mountainous central region Borikén (Puerto Rico). This case study highlights innovative participatory methods, resources, and lessons learned to inform processes for aligning cultural and academic institutional protocols for research integrity. My dissertation also explores benefits, barriers, and resources for Indigenous scholars and practitioners engaging Indigenous knowledge systems in their work and research through an in-depth regional case study in the Caribbean. Findings from this research enhance our understanding of how colonial legacies manifest as unique and complex challenges and identifies sources of capacity-building for overcoming these challenges, centering underrepresented narratives from those community members directly impacted by colonial histories. Together, these contributions shape our understanding of how every stage of research process itself, beyond solely the outputs, serve a

critical role in decolonizing research and how researchers and institutions can adapt this process

towards raising ethical standards in research.

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(Arapaho), So'taa'e (Cheyenne) Nations, and other peoples of the land on which this university

sits today, for their sacrifices made in order for this land grant institution of learning to be here.

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1. INTRODUCTION

Indigenous knowledge systems (see table 1.1 for definition of terms), encompassing collective and dynamic bodies of knowledge formed from centuries of observation of Earth and space systems, have long guided environmental stewardship practices, such as watershed management (Kagawa & Vitousek, 2012), soil conservation through sustainable agriculture (Altieri, 2004), intentional burning for forest management (Kimmerer & Lake, 2001), sustainable forestry (Trosper, 2007), and fish harvests (Menzies & Butler, 2007). These knowledge systems reflect longitudinal studies reaching across generations in which Indigenous communities around the world form, test, adapt, and refine their scientific understandings, often at the necessity of maintaining the survival and wellbeing of their families and communities, including non-human community members (Berkes, 2008; Berkes, Colding, & Folke, 2000; Cajete, 2000; A. O. Kawagley, Norris-Tull, & Norris-Tull, 1998). Thousands of unique Indigenous cultures across the world currently maintain diverse ways of knowing and place-based understandings regarding complex and dynamic natural processes while maintaining environmental stewardship of "over a quarter of the world's land surface [which] intersects about 40% of all terrestrial protected areas and ecologically intact landscapes" (Garnett et al., 2018), yet the vast majority of environmental scientists in academia, with the exception of a growing number of Indigenous scientists and cross-cultural collaborations, remain working with incomplete datasets, neglecting to engage with Indigenous knowledge systems and peoples in their research (David-Chavez & Gavin, 2018, p.; Kimmerer, 2002).

Table 1.1: Glossary of Terms (in relevance to the context of this dissertation research)

Glossary

Indigenous*: "people of the land" holding intergenerational/familial ties to a community whose lifeways (e.g., language, natural resources, sciences, cultural practices, etc.) both sustain and are sustained by their relationship to a particular place/region (Cunningham & Stanley, 2003), and who have historically experienced marginalization, dispossession, exclusion or discrimination" imposed by external governing entities affecting their livelihoods (Stavenhagen, 2005), as identified through self-determination and the sovereign rights of Indigenous communities for defining community membership and acceptance (Anaya, 2004; United Nations General Assembly, 2007)

Indigenous knowledge systems: "dynamic systems of knowledge [including scientific knowledge] collectively held by Indigenous community members that draw from intergenerational, place-based, culturally-embedded relationships and experiences" (David-Chavez & Gavin, 2018)

Science: the process of systematically building knowledge through observational evidence described as "a rational empirically based way of knowing nature that yields, in part, descriptions and explanations of nature" (Aikenhead & Ogawa, 2007, p. 544)

Community: those who are directly "connected to and caring for the places and resources impacted by research activities" (Kūlana Noiʻi Working Group, 2018), who share "a sense of identification and emotional connection to other members, common symbol systems, shared values and norms, mutual—although not necessarily equal—influence, common interests, and commitment to meeting shared needs" (Israel, Schulz, Parker, & Becker, 1998, p. 178)

Decolonizing: "a process which engages with imperialism and colonialism at multiple levels…[including] having a more critical understanding of the underlying assumptions, motivations and values which inform research practices" (L. T. Smith, 2012, p. 21), focused towards healing and restoring Indigenous lifeways

Indigenous research methodologies: research that is centered in the relational role of the researcher in terms of developing methods and gathering data with an ongoing commitment of accountability to "*all your relations*" (Wilson, 2001), and which centers Indigenous community needs for self-determination and wellbeing

Indigenous data sovereignty: "the inherent right of Native nations to govern their peoples, lands, and resources" (National Congress of American Indians, 2018), including "the right of Native nations to govern the collection, ownership, and application of [their] own data" (Rainie, Rodriguez-Lonebear, et al., 2017a)

Relational accountability: "methodology needs to be based in a community context (be relational) and has to demonstrate respect, reciprocity and responsibility (be accountable as it is put into action)" (Wilson, 2008)

* Note that the term "Indigenous" is inherently complicated by political tensions that vary by region and historical context, therefore international Indigenous peoples' working groups referenced here provide informal working definitions based on these and similar characteristics (Corntassel, 2003)

Further, it is only recently that formal scientific forums have officially recognized the critical value of Indigenous knowledge systems for addressing some of the Earth's most complex social-ecological challenges, such as climate adaptation and resilience (Adger et al., 2014; Douglas J. Nakashima, McLean, Thulstrup, Castillo, & Rubis, 2012). Despite these increasing calls for Indigenous community engagement (Maldonado et al., 2015; Thaman et al., 2013), Indigenous scholars, along with the Indigenous knowledge systems, historical narratives, and values held within their communities, often remain underrepresented in the sciences (National Science Foundation, 2017). Relatedly, Indigenous knowledge systems and contributions from marginalized populations to what is currently considered "science" remain vastly unacknowledged across much of the larger scientific community (Conner, 2005). Few scholarly works (especially in terms of Indigenous authorship) research underlying impacts from colonization or contemporary issues regarding sovereignty and self-determination that influence underrepresentation of diverse ways of knowing and diverse community engagement in the sciences (Simpson, 2004).

Among studies that do engage Indigenous knowledge systems, most focus on the "supplemental value" of Indigenous knowledges, looking at how they can enhance and contribute to environmental science data, while overlooking their intrinsic "governance value" in which they are recognized "as irreplaceable sources of guidance for Indigenous resurgence and nation building" (Whyte, 2018, p. 63). As increasing numbers of scientists seek to document Indigenous knowledges, common practices include conserving data and findings outside of the contributing communities in the form of databases or academic publications, raising critical concerns regarding how to most effectively sustain Indigenous knowledge systems (Agrawal, 2002; McCarter, Gavin, Baereleo, & Love, 2014; Tang & Gavin, 2016). Research on traditional

ecological knowledge identifies colonization at the root of many threats to Indigenous

knowledge systems (Tang & Gavin, 2016), therefore we still require further efforts to activate a

shift in dominant research practices to more directly address this threat.

A growing movement, primarily led by Indigenous scholars, researchers, and community

leaders, focuses on restoring and honoring inherent rights to sovereignty and Indigenous

governance in the research process and data practices. Indigenous data sovereignty, defined by

"the inherent right of Native nations to govern their peoples, lands, and resources" (Māori Data

Sovereignty Network, 2016; National Congress of American Indians, 2018), which includes "the

right of Native nations to govern the collection, ownership, and application of [their] own data"

(Rainie, Rodriguez-Lonebear, & Martinez, 2017a), reflects recent growth in this movement.

Within this movement, Indigenous data governance represents the support mechanisms for

upholding these rights (Rainie, Rodriguez-Lonebear, & Martinez, 2017b). As Michi Saagiig

Nishnaabeg scholar Leanne Betasamosake Simpson articulates, "the answers to how and why

our knowledge has become threatened lie embedded in the crux of the colonial infrastructure,

and unless properly dismantled and accounted for, this infrastructure will only continue to

undermine efforts to strengthen [Indigenous knowledge] systems and to harm the agenda of

decolonization and self-determination" (Simpson, 2004, p. 375). This speaks to an intentional

agenda many of us are working collectively towards, within a specific historical context, which

is continuing to develop and apply decolonizing research practices and methodologies, such as

those developed in the 1990s in Aotearoa (New Zealand) through the Kaupapa Māori research

principles (G. H. Smith, 1990; L. T. Smith, 2015), and through groundbreaking Indigenous and

postcolonial research frameworks emerging in the years to follow that focus on restoring

relational accountability, Indigenous governance in research, and honoring inherent rights to sovereignty (Chilisa, 2012; Kovach, 2010; Louis, 2007; Weber-Pillwax, 1999; Wilson, 2001).

In environmental and natural resource sciences, we still require theoretical growth and development to allow for adapting and applying principles for relational accountability towards Indigenous communities, lands, and futures in research practice. We need research initiatives that work to untangle the systems and infrastructures set into place by longstanding colonial research agendas in order to foster more balanced, respectful knowledge exchanges centuries overdue in many communities. For example, imbalanced power dynamics born from continuous sanctioned oppression towards Indigenous communities through policies of assimilation and denial of rights to governing processes continue to erode Indigenous knowledge systems (Marie Battiste, 2008). Education systems engineered by colonial assimilation policies threaten and disrupt pathways for transmitting knowledge between generations, forming epistemological barriers where Indigenous knowledge systems are devalued and ignored (Harrison, 2018; Kirkness & Barnhardt, 2001; Tang & Gavin, 2016). In terms of science research, Indigenous communities hold high levels of distrust and concern due to ethical violations and a longstanding record of lack of cultural-sensitivity (Quigley, 2001; Sahota, 2007; Smith, 2012). Reconciling these legacies requires acknowledging, identifying and understanding how cultural bias historically and presently influences research and data stewardship, including how and where symptoms of power imbalance manifest in the research (Marie Battiste & Youngblood Henderson, 2000; Simpson, 2004). As described by Davidson-Hunt and O'Flaherty, "research can reinforce existing inequalities within and between social groups when one social group is able to make its own truth claims that become the basis by which decisions are made (e.g., a given area needs protection because of values identified by regional ecologists)" (2007, p. 293).

Numerous studies emphasize the need to prioritize community-based pathways for sustaining Indigenous knowledge systems, and the need for supporting governance and autonomy of Indigenous communities who maintain them (Agrawal, 1995; McCarter et al., 2014a). While efforts have been made towards this end in some disciplines, we currently lack cross-disciplinary knowledge transfer to adapt and ground truth these developments within many fields of science. This effort also requires a working research model that raises ethical standards and commitments across all stages of the research process (initiation, design, implementation, analysis, dissemination) to align principles of cultural and scientific integrity.

At the broadest scale my dissertation research works towards filling current knowledge gaps for understanding and addressing fundamental issues, such as those described in this discussion, for Indigenous community engagement in the sciences. The body of work I present here, seeks to increase our contextual understanding of the factors inhibiting Indigenous engagement in the sciences and to identify support mechanisms for more balanced, respectful exchanges between diverse knowledge systems, especially within the context of environmental and natural resource sciences. Studies in stakeholder participation in environmental management find that quality participation in research is dependent upon the quality of the underlying research process, and from the philosophies that process builds upon, such as community members' ability to engage effectively in decision-making, addressing preexisting power imbalance, and supporting shared learning between participants and researchers (Reed, 2008). My research fills knowledge gaps in understanding complexities within the research process in an Indigenous community context, looking at potential across all stages in the research, rather than the research outputs alone, as a critical means for improving effective, long-term relational outcomes in scientific research. These include pathways for sustaining diverse knowledge

systems and biocultural diversity, for supporting climate resilience, increasing community engagement, and for improving ethical standards in research in terms of honoring inherent and historic Indigenous rights to self-determination and sovereignty.

1.1　Research Gaps Addressed by Dissertation Manuscripts

Each manuscript included in this dissertation represents a unique contribution advancing research and knowledge to address different aspects of the research gaps identified in the previous discussion:

Manuscript 1: Researchers worldwide contributing to the Intergovernmental Panel on Climate Change Working Group reports found high agreement regarding the critical importance of Indigenous knowledge systems and involvement of the communities who maintain them in decision-making for understanding and adapting to climate change (Adger et al., 2014). Within the same context, the United Nations report on Indigenous knowledges in climate change assessment and adaptation, emphasized collaboration, co-production of knowledge, and cross-cultural methods reflecting a need to shift to more inclusive methods in science research (Douglas J. Nakashima et al., 2012). In terms of U.S. efforts concerning climate initiatives and Indigenous knowledge systems, the Climate and Traditional Knowledge Workgroup guidelines similarly focus on tribally-led, ethical partnerships across tribes, agencies, and organizations (CTKW, 2014). Yet no comprehensive, evidence-based analysis has been conducted into *how* climate studies engage Indigenous communities. Further, in terms of environmental sciences and climate research, we currently have neither a standard set of indicators for responsible inclusion of Indigenous knowledge systems and communities who hold them, nor an understanding of the degree to which research studies adhere to responsible research practices. Previous studies highlight the importance of engaging and empowering Indigenous community members in every

stage of research relating to their communities, from design, implementation, and analysis, through to dissemination (Fisher & Ball, 2003; Rainie, Briggs, Riggs, Palmanteer-Holder, & Schultz, 2017; Sims & Kuhnlein, 2003). Although research has been underway regarding ethical conduct with Indigenous communities in biomedical, community health, and biodiversity research (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, & and Social Sciences and Humanities Research Council of Canada, 2014; ISE, 2006; Taniguchi, Taualii, & Maddock, 2012; Thaman et al., 2013), this work has yet to be applied towards research standards within many disciplines and contexts, such as within climate research. This study fills these research gaps by developing an evidence-based, practitioner-informed analytical framework that can be applied for guiding and evaluating responsible Indigenous community engagement across a wide range of research fields. Using this framework, this study also provides data findings from the first comprehensive global assessment on Indigenous community engagement in climate research studies.

Manuscript 2: Colonial histories have continuously impacted and shaped academic research and education by instituting agendas and norms that promote systemic racism and marginalization towards Indigenous and other underrepresented communities (Simpson, 2004; Smith, 2012). Numerous bodies of work highlight the need to understand and address the consequences of colonial legacies and emphasize the critical role of Indigenous scholars and educators in transforming and improving educational systems (Marie Battiste, 2002; Goodyear-Ka'ōpua, 2009; Kawagley & Barnhardt, 1998; Kimmerer, 2002; Penetito & Sanga, 2003). This study addresses this research gap, building an understanding of contemporary concerns and colonial historical contexts within Caribbean Indigenous Taíno and Kalinago island communities, where the unique systems of knowledge and histories held regarding their natural

environment, remain in a state of near invisibility within academic and scientific communities. Specifically, the second manuscript in this dissertation provides a critically grounded empirical understanding of the deeper socio-political and historical factors underlying the barriers Indigenous scholars and practitioners face for bringing Indigenous knowledge into their work in environmental science research and education and identifying support mechanisms enabling them to overcome these barriers.

Manuscript 3: Although we observe a growing interest and openness towards diversity and inclusion in the sciences, few efforts have addressed the need to reconcile the impacts of centuries of oppression, extractive models of research, and lack of accountability evidenced in the record of colonial-driven research agendas in Indigenous communities (Simpson, 2004; Smith, 2012). Further, Indigenous communities recognize an ongoing need for improving access to data that reflects the needs, knowledges, and priorities of their communities, rather than externally-driven agendas (Moore, Castelden, Tirone, & Martin, 2017; Rainie, Briggs, et al., 2017; Schultz & Rainie, 2014; Whyte, 2018). This conceptual paper and case study summary address this gap through the development of a working model for restoring relational accountability and decolonizing community-based science research with Indigenous communities. In doing so, this study synthesizes theoretical developments across disciplines and institutional contexts, grounding them within experiential practice to provide a comprehensive cross-disciplinary, and cross-cultural conceptual map bringing together codes of ethics and principles for upholding Indigenous sovereignty and self-determination in an actionable working model for researchers working with Indigenous communities.

1.2   Positionality Statement

I identify as a multicultural Indigenous Caribbean-American community member, one generation removed from the islands. My mother identifies as Afro-Caribbean and Caribbean Indian (*Taíno*), also as *Jíbaro/a* and *Boricua* in her local dialect, and my biological father holds heritage two generations removed from Eastern Europe, where his ancestors fled the Holocaust in the region of Ukraine and Hungary. I grew up for the most part in rural Montana, only hold fluency in English, and display a mixed phenotype. These traits invariably influence how I am perceived by our community, often as an insider-outsider (Kerstetter, 2012). For some phases of my fieldwork with non-English speaking Caribbean community members, my lack of Spanish language fluency required intense collaboration with local interpreters. Having only lived for a limited time on the islands and recognizing the language and cultural considerations that I still needed to learn, I found it most appropriate to define my role as primarily that of a research facilitator and learner. In these roles, I centered the local community members as the researchers with an emphasis on youth and elders and referenced local community members as the authority on the knowledge and data that were shared. Reflexivity and memo journaling (Birks, Chapman, & Francis, 2008) helped me to identify and remain conscientious of where and how I held my own biases in this research. I also worked to maintain transparency in my role and intentions with community research participants and partners throughout the research process.

During the longest extent of my fieldwork in Borikén (original name of the U.S. Territory of Puerto Rico), I lived just adjacent to the field site communities where we carried out our research projects and my daughter was enrolled in one of the field study school sites for just under six months during that time. One of the field sites was also where my maternal grandmother was born, and my mother and many family members grew up and lived in nearby

rural communities. At many times throughout my fieldwork, my mother, children, and other family members would accompany me, and this also influenced many interactions in the field.

When beginning my fieldwork, I carried cultural context from my own upbringing and cultural traditions, as well as from the oral history record held within my own family. Given this context, I often critically screened academic and government documents, noting instances where the historic record and data misaligned with and misinterpreted the lived experiences of people within my own family and within our broader community. Knowing the potential impact of research and data on the livelihoods of my relatives and community members and knowing the historic record of harm and bias against rural and Indigenous communities in the Caribbean, I held my work to the highest possible standard. Often this meant obtaining multiple sources (including oral history accounts), to triangulate data for accuracy. Both while reading through the literature, and in my interactions with academic and federal agency researchers, over the course of this research I was often face-to-face with systematic racism and oppressive narratives that proved difficult to disrupt, resulting in hours of research and discussion far beyond what is represented in this body of writing. While I was able to address some of these concerns, it was an impossible and exhaustive task that I hope to see many more Indigenous scholars and allies rise up to remedy in the coming years. These concerns also continue to motivate me to mentor both Indigenous youth and early career scholars in my own Native community, and Native scholars at my university, and to advocate for Indigenous rights when and where I can.

1.3   Ethical Considerations

Ethical considerations, including protocols for consent, are included with further detail within each of the manuscripts and vary based on the nature of each study. I have completed the CITI training certification program on the protection of human subjects as well as the National

Science Foundation's Responsible Conduct in Research trainings. Furthermore, all aspects of research were conducted in accordance with the code of ethics set forth by the International Society for Ethnobiology (2006) and honored principles outlined in the United Nations Declaration on the Rights of Indigenous Peoples (United Nations General Assembly, 2007). Local community consent and intellectual property rights agreements were included in the case studies and collaborative agreements regarding research protocols honored throughout the research process. Consent and assent forms for participating youth and their families, were also reviewed and approved by the Puerto Rico Department of Education. All research was conducted in accordance with Colorado State University's Research Integrity and Compliance Review Office requirements (see Appendix 8.1).

1.4   Dissertation Structure

This dissertation structure follows a manuscript format, with three broadly related yet independent studies prepared for separate publications. In addition to the academic outputs described below, in light of honoring relational accountability within my own research process, and in an effort to decolonize this dissertation format to reflect more balanced contributions to the communities that I engaged in this research, I include a summary community outputs generated and currently underway from my dissertation work. In the section below, I include the title, publication outlet, authorship, and a brief summary of the research focus and framework applied within each study. More detailed descriptions of these studies, including literature review, conceptual and theoretical frameworks, methods, analyses results, and discussions follow in each of the manuscripts.

Manuscript 1, titled *A global assessment of Indigenous community engagement in climate research*, was published in 2018 in the *Environmental Research Letters* journal (reprinted here

with permission) and co-authored with Michael Gavin. This manuscript explores human dimensions of climate research through a mixed-methods global systematic review evaluating levels of Indigenous community participation and decision-making in all stages of the research process (initiation, design, implementation, analysis, dissemination) of climate field studies that access Indigenous knowledge. This study also details the development of an analytical framework for assessing responsible community engagement in research practice and provides an evidence base to inform our understanding of broader social impacts related to research design, concluding with a series of guiding questions and methods to support responsible research practice with Indigenous and local communities. Expert-practitioner review and guidance for the systematic review protocol used for this study was provided by: Meena Balgopal, Gregory Cajete, Maria Fernandez-Gimenez, Kathleen Galvin, Lisa Lone Fight, Shannon McNeeley, Kyle Powys Whyte, and Shelly Valdez. Inter-rater testing was provided by Richard E. W. Berl.

Manuscript 2, titled, *Communal research - communal regeneration: Understanding benefits, barriers and resources for Indigenous science education and research*, is in preparation to submit to *AlterNative: An international journal of Indigenous peoples* and is co-authored with Shelly Valdez, Jorge Baracutei Estevez, Carlalynne Meléndez Martínez, Ángel Garcia, Keisha M. Josephs, and Abril Troncoso. This manuscript describes the process and findings from an inter-island knowledge exchange, drawing from Indigenous research methodologies, participatory action research, and constructivist grounded theory frameworks to explore benefits, barriers, and resources for Indigenous scholars and practitioners who are engaging Indigenous knowledge systems in science education and research in the Caribbean islands.

Manuscript 3, titled, *A research model for decolonizing community-based science research*, is in preparation for *Ecology and society: A journal of integrative science for resilience and sustainability*, and is co-authored with Michael Gavin, Norma Ortiz, and Shelly Valdez. This final manuscript is a conceptual paper and case study summary that includes: a summarized history of science research by, on, and with Indigenous communities; defines and justifies critical components necessary for integrity in research with Indigenous communities through synthesizing numerous research frameworks and concepts across disciplines as resources for improving ethical standards in environmental science research; visualizes a working model that draws these resources together; and presents a case study field-testing this working model.

For all three studies I maintained primary responsibility for design, data collection, analysis, writing and editing, while also facilitating community-based participatory methods throughout the various stages of the research design for Manuscripts 2 and 3. Therefore the material presented here represents my original intellectual work with the support of numerous mentors, practitioners and community research partners whose contributions are represented by means of co-authorship and detailed within the acknowledgements sections of each manuscript.

2. MANUSCRIPT 1: A GLOBAL ASSESSMENT OF INDIGENOUS COMMUNITY ENGAGEMENT IN CLIMATE RESEARCH[1]

2.1   Background

2.1.1   Indigenous knowledge systems and environmental science research

Indigenous communities around the world continue to cultivate and sustain Indigenous knowledge systems developed from long-term careful observation of environmental processes. Calls for inclusion of Indigenous knowledge systems in climate research come from both Indigenous communities and collaborative scientific forums, including for example, the Intergovernmental Panel on Climate Change (IPCC) Working Group II, Secretariat of the Convention on Biological Diversity, U.S. National Climate Assessment, and the Indigenous Environmental Network (Adger et al., 2014; Maldonado et al., 2015; Maynard, 2014; Douglas J. Nakashima et al., 2012). Reasons behind this call include improvements both in the effectiveness of research and in the standards of ethical research (T. D. Pearce et al., 2009). Indigenous communities whose knowledge and subsistence systems remain tightly woven with ancestral lands often suffer disproportionate impacts from accelerating climate-related biological disruptions and land-loss, as well as from political, social and ideological marginalization and persecution (J. D. Ford, Cameron, et al., 2016; United Nations, 2009). Currently, we have neither a standard set of indicators for responsible inclusion of Indigenous knowledge and communities in environmental sciences, nor an understanding of the degree to which research projects follow

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responsible research practices. This study fills these two research gaps and develops an analytical framework that can be applied for assessing Indigenous community engagement across a wide range of research fields.

2.1.2   Answering the global call for inclusion

Within the past decade, global networks of scientists and practitioners have formally recognized the immense value of Indigenous knowledge systems for the adaptive capacity of humankind in times of extreme climate variability. Both the fourth and fifth assessment reports of the IPCC's Working Groups emphasize Indigenous knowledge systems as critical resources for effectively adapting to climate change. Regarding human security, the latter report found "high agreement among researchers that involvement of local people and their local, traditional, or indigenous forms of knowledge in decision making is critical for ensuring their security" (Adger et al., 2014, p. 765). In the United Nations publication titled *Weathering uncertainty: traditional knowledge for climate change assessment and adaptation*, an emphasis on collaboration, co-production of knowledge, and cross-cultural methods reflect the call to shift to more inclusive methods in scientific research (Douglas J. Nakashima et al., 2012). Similarly, in the National Aeronautics and Space Administration's (NASA) most recent *Native People Native Homelands Climate Change Workshop Report* several regional working groups identified community involvement and utilizing diverse ways of knowing as important action strategies and as areas needed to implement coping and adaptation strategies (Maynard, 2014). Most recently, the Climate and Traditional Knowledge Workgroup published guidelines for U.S. tribes, agencies, and organizations in an effort to inform culturally ethical, tribally-led partnerships that weave multiple knowledge sources for climate initiatives (CTKW 2014). As the number of climate research studies engaging Indigenous knowledge systems continues to increase,

Indigenous communities from across the globe are simultaneously coordinating efforts to reclaim authority over their knowledge systems, languages and practices. One of the most formative efforts, the *United Nations Declaration on the Rights of Indigenous Peoples* (UNDRIP), directly addresses concerns regarding Indigenous peoples' authority over their knowledge systems in Article 31:

> *Indigenous peoples have the right to maintain, control, protect and develop their…traditional knowledge…as well as the manifestations of their sciences, technologies and cultures …They also have the right to maintain, control, protect and develop their intellectual property* (UN General Assembly 2007, p 10).

A decade since this declaration was established, there remains little evidence of action in the climate science research community for addressing these concerns in practice. In this time of increasing climate variability and ongoing socio-political vulnerability, the need persists to ask how the scientific processes for engaging Indigenous knowledge systems support or neglect the rights and capacities of the communities maintaining these knowledge systems (United Nations Framework Convention on Climate Change, 2013; Whyte, 2017). This study documents a systematic analytical exploration of climate research studies that draw from Indigenous knowledge systems to provide the first comprehensive global assessment on how Indigenous knowledge systems and the communities who hold them are engaged in scientific studies. We first develop an analytical framework synthesizing theory of effective practices for responsible community engagement in research and then apply this framework to examine the degree to which these practices are followed in climate research with Indigenous communities.

2.2 Methods for Assessing Community Engagement in Climate Studies

2.2.1 Conceptualizing Indigenous communities and knowledge systems

For the context of this interdisciplinary study, we recognize the need to build a shared conceptual understanding of terms such as "Indigenous communities" and "Indigenous

knowledge systems". When the United Nations Working Group on Indigenous Peoples

developed the *Draft Declaration on the Rights of Indigenous Peoples* (2007), they emphasized

the need to retain autonomy within each respective community for defining Indigenous

communities and peoples. For the context of this study, "Indigenous" should be understood to

reference a community of peoples sharing intergenerational ancestry and cultural aspects with

original (i.e. pre-colonial) occupants of ancestral lands in a specific region of the world. Within

this definition, membership to an Indigenous community should be understood as a sovereign

right established both through self-determination and community acceptance (Anaya, 2004).

Following this understanding, the concept of "Indigenous knowledge systems" is included in this

study to mean dynamic systems of knowledge collectively held by Indigenous community

members that draw from intergenerational, place-based, culturally embedded relationships and

experiences. Shared terms also used in academia and policy that reflect these unique systems of

knowledge include: 'Indigenous environmental knowledge', 'indigenous knowledge',

'indigenous ways of knowing', 'Native science', 'traditional ecological knowledge', and

'traditional knowledge' (Berkes, 2008, 2009b; Burkett, 2013; Cajete, 2000; International Council

for Science, 2002; D. Nakashima & Roué, 2002).

2.2.2   Developing an analytical framework

The following section describes our development of an analytical framework for

examining community engagement in research practice, including two main components: a scale

of levels of community participation and a set of indicators for responsible research practice with

Indigenous communities. Recent calls for improvements in inclusion and collaboration with

Indigenous communities in climate science research (J. D. Ford, Cameron, et al., 2016; H. A.

Smith & Sharp, 2012) guided us towards developing a relevant framework grounded in

Indigenous and community-based participatory research guidelines and ethical standards. We also recognized that beyond levels of engagement, consistency and quality of engagement for community members also require consideration for effective research practice (Israel et al., 1998; T. D. Pearce et al., 2009; Reed, 2008).

2.2.2.1 *Scaling levels of community participation*

Within participatory research we commonly find scales and typologies for assessing participation in environmental science related literature (Arnstein, 1969; Biggs, 1989; Lilja & Ashby, 1999; Rodriguez-Izquierdo, Gavin, & Macedo-Bravo, 2010; Shirk et al., 2012). We adapted these scales for our analytical framework while also drawing from Indigenous, community-based and participatory action research theory. An ever-growing number of Indigenous researchers and communities continue to develop and implement research frameworks reflective of their own cultural values and systems through Indigenous epistemologies and research models (e.g. Estrada 2005, LaFrance and Nichols 2009, McGregor *et al* 2010, Smith 2012, Weber-Pillwax 1999, Wilson 2008). These frameworks share considerations outlined in participatory action and community-based research, such as who retains authority over research design and whose interests are served (Chilisa, 2012). Indigenous research frameworks are also distinct in their explicit emphasis on self-determination and relational accountability to one's own community, including non-human communities (Weber-Pillwax, 1999; Wilson, 2001). Another common theme among Indigenous research frameworks is that the research process is centered on values, definitions and protocols developed within the Indigenous community engaged in the research (J. LaFrance & Nichols, 2009). These research models recognize and account for colonial, historical and socio-cultural contexts in which

research takes place, and the unique challenges and strengths inherent in Indigenous communities (Kovach, 2010).

When implemented within a culturally-relevant, community-centered framework, research should reflect the value-centered approach of Indigenous research methodologies (P. A. Cochran et al., 2008; LaVeaux & Christopher, 2009; Smith, 2012). Participatory action research closely reflects this value-centered process (Kindon, Pain, & Kesby, 2007). However, the interpretation and applied practice of community-based and participatory research varies considerably from study to study (Cornwall & Jewkes, 1995). In an effort to identify best practices in participation , Reed's (2008) review of stakeholder participation in environmental management finds that the quality of participation is highly dependent on the quality of the process it builds from, and furthermore the philosophy upon which that process is built. Philosophical qualities identified in Reed's review include participants' ability to engage effectively in decision-making, recognizing and limiting pre-existing power inequalities, and supporting ongoing two-way learning between participants and researchers.

For our adapted scale, we assess levels of community participation ordered along a continuum ranging from contractual (employment-related) participation in which community members have at most a contracted role in the study with no decision-making authority, up to an Indigenous process in which all aspects of a study are contextualized and decided upon within the community (Figure 2.1). Each level in the scale varies according to what degree community members engage in the process and who holds primary decision-making authority in the research.

Contractual	Consultative	Collaborative	Collegial	Indigenous
Community members contracted to perform tasks, researchers make all decisions	Community members asked for opinions and consulted, decisions made by researchers	Community members and researchers work together, researchers have primary authority over the process	Community members and researchers work together, community members have primary authority over the process	Process is centered in Indigenous value systems & historical context, community members have authority over the research process

Decreasing   LEVELS OF COMMUNITY PARTICIPATION   Increasing

(based on who has authority over the research process, adapted primarily from Biggs, 1989; Johnson, Lilja, & Ashby, 2003)

Figure 2.1: Scale for Assessing Levels of Indigenous Community Participation

One key feature emphasized in best practices for community participation, is continuity in community engagement throughout all stages of the research process (Fisher & Ball, 2003; Johnson et al., 2003; Reed, 2008; Sims & Kuhnlein, 2003). Likewise, the United Nations Framework Convention on Climate Change technical paper on best practices for use of Indigenous and traditional knowledge calls for "involving indigenous and local knowledge in all assessment phases, from conception through to outputs", and that a prerequisite to including Indigenous knowledge is "full and effective participation of [knowledge] holders" (2013, p. 24). Each stage in the research process holds a unique purpose and impact for the participating community members. Following these recommendations, we apply this scale to various stages along the research process of field studies identified for this review, including design (proposal development, defining goals and objectives, defining research questions etc.), implementation

(fieldwork, sampling, data collection, monitoring etc.), and analysis (data interpretation, evaluation etc.).

2.2.2.2 *Identifying indicators for responsible community engagement*

In addition to levels of engagement, we developed indicators for responsible research standards to assess quality of engagement undertaken by field studies. Withstanding centuries of challenges to their rights to maintain their own knowledge systems and practices, Indigenous peoples continually speak to a need for quality standards for research in their communities. Numerous Indigenous peoples' and collaborative science working group reports and codes of conduct present ethical guidelines and recommendations for responsible research partnerships (Convention on Biological Diversity, 2011; CTKW, 2014; ISE, 2006; Thaman et al., 2013; United Nations Framework Convention on Climate Change, 2013; United Nations General Assembly, 2007). For the purpose of this study, we identified best practices from literature on community-based, participatory and Indigenous research methods, and Indigenous community concerns identified in working group reports to develop indicators for responsible community engagement. Indicators reflect both foundational standards for responsible research (e.g. free prior and informed consent) and benefits for local communities (e.g. accessibility to findings). We include six indicators for responsible research practice in our assessment of reported data from climate field studies that speak to these concerns:

Indicator 1 - Access: Are findings accessible to Indigenous community members? Access indicates whether field studies address community access to findings (e.g. local presentations and distribution of publications regarding findings from study; data available to or stored with community members; materials from study produced in local languages). Mechanisms for community access should be addressed from the outset of the study design (CIDA, 2002).This

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indicator reflects the "principle of reciprocity", often lacking in existing academic research ethics protocols, for disseminating study results back to contributing community members in an accessible language and format (Smith, 2012, p. 16). Reciprocity in knowledge sharing is also identified as a method for "promoting inter-cultural exchanges, knowledge and technology transfer" (Convention on Biological Diversity, 2011).

Indicator 2 - Relevance: Are findings reported in the context of concerns, issues or interests defined by Indigenous community members? Relevance is defined by the degree to which reported findings are explicitly relevant to concerns and interests pre-identified by members of the community. The *UN DRIP* (2007), *Kaupapa Māori* principles (L. T. Smith, 2015), and the *International Society of Ethnobiology (ISE) Code of Ethics* (2006), all reflect this philosophy towards looking critically at how developments and research designs support communities within their existing cultural and organizational needs and concerns.

Indicator 3 - Credit: How were Indigenous community members credited for their knowledge contributions and efforts (acknowledgement, co-authorship)? Credit is defined by the degree to which research credits knowledge holders for their contributions (i.e. no acknowledgement, acknowledgement only, co-authorship). This indicator reflects the Climate and Traditional Knowledges Workgroup call for ensuring that "contributions of tribal partners are recognized in final products, publications, and efforts to publicize projects" (2014, p. viii). The ISE Code of Ethics' "Principle of Acknowledgement and Due Credit" also emphasizes the importance of crediting knowledge contributions: "researchers will act in good faith to ensure the connections to original sources of knowledge and resources are maintained in the public record" (2006, p. 8).

Indicator 4 - Ethics: Did the study report ethical guidelines followed, such as Free Prior and Informed Consent? Fundamental ethical principles that have long been recognized in medical and legal practice, such as "free, prior and informed consent" (FPIC), now form basic requirements for academic and institutional research with human communities. *Ethics* indicates whether studies reported ethical guidelines followed in the research process (e.g. FPIC, approval from Indigenous ethics group, reference to applied code of ethics). Ethical responsibilities researchers hold to Indigenous communities require careful consideration in order to promote benefit for community members and reduce harm (Piquemal, 2001; Williams & Hardison, 2013). As one example of ethical guidelines, the principle of FPIC works to ensure that knowledge holders within Indigenous communities retain informed decision-making authority regarding their participation in the research process. Numerous ethics guidelines emphasize the importance of providing knowledge of and receiving prior approval for research that impacts Indigenous communities (Convention on Biological Diversity, 2011; CTKW, 2014; ISE, 2006; United Nations General Assembly, 2007) .

Indicator 5 - Cause no harm: Did the study address intellectual property rights or risks for Indigenous communities? The principle of *cause no harm* or *do no harm* represents another fundamental ethical standard relevant to climate research practice with Indigenous communities (CTKW, 2014). *Cause no harm* indicates whether studies address concerns regarding the Indigenous intellectual property (e.g. community review and/or ownership of data, sensitive data identified and protected). The principle of *cause no harm* denotes a critical step in assessing risk and potential harm, both socio-cultural (e.g. appropriation of cultural and intellectual property) and material (e.g. resource exploitation), for Indigenous communities in the research process. The *Mataatua Declaration on Cultural and Intellectual Property Rights of Indigenous Peoples*,

calls for state, national and international agencies to "recognise that indigenous peoples are the guardians of their customary knowledge and have the right to protect and control dissemination of that knowledge" (1993, p. 3). In addition, guides for best practices in international project planning with Indigenous peoples call for safeguards that increase Indigenous peoples' decision-making authority proportional to higher levels of risk associated with sharing of Indigenous traditional knowledge (CIDA, 2002). This consideration also reflects issues reported by Native Americans, Alaska Natives, and Pacific Islanders disproportionally impacted by climate change regarding the issue of intellectual property, in which they emphasized Indigenous communities as the best resources for ensuring that protocols for integrating diverse knowledge systems include cultural protections (Maynard, 2014).

Indicator 6 - Outputs: Did the study report any outputs or outcomes for the Indigenous community? Outputs and outcomes that indicate quality practices include whether projects lead to any actions or changes within the community (e.g. capacity-building, adaptation plans), or whether any products developed from a given study directly benefit the community (e.g. maps, curriculum materials). Much like access, this indicator also links back to the foundational principle of reciprocity centered in Indigenous research methodologies and codes of ethics. For example, the ISE Code of Ethics recognizes the right for community members to benefit from outcomes and results produced by research that accesses Indigenous knowledge systems (ISE, 2006). In their study on integrating local and scientific knowledge for environmental management, Raymond et al. state that an indication of project success is "the extent to which the knowledge integration outputs are used by those who input their knowledge" (2010, p. 1770).

The scale and indicators described in detail above served as analytical tools for assessing the degree of Indigenous community engagement in climate studies. The following section

further describes how we identified studies and specific criteria for justifying inclusion in our global review.

2.2.3 Protocol development and expert review panel

We adapted methods for this review from existing systematic review frameworks (Grant & Booth, 2009; Munroe et al., 2012; Pullin & Stewart, 2006). The process included developing a review protocol in consultation with a panel of experts, a comprehensive search of peer-reviewed and grey literature, qualitative synthesis and a quantitative analysis. The supplementary materials associated with this article include full details of the search and screening results, description of attributes and codes (Appendix 8.2), data analysis results, and a bibliography (Appendix 8.3) for all articles included in the review.

Based on systematic review guidelines adapted from health services research for environmental sciences (Pullin & Stewart, 2006), we invited subject experts early in the process to ensure a more robust protocol that is relevant to research practice and policy. In addition to the two authors, eight additional panel members (see *credit and acknowledgements* section) whose work focuses on Indigenous knowledge systems and environmental sciences provided feedback to help refine the research questions and search terms and to identify relevant field studies. Five of the panel members are Indigenous community members currently working on climate research, including the lead author D. M. David-Chavez. The five remaining members maintain expertise in working collaboratively with Indigenous communities and knowledge systems.

2.2.4 Screening and inclusion criteria

2.2.4.1 *Search terms*

Search terms developed and refined with the expert panel represent three unique overlaying concepts—one identifying the appropriate populations and two defining thematic content:

1. Indigenous populations: (*indigenous* OR *native* OR *tribal* OR *aborigin** OR *"first nation*"* OR *"local communit*"* OR *indian)* AND

2. Indigenous knowledge systems: ("*traditional ecological knowledge**" OR "*traditional knowledge**" OR "*traditional environmental knowledge**" OR "*native science**" OR "*oral histor**" OR "*indigenous knowledge**" OR "*indigenous ecological knowledge**") AND

3. Climate science: ("*climat* change*" OR "*climat* science*" OR *phenolog** OR "*weather forecast**" OR "*envir* change**" OR "*envir* observation**" OR "*climat* adaptation**")

The final list of search terms presented here represent results from several scoping searches through the Web of Science database in which we identified terms that most accurately and comprehensively located thematically relevant climate field studies. We also checked database results for field studies pre-identified by the expert review panel as indicators for whether search terms were reaching the necessary scope to capture all relevant case studies. Final results from the Web of Science database search (n=311) included publications from all past years up to 8th of April 2016. To reduce potential publication bias (Conn, Valentine, Cooper, & Rantz, 2003), we identified additional literature (n=228), including grey literature identified through manual hand-searching of reference lists and by using a modified search string in Google Scholar conducted

25th of April 2016 (first 200 results, sorted by relevance). Although we included results from all years, the earliest article meeting inclusion criteria for the final review dates to 1996 (Figure 2.2).
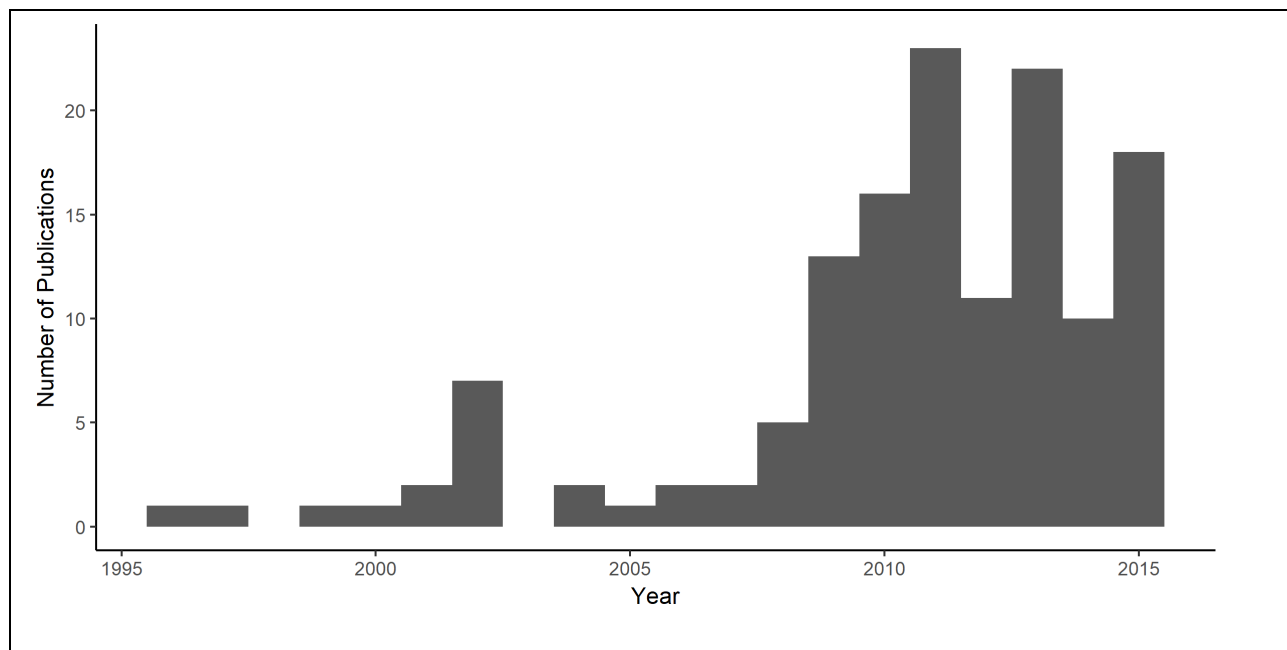
Figure 2.2: Number of Publications Meeting Review Criteria by Year (excluding 2016 data for partial year)

2.2.4.2 *Criteria for selection for full review*

Screening criteria for titles and abstracts included three main criteria for inclusion. Firstly, we required original field studies containing climate-related environmental research. "Climate-related environmental research" includes knowledge systems and biocultural relationships humans hold in regard to long term weather patterns, their environmental impacts, and environmental adaptation in a particular place. Secondly, we required studies to include Indigenous knowledge system(s) (e.g. traditional ecological knowledge, Native science) from specific Indigenous community(ies). Thirdly, we required studies to be published in English (due to reviewers' language fluency limitations). Publications meeting these criteria, or those we could not clearly determine based on title and abstract alone, were included for full-text review (n=232). Publications meeting all criteria that also contained enough methodological and

contextual information regarding the research process were included in the final analysis (n=140;

figure 2.3).

(Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009)
*Reasons for exclusion: Secondary research (not an original field study), Research content (not focused on climate-related environmental research), Population (does not include specific Indigenous community), Methods unavailable (not enough context reported on research methods), Multiple studies (included several individual case studies separated for individual analysis), and Non-English

Figure 2.3: Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) Search Results Flowchart

2.2.5 Data collection, coding and analysis

We recorded data obtained from full-review articles meeting all inclusion criteria in a spreadsheet for cross-case qualitative and quantitative content analysis (Stemler, 2001). For multiple articles containing content from the same field study (n=15), we aggregated notes and coded data as a singular case under the most current publication year to allow for a balanced comparison in quantitative analyses of research practices across field studies. Attributes recorded for each field study included demographic data, disciplines of study authors, levels and methods of Indigenous community engagement in all stages in the research process (i.e. initiation, design, implementation, analysis, dissemination), and quality indicators for responsible research practice. This process for data collection allowed for an inclusive analysis of a diverse range of qualitative, quantitative and mixed methods studies. We developed categorical codes to indicate the levels of Indigenous community participation at the initiation phase of field studies: A-outside academic researchers, M-mutual agreement between outside researchers and Indigenous community members, C-community initiated, O-other, NR-not reported. For the design, implementation, and analysis stages of the research we applied the ordinal scale developed in our analytical framework to record levels of Indigenous community participation: 0-Contractual/No participation, 1-Consultative, 2-Collaborative, 3-Collegial, 4-Indigenous. Although at the time of this review no studies met criteria for *Indigenous* level on scale, we retained this code for future analyses. We also coded reported data for each indicator of responsible community engagement as follows: *access* (0-not reported, 1-accessibility is directly addressed); *relevance* (0-not reported, 1- relevance for community is directly addressed); *credit* (0-not reported, 1-acknowledgement only, 2-co-authorship); *ethics* (0-not reported, 1-some form of ethical guidelines/consent process reported); *cause no harm* (0-not reported, 1- intellectual property

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rights/risks addressed); *outputs* (0-not reported, 1-proposed, 2-actual). Upon completion, the final spreadsheet comprised a case-based matrix with coded values visually linked with qualitative notes referencing evidentiary criteria used for identifying patterns of association (Bazeley, 2013). After excluding aggregated studies, a secondary reviewer unfamiliar with the study beyond the specific coding criteria analyzed and coded a random sample of field studies (n=29). We included an inter-rater reliability test (kappa = 0.907) using Cohen's weighted kappa to assess for consistency in coded values (Cohen, 1968).

In our analyses we searched for patterns across space, patterns across disciplines, patterns across time, and patterns in responsible community engagement in climate field studies. These included geospatial and statistical analyses using R Studio software (version 3.4.2). To view patterns across time, we compared levels of community participation within the design, implementation and analysis research stages. Different research stages represent unique components in terms of the research processes, and we recognize that active participation may vary across the length of a study. Further, in the ISE Code of Ethics 'Principle of Active Participation,' community participation is stressed within these distinct stages (2006, p. 6). We also compared levels of participation based on who initiated each study (i.e. outside researchers, mutual collaborations between researchers and community, or community initiated). Practical guidelines outlined in the ISE Code of Ethics recognize that "objectives, conditions and mutually agreed terms should be totally revealed and agreed to by all parties prior to the initiation of research activities" (2006, p. 11). To test for evidence whether proportions for each indicator of responsible community engagement reported in studies varied by who initiated the studies we used descriptive statistics and Fisher's exact test of independence with Holm's correction. Due to limitations in language fluency and time, we acknowledge some potential underestimation in

values for relevant case studies published in languages other than English and for grassroots-driven climate studies occurring yet not represented in any publications.

2.3   Findings and Discussion

2.3.1   Patterns across space

On a global scale we find that the vast majority of climate studies (87%) practice an extractive model in which researchers use Indigenous knowledge systems with minimal participation or decision-making authority from communities who hold them (Figure 2.4). Several geographic clusters denote where Indigenous knowledge systems have most often been accessed for climate research, with the most prominent groupings in the North American Arctic, Sub-Saharan East Africa and the Tibetan Plateau.
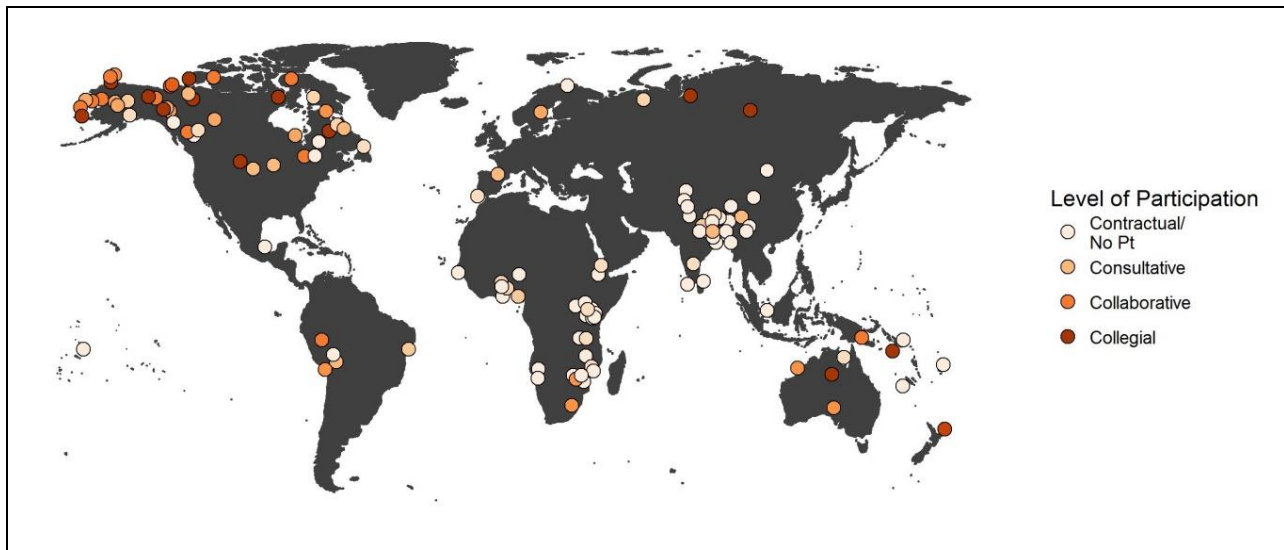
Figure 2.4: Patterns Across Space: Global Distribution of Field Sites Classified by Levels of Indigenous Community Participation.

Average levels of participation vary considerably between these three geographic regions, with the highest levels of Indigenous community participation concentrated in northern Canada and Alaska. In their study on community-level climate vulnerability assessments McDowell *et al* (2016) also note a higher than average concentration in participatory approaches in the North American Arctic, including stakeholder consultation in developing research

objectives and Indigenous evaluation of quality of results. Although the limited scope of our study did not explore drivers for these geographic patterns in detail, we note that these similarities invite further research into why these regional variations in Indigenous community participation occur. Many different factors may influence the variation in geographical distribution, including differences in research policies across countries regarding engagement and documentation of involvement with Indigenous communities. For example, in response to non-Indigenous research priorities and over-researched communities, Canadian First Nations standardized new ethical guidelines on data ownership, data sharing and self-determination (Schnarch, 2004). Further, within the U.S. Arctic, principles regarding ethical responsibilities towards Indigenous communities guide some federally-funded research initiatives (National Science Foundation, 1990). Observing global distribution of field studies also reveals extensive geographic gaps representing areas where Indigenous knowledge systems and communities may not yet be included in climate research. These include areas, such as low-lying islands, drought and flood-prone regions, and coastal regions where changes in hydrological, marine, terrestrial and food systems attributed to climate impacts continue to raise increasing concern (Field, Barros, & Intergovernmental Panel on Climate Change, 2014).

2.3.2   Patterns across disciplines

Climate research studies inherently span a broad reach of disciplines and approaches. We found that within climate research that engages Indigenous knowledge systems, patterns in authorship reflect an ongoing shift in scientific knowledge production from intradisciplinary approaches (drawing from a single field of theory and methods), towards application-oriented research achieved through interdisciplinary (integration of theory and methods from two or more disciplines), multidisciplinary (collaborations between people working within different

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disciplines), and transdisciplinary (reaching beyond disciplines to include stakeholders and

practitioners) methods (Figure 2.5).
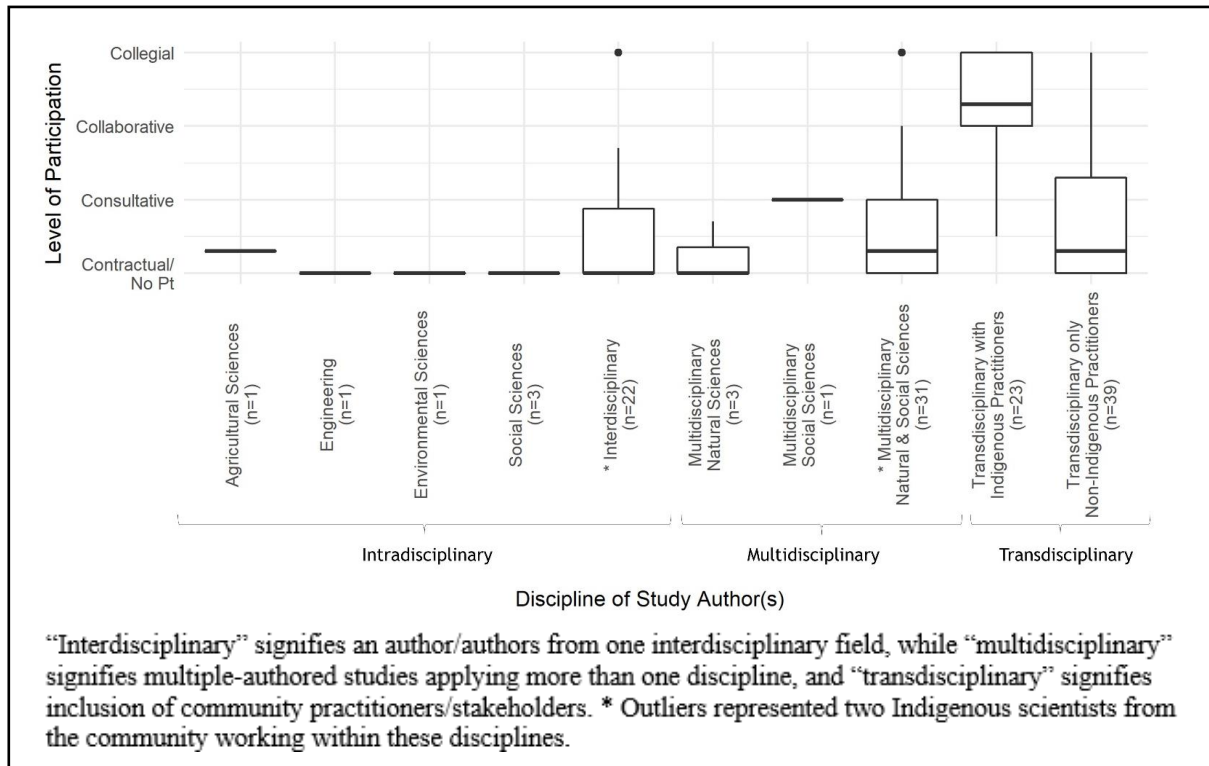
Figure 2.5: Patterns Across Disciplines: Variation in Levels of Participation by Discipline(s) of
Study Author(s).

The highest proportions of climate studies engaging Indigenous knowledge systems

include studies authored by interdisciplinary (18%), multidisciplinary natural and social sciences

(25%), and transdisciplinary researchers (50%). We observed the highest levels of engagement

(collaborative and collegial) in studies authored by teams that include Indigenous scientists and

community members and/or local practitioners. Studies that included only non-Indigenous

practitioners and non-Indigenous authors from multiple disciplines remain heavily weighted

towards contractual participation. Analysis of distributions of disciplines within these climate

studies demonstrate an ongoing shift beyond only traditional scientific disciplines, towards the

inclusion of application-oriented and integrated disciplinary approaches that address usability

and social relevance of knowledge (Van den Besselaar & Heimeriks, 2001). We consider these

findings in parallel with ongoing emphases in global environmental change research for collaborative and transdisciplinary research—harnessing strengths from natural sciences, social sciences, humanities and community knowledge alike, to address complex challenges (Belmont Forum, 2016; Mauser et al., 2013; Palsson et al., 2013).

2.3.3 Patterns across time

We also sought to understand variations in levels of Indigenous community participation across different stages in the research process. Among studies reporting methods in the design, implementation and analysis phases of research, we find that a substantial number of studies (39% in design, 48% in implementation, 56% in analysis) practice no or contractual (employment-related) levels of Indigenous community participation (Figure 2.6).

design (n=92), implementation (n=124), analysis (n=106); crossbar indicates mean
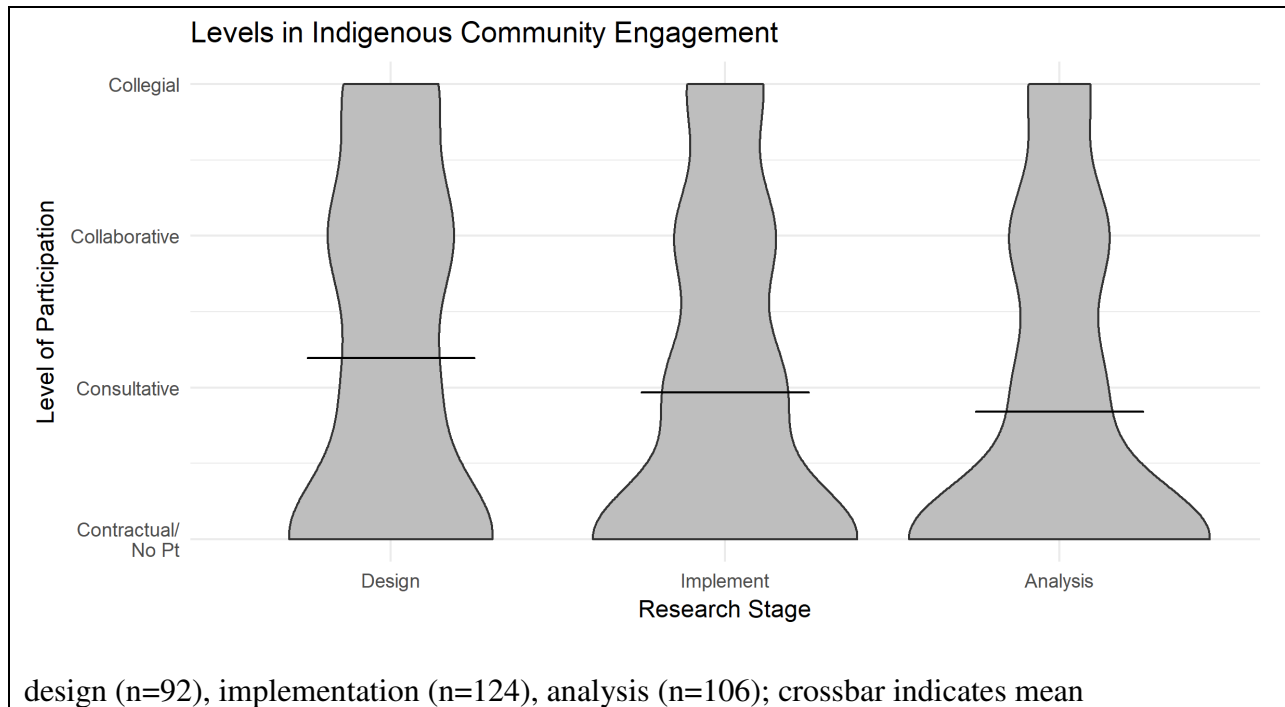
Figure 2.6: Patterns Across Time: Variation In Levels Of Participation By Research Stage.

Participation in all stages of research varied considerably depending on who initiated the project. Research initiated with (n=21) or by (n=10) Indigenous communities had higher levels of engagement and inclusion throughout all stages of the research process (Figure 2.7). However,

studies initiated in mutual collaboration between outside researchers and community members

vary more widely in levels of participation, especially in the analysis phase of the research.

n=120; 5 studies coded 'other' or 'not reported' for project initiator excluded; portion above dotted line represents decision-making authority held with community knowledge holders
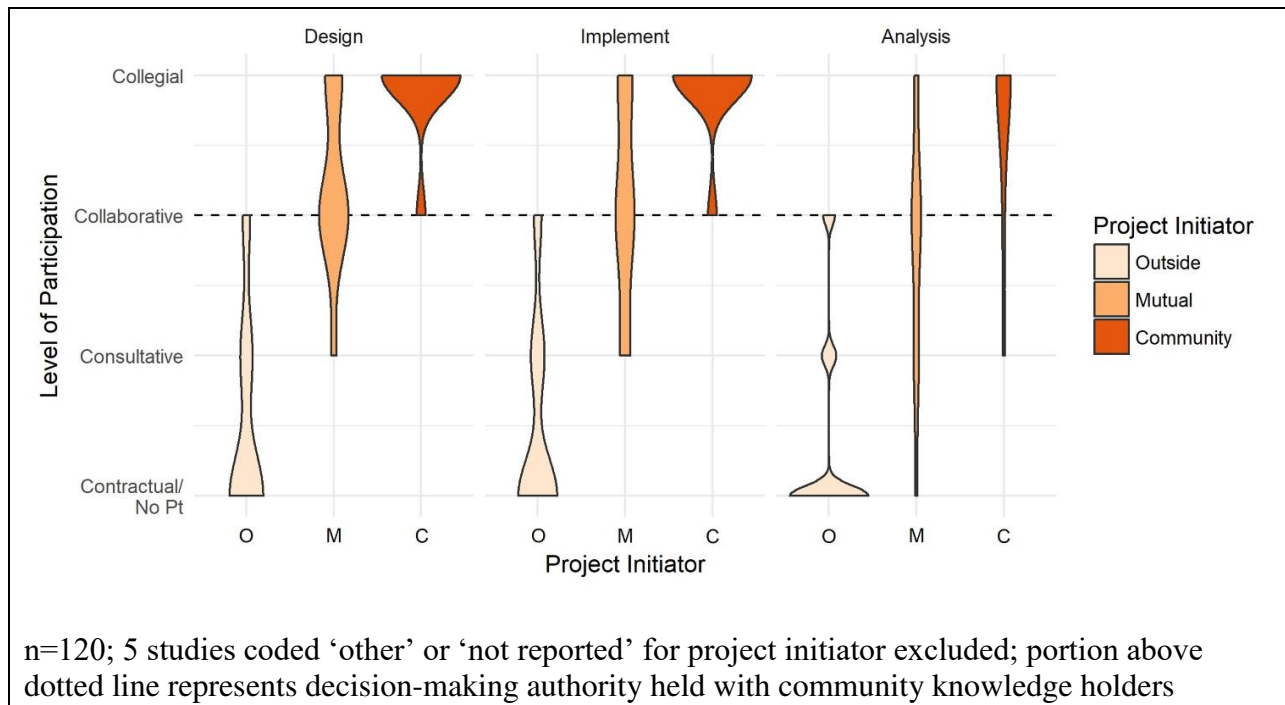
Figure 2.7: Patterns Across Time: Variation In Levels Of Participation By Research Initiator.

By contrast, studies initiated solely by outside researchers (n=89) tend to maintain lower

levels of participation across all stages of the research process. The greatest variation in

participation levels across study groups occurred in the analysis stage. These results may speak

to needs and challenges identified in similar studies on community engagement in research,

including local employment and training (Fisher & Ball, 2003; T. D. Pearce et al., 2009), and

adapting research for analyses that can draw on more diverse knowledge systems by allowing for

knowledge co-production (Harvey, Cochrane, Van Epp, Cranston, & Pirani, 2017). Likewise,

increasing levels of participation across various stages of research may call for additional

capacity building among researchers towards understanding rights, risks, cultural protocols and

methods for respectful inclusion of diverse ways of knowing in climate research (P. Cochran et

al., 2013; CTKW, 2014). Overall, many studies that verbally referenced community inclusion

and engagement (e.g. "participatory research"), lacked evidence to demonstrate community engagement beyond contractual tasks. This parallels McDowell *et al* (2016) and Pearce *et al's* (2009) observations that although local knowledges are recognized for their importance in climate research, participatory design remains lacking in applied practice. This observation also reflects challenges with how the idea of participation is applied in research. While terminology such as "community-based" and "participatory" are used in a variety of ways, they may not be consistently applied in practice.

2.3.4 Patterns in responsible community engagement

The majority of studies did not report the presence of 5 of the 6 indicators of responsible community engagement (Figure 2.8). The lone exception was with credit for community contributions in the form of an acknowledgement. However, although most studies included a formal acknowledgement for Indigenous knowledge contributions to field studies, less than a quarter of all studies included co-authorship for Indigenous knowledge contributors.
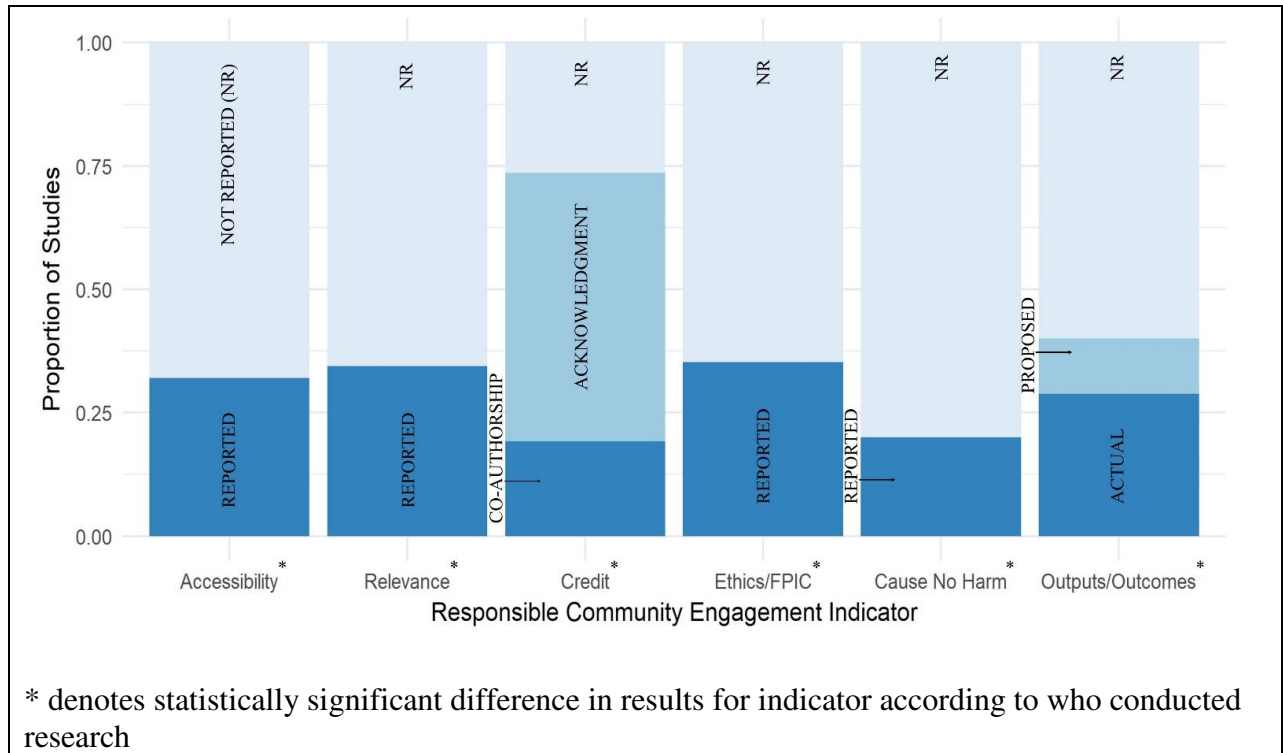
Figure 2.8: Patterns in Quality: Variation in Proportions of Indicators for Responsible Research Engagement in Reported Data from Climate Studies.

Engaging Indigenous community members from the beginning of the research process does not necessarily guarantee sustained responsible research engagement throughout the length of the research, however we found statistically significant differences in all six indicators for responsible community engagement depending upon who conducted climate studies (*p* values: Initiated by vs. Access 3.30549e-11; Initiated by vs. Relevance 6.457925e-10; Initiated by vs. Credit 2.186311e-11; Initiated by vs. Ethics/FPIC 0.005697953; Initiated by vs. Cause No Harm 1.194242e-07; Initiated by vs. Outputs/Outcomes 1.405891e-06).

Overall, studies that engaged Indigenous community members from the beginning of the research process (those initiated by community members or in mutual agreement between outside researchers and community members) consistently reported higher proportions of indicators for responsible community engagement (Figure 2.9). Some of these indicators (i.e. *ethics/FPIC*, *cause no harm*) represent foundational research principals recommended in ethical

research conduct with all human communities. Other quality indicators (i.e. *accessibility*, *relevance*, *credit*, *outputs/outcomes*) also speak to best practices in community-based and participatory research practices.
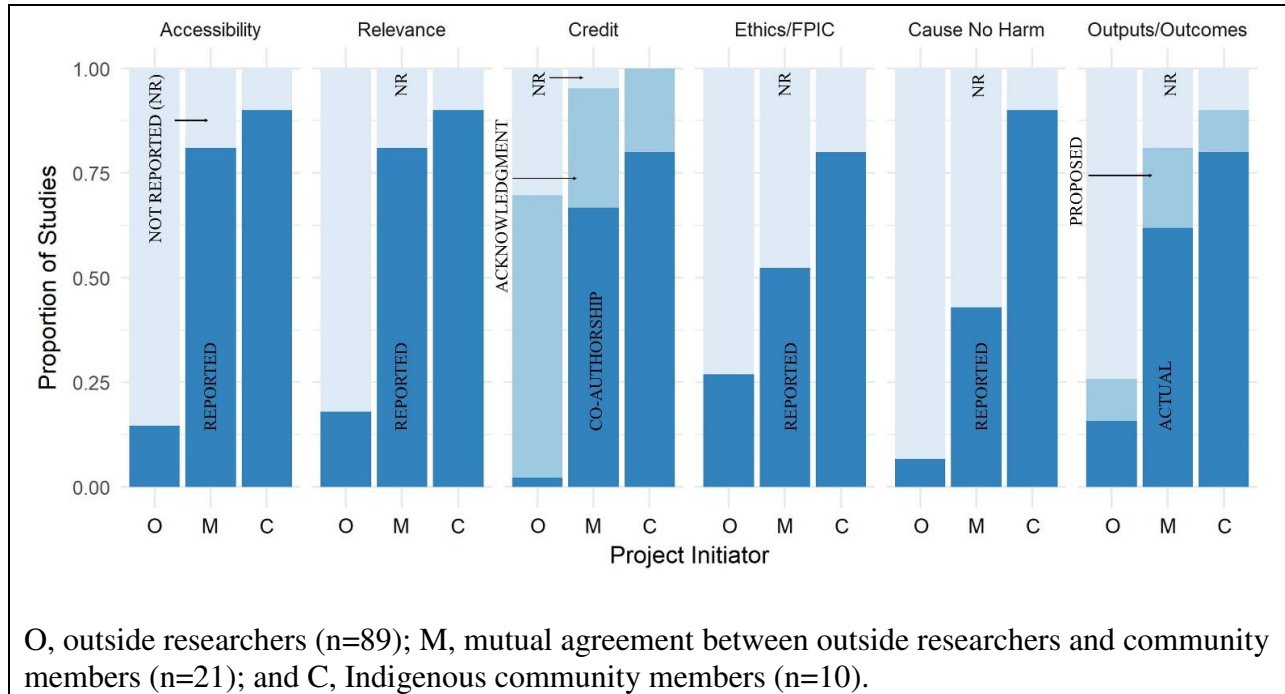
O, outside researchers (n=89); M, mutual agreement between outside researchers and community members (n=21); and C, Indigenous community members (n=10).
Figure 2.9: Patterns in Quality: Variation in Proportions of Indicators for Responsible Research Engagement Present in Reported Data from Climate Studies Grouped by Who Initiated Studies.

Just under 15% of studies initiated by outside researchers reported community access to research findings, compared to 80-90% for those that included Indigenous community members from the initial stages of the research process. Similarly, 18% of studies initiated by outside researchers, 81% of studies initiated in mutual agreement between outside researchers and community members, and 90% of community-initiated studies reported findings within the context of concerns, issues or interests relevant to Indigenous community members.

Although all the studies in our analyses accessed and included Indigenous knowledge systems in the research, 22 of the 24 studies that attributed co-authorship to Indigenous knowledge holders or tribal communities were initiated in mutual agreement with or by Indigenous community members from the outset. When considering Indigenous knowledges in

climate research studies we must also consider intellectual property rights and potential

problematic risks to communities. Findings from this study infer that for most climate studies

(n=101, 81%), researchers from outside the community will inevitably be cited in connection

with Indigenous knowledge reported in the research findings. As Williams and Hardison (2013)

point out, few social or political governing principles exist in practice regarding obligations

towards Indigenous knowledge holders for outside researchers who share Indigenous knowledge

with third parties and secondary users.

Among climate studies initiated by outside researchers alone, 27 % report any indication

of including ethical guidelines in the research process, including free, prior, and informed

consent, and only 7% report any indication regarding intellectual property rights and risks for

participating communities. However, substantially more studies that include Indigenous

community members from the beginning of the research process (52% mutually initiated studies,

80% community-initiated) reported the use of ethical protocols and exercising the principle to

cause no harm (43% mutually initiated studies, 90% community-initiated).

Just under 16% of studies initiated by outside researchers reported actual outputs or

outcomes for Indigenous communities in their studies. Alternately, 62% of mutually initiated

studies and 80% of studies initiated by community members reported outputs or outcomes

relevant to the communities, including: capacity building, climate adaptation plans, educational

curriculum, maps, and digital media resources for the study community.

We developed each of these indicators of responsible engagement based on research

standards identified within both Indigenous communities and professional scientific forums. The

fact that the majority of studies do not report evidence of adhering to these indicators of

responsible engagement raises concerns. When considering broader impacts such as public

understanding and support of scientific research, these patterns identify areas in need of improvement. These findings also represent an imbalanced exchange between outside academic researchers and Indigenous knowledge holders. The large proportion of studies reporting lack of community access to findings, relevance, credit, ethical considerations, or benefit to Indigenous communities indicate a deficiency in long-term accountability and reciprocity towards Indigenous knowledge holders. Most of the studies assessed here demonstrate an extractive process in their interaction with Indigenous communities and their knowledge systems.

Several pathways should be explored to encourage more responsible research engagement in the future. For one, publication journals and funding agencies could hold an important role in improving research standards by requiring reporting on these indicators. For example, *AlterNative: An International Journal of Indigenous Peoples*, founded by New Zealand's Māori Centre of Research Excellence, requires that authors have approval from Indigenous knowledge holders through research agreements, approval from ethics committees, and that they "design a study with participatory research and give the community and individual participants say in the anonymity and use of data" (Ngā Pae o te Māramatanga, 2016). Additionally, the Climate and Traditional Knowledges Workgroup Guidelines for Considering Traditional Knowledges (TKs) in Climate Change Initiatives document calls to, "develop guidelines for review of grant proposals that recognize the value of TKs, while ensuring protections for TKs, indigenous peoples, and holders of TKs" (2014, pp. 21–22).

Increasing access for involvement of Indigenous communities in research should also be supported. Mauro and Hardison (2000) call for scientific institutions and societies to support Indigenous community rights and development in managing their own data. In their study on traditional knowledge and science, Fernandez-Gimenez *et al* found that studies documenting

traditional ecological knowledge (TEK) were "less useful for the integration and application of knowledge than direct involvement by TEK holders (in this case hunters) in research and management" (2006, p. 313). Agrawal (1995) also underscores the need to remain intent on *who* knowledge is useful for. Several studies included in our assessment claimed a need to extract and catalog Indigenous knowledges due to the risk of the host cultures dying out. However, Agrawal warns against some of the risks in *ex situ* conservation of Indigenous knowledges, looking to *in situ* preservation as a new direction in research. This form of preservation, he states, requires that Indigenous communities "possess the right to decide on how to save their knowledge, how to use it, and who shall use it" (1995, p. 432). Likewise, Tang and Gavin (2016b) emphasize community-based initiatives and community engagement as a primary factor in preventing further loss and degradation of traditional ecological knowledge in Indigenous communities. Indigenous scholars such as Whyte (2018), further deepen this discussion by looking beyond the commonly referenced "supplemental-value" (value as added input to supplement gaps in scientific data) of Indigenous knowledge systems in climate research, to further understanding and supporting "governance-value" (value for sustainable planning initiatives and wellbeing in Indigenous communities), embedded within these knowledge systems. Future direction in this work will also continue to be shaped through the rapidly emerging fields of Indigenous data sovereignty and data governance, as led by Indigenous scholars and researchers around the world, which center the inherent pre-colonial rights of Indigenous peoples to govern the collection, stewardship and dissemination of data regarding their communities (e.g. Kukutai and Taylor 2016, Rainie *et al* 2017, Robertson 2018).

We also encourage further research assessing levels of engagement of underrepresented populations within Indigenous communities, such as marginalized genders, ethnic, and socio-

economic groups. For example, not all Indigenous community members may have an interest in or access to higher levels of engagement in research studies and participating in various aspects of the research may place disproportionate burden on community members, especially in the case of marginalized populations. Areas in the Arctic heavily researched for climate impacts also note concerns with research fatigue and consultation fatigue due to tokenizing or non-reciprocal interactions with community members (J. D. Ford, Stephenson, et al., 2016). United Nations' best practices for use of Indigenous knowledges in climate adaptation emphasizes the need for further understanding regarding "not only how different social groups are affected but also how different groups can bring vital resources to the adaptation process" (2013, p 5).

2.4   Conclusion and Recommendations

Our primary goal was to develop an analytical framework to assess how Indigenous knowledge systems are being accessed and identify how current standards in climate research practice are addressing calls for increased inclusion and engagement of diverse knowledge holders. In addition to observing temporal variation in patterns of engagement across studies, we also identified geospatial patterns, patterns in disciplines, and patterns in reported ethical practices and outcomes. By necessity our review could only examine details that researchers explicitly reported. However, researchers may not have reported all the procedures they implemented. We encourage future research projects to recognize the importance of community engagement and to embrace transparency in all methods used across the research process. Similarly, we would suggest that academic journals require more rigorous reporting of research methods and the level of engagement with local communities. Among the handful of studies in this global review demonstrating quality practices regarding responsible Indigenous community engagement (see references highlighted in supplementary data file), we observed numerous

opportunities that could serve as recommendations for removing barriers between researchers

and Indigenous community members and increasing scientific engagement. For example, most

high standard studies we observed used some form of on-site community workshops for opening

pathways for science communication and discussions with community members (Douglas et al.,

2014; Magga, Mathiesen, Corell, & Oskal, 2009; Nichols, Berkes, Jolly, & Snow, 2004). These

forums also provided a way to develop research topics and define priorities that could prove

useful to local knowledge users and policymakers (Doyle, Redsteer, & Eggers, 2013; J. Ford et

al., 2007). Another method we observed at high rates among quality studies was community

review of data prior to publication as a means of providing what Kendrick and Manseau refer to

as "culturally appropriate peer review processes" (2008, p. 415) (Lyver, Jones, & Doherty, 2009;

Sanderson et al., 2015). Additional recommendations for increasing science communication and

community engagement that we draw from this sample of high standard studies include: locally

produced and disseminated findings (booklets, videos, maps, curriculum, posters, etc.) (Crate &

Fedorov, 2013; Kofinas & Communities of Aklavik, Arctic Village, Old Crow, & Fort

McPherson, 2010; Turpin, Ross, Dobson, & Turner, 2013); opportunities to train and employ

community researchers (Lemelin et al., 2010; Tremblay et al., 2008); youth engagement (C. G.

Flint et al., 2011; Gill, Lantz, & the Gwich'in Social and Cultural Institute, 2014); prioritizing

Indigenous language to frame scientific concepts (Krupnik, 2010); creative and participatory use

of multimedia tools (photography, videography, local illustrators, etc.) (Peace & Myers, 2012);

participatory mapping (Leon et al., 2015); opportunities for cultural exchange and experiential

trips out on the land (Gearheard et al., 2006); deferring to community advisory groups or tribal

councils for guidance (Voorhees, Sparks, Huntington, & Rode, 2014); compensating participants

(Thorpe, Eyegetok, Hakongak, & Elders, 2010); developing research agreements (e.g.,

memorandum of understanding, see Cummins et al., 2010); and use of qualitative methods (e.g., focus groups, informal and semi-structured interviews, ethnographic approaches, transect walks etc.) (Gadamus et al., 2015; T. Pearce et al., 2010).

When viewed as a whole, our findings provide an evidence-base for identifying areas for improved standards in quality research practice. These findings reveal the variety of ways in which the scientific community is engaging Indigenous knowledge systems and communities who hold them in climate research, from extractive to action-oriented research. For the scientific community to value Indigenous knowledge systems, we understand the necessity to also respect the needs and values of the societies who hold these knowledge systems and the need for appropriate standards of responsible engagement within our research processes. Our current challenge is to develop normative standards of scientific research practice that support Indigenous communities in their ongoing efforts to maintain and practice these knowledge systems. Shifting research standards and practice will likely come with challenges such as adapting funding and timelines for cultural sensitivity and research reflexivity. However, the value that Indigenous knowledge systems hold for understanding and adapting our human communities to changes in our natural environment, far outweigh the costs of meeting these challenges.

Based on these findings, we call for action on the part of funding and research agencies, publication outlets, and institutional review boards to identify how they address responsible research concerns, such as those identified in the analytical framework presented here, in current standards for scientific research proposals and protocols. We offer ten guiding questions for researchers, funding agencies, journal editors and policy makers to further reflect on how research practices address these standards for responsible research practice with Indigenous

communities in every stage of the process (Figure 2.10). These guiding questions also hold

application for local, non-Indigenous communities. Through the efforts of this publication and

global assessment, it is our hope that this evidence-base serves as a reminder and practical guide

for cultivating balanced respectful exchanges of knowledge centuries overdue within our

scientific community. We also honor and recognize the value of the few shining examples

highlighted in supplementary data that exist for responsible research with Indigenous

communities as we strive to enhance ethical and intellectual standards for future research

practice.

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10 Questions for Guiding Responsible Research Practice with Indigenous Communities

1. Are Indigenous community members included in the decision to initiate the study?

2. To what level do Indigenous community members have authority in the research design (see scale for levels: None or Contractual (employment-related), Consultative, Collaborative, Collegial, Indigenous)?

3. To what level do Indigenous community members have authority regarding the implementation of the research?

4. To what level do Indigenous community members have authority regarding the analysis of the research?

5. Are findings accessible to Indigenous community members?

6. Are findings reported in the context of concerns, issues or interests defined by Indigenous community members?

7. How were Indigenous community members credited for their knowledge contributions and efforts (i.e. acknowledgement, co-authorship)?

8. Did the study report ethical guidelines followed, such as Free Prior and Informed Consent?

9. Did the study address intellectual property rights or risks for Indigenous communities?

10. Did the study report any outputs or outcomes for the Indigenous community?

Also, may be applicable to local, non-Indigenous communities. Adapted primarily from the UN Declaration on the Rights of Indigenous Peoples, the Climate and Traditional Knowledges Workgroup guidelines for considering traditional knowledge in climate change initiatives, and the International Society of Ethnobiology Code of Ethics.

Figure 2.10: Questions for Guiding Responsible Research Practice with Indigenous Communities.

3. MANUSCRIPT 2: COMMUNAL RESEARCH - COMMUNAL REGENERATION: UNDERSTANDING BENEFITS, BARRIERS AND RESOURCES FOR INDIGENOUS SCIENCE EDUCATION AND RESEARCH

3.1   Research Purpose and Context

Indigenous scholars and education practitioners hold heavy-burdened responsibilities for addressing the unique circumstances that have historically prevented balanced and respectful engagement of their communities in the sciences. Indigenous scholar and writer Leanne Simpson maintains that "the answers to how and why our knowledge has become threatened lie embedded in the crux of the colonial infrastructure", which must be carefully dismantled to advance efforts towards self-determination (2004, p. 375). This research represents a collective effort to support Indigenous scholars and practitioners in their work by deconstructing the unique context surrounding issues of Indigenous underrepresentation in the Caribbean and by detailing how a communal research process can serve as a means of challenging and healing from a colonial legacy. Our primary research question in these efforts asks: *What benefits, barriers and resources do Indigenous education practitioners and scholars identify for including Caribbean Indigenous science knowledge in their work*?

Indigenous knowledge systems, sometimes referenced as native science or traditional ecological knowledge, provide intergenerational, observation-based data about our natural environment (Berkes, 2008; Cajete, 2000; Kawagley, 1993). At the international level, formal accords, such as the Convention on Biological Diversity (2011), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Thaman et al., 2013), and the World

Conference on Science (UNESCO, 1999), officially recognize the value of diverse ways of knowing to understand and sustain healthy socio-ecological systems. Yet, as scientists increasingly seek out Indigenous knowledge systems, evidence remains of ongoing extractive methods by researchers that neither benefit Indigenous communities nor address underlying historical threats to sustaining Indigenous knowledge systems (David-Chavez & Gavin, 2018; Simpson, 2004).

Lack of balanced inclusion for Indigenous science perspectives holds implications for both the Indigenous communities that harbor those knowledge systems and for humanity's broader adaptive capacity to cope with environmental and social challenges (Adger et al., 2014). A growing movement centered in Indigenous communities continues to draw attention towards *how* diverse knowledge systems are valued and included in the sciences, policy, and education. Specifically, Indigenous communities persistently call for recognition and support in asserting inherent rights to sovereignty over their knowledge systems and ancestral lands (Marie Battiste, 2008; Kukutai & Taylor, 2016; Rainie, Rodriguez-Lonebear, & Martinez, 2017b; United Nations General Assembly, 2007). Our broader directive is to guide a transformative shift away from a colonization-driven narrative of "discourse of discovery" to more relational ways of interacting with the world (Cajete, 1994; Chan et al., 2016; Smith, 2012). This requires mapping a new path away from dominant standards of practice that have historically created ethical and epistemological barriers inhibiting cross-cultural exchanges between diverse knowledge systems. Epistemological barriers include marginalization and social racism reinforced by dominant social structures. For example, educational institutions often fail to acknowledge or respect Indigenous knowledge systems (Kirkness & Barnhardt, 2001). In many parts of the world where educational systems originate from foreign colonial and religious agendas, policies and curriculum

promoting assimilation and erasure persist (Freire, 2000; Harrison, 2018). Among what is

included within mainstream educational curriculum, narratives and data from Indigenous sources

remain severely underrepresented resulting in ongoing misrepresentation, appropriation, and

erasure of Indigenous histories, knowledges, and contexts (Marie Battiste & Youngblood

Henderson, 2000; Smith, 2012). Another related challenge is the privileged position of colonial

languages, concepts, and pathways for knowledge transmission. Formal schooling developed

within this colonial historical context disrupted longstanding culturally contextualized

intergenerational pathways for knowledge transmission (McCarter et al., 2014a). In terms of

ethical barriers, Indigenous communities often experience trauma and broken trust with external

authorities and researchers due to ongoing abuses in their communities (Guillemin et al., 2016;

Smith, 2012; Yellow Horse Brave Heart & DeBruyn, 1998). Further, overcoming these barriers

will require recognizing imbalanced power dynamics and ethical abuses in academic research

and social relations born from centuries of sanctioned injustices towards Indigenous

communities in the forms of genocide, slavery, assimilation, and denial of rights to governing

processes (Marie Battiste, 2008).

A growing body of work seeks to better understand and address the consequences of

these legacies, often identifying the critical role of Indigenous scholars and educators in

reorienting and transforming educational systems (Marie Battiste, 2002; Goodyear-Ka'ōpua,

2009; Kawagley & Barnhardt, 1998; Kimmerer, 2002; Penetito & Sanga, 2003). Although few

studies detail the experiences of these scholars and practitioners in the Caribbean context

specifically, we do find contributions towards understanding benefits, barriers, and resources for

sustaining Indigenous science knowledge from other regions of the world. For example, in an

international practitioner and literature-informed study identifying underlying factors

contributing to loss of traditional ecological knowledge (TEK), primary threats to TEK included: "loss of pathways of TEK transmission" (both between generations and across communities), "change of traditional livelihood practices," "change of traditional religion and beliefs," "change of environmental and natural resources" (due to degradation and/or displacement), "loss of traditional rights," and "loss of traditional institutions" (Tang & Gavin, 2016, p. 60). Alternately, actions for conserving TEK knowledge identified through this study included "Indigenous capacity building," "community-based TEK conservation actions," "education and awareness building," "policy and legislative support," and "research and documentation of TEK" (Tang & Gavin, 2016, pp. 64–65). These findings recognized colonization at the root of many threats to TEK, echoing the insights of numerous Indigenous scholars who draw attention to understudied issues regarding Indigenous knowledge systems in science research and education, such as institutional racism, Indigenous epistemologies (ways of knowing/philosophies), and sovereignty (Brayboy & Castagno, 2008; Simpson, 2004; Smith, 2012; Whyte, 2018). Additional studies addressing Indigenous science knowledge emphasize the importance of prioritizing community-based pathways for knowledge transmission and maintenance, and the need for ensuring governance and autonomy for Indigenous communities who maintain these knowledge systems (Agrawal, 1995; McCarter et al., 2014a).

In regards to Indigenous knowledge systems in our current education system, we find numerous pathways for regenerating educational practices that engage multiple worldviews through community-based, culturally-relevant, and decolonizing methodologies (Aikenhead & Ogawa, 2007; Cajete, 2015; Kawagley & Barnhardt, 1998; McCarter & Gavin, 2014; L. T. Smith, Tuck, & Yang, 2019). Research in this area identifies a need to honor spaces, including informal (out-of-school, within-community) science learning environments, for diverse student

experiences and knowledge-bases that have historically received limited representation (Cajete, 2008; Lee, Miller, & Januszyk, 2014; Snively, 1995). Educational resources developed to meet this need such as, place-based, culturally-responsive, informal, experiential, and multicultural science education find that valuing students' cultural worldviews leads to increased youth engagement, quality participation, and enhanced learning (Bang & Medin, 2010; Barnhardt, 2007; Barnhardt & Kawagley, 2005; Brayboy & Castagno, 2008; Semken et al., 2009). What is needed now is critically grounded empirical research identifying barriers and support resources impacting Indigenous scholars and education practitioners who are leading efforts for restoring value and inclusion of Indigenous knowledge systems in their work.

Our study helps to fill this research gap through developing an understanding of these issues and how they influence the lives and practice of Indigenous educators and scholars within a specific regional setting. In the Caribbean islands recent studies contextualize the tensions and complexities around engaging diverse ways of knowing in a present-day educational setting and call for further research on specific methods that can support Indigenous education practitioners (Burke, 2014; George, 2013; Harrison, 2018). Caribbean Indigenous communities and the unique systems of knowledge they hold about the environment, remain in a state of near invisibility within the current education system. While Indigenous communities continue to live across this region, the myth of extinction perpetuated across school curriculum, literature, and media both on the islands and continental mainland continues to misrepresent and challenge their existence (Barreiro, 2006; Benn Torres, 2014; Castanha, 2010; Guitar, Ferbel-Azcarate, & Estevez, 2006; Neeganagwedgin, 2015; Schroeder et al., 2018). Colonial legacies, such as lack of formal recognition of Indigenous communities, affect numerous issues of sovereignty. These include, for example land rights and tenure (Welch, 2014), food security (Vivian Carro-Figueroa, 2002),

and protections of cultural sites and artifacts (Martínez Torres, 2018; Taboas Cruz, 2017). Within this context we acknowledge two interrelated issues requiring attention: addressing barriers for underrepresented communities to engage in leadership roles in the sciences, and the vulnerable state of Indigenous science knowledges in the existing paradigm. While numerous research studies reference Indigenous underrepresentation in the science (Martin, Nakata, Nakata, & Day, 2017; National Science Foundation, 2017; Quaye & Harper, 2014), few studies detail barriers for Indigenous science research scholars and education practitioners leading inclusion efforts on the ground. Further, despite prevalent degradation and loss of Indigenous science knowledge, few studies address the underlying colonial socio-political drivers beneath these issues (Simpson, 2004; Tang & Gavin, 2016). In the Caribbean island region, where contemporary Indigenous-led research remains scarce, this study seeks to fill a key research gap through providing empirical data identifying barriers and resources for more balanced inclusion of Indigenous science knowledge and perspectives in research and education.

To address this research gap, this study emphasizes the narratives of community members whose families, lands, and lives are directly impacted by colonial histories. In this article we use a collective first-person narrative voice, yet the authors held different roles in various parts of the research process as detailed in the acknowledgements section. As Indigenous educators and scholars we hold similar roles, often required to confront injustices in the education system based in our colonial histories, simultaneously deconstructing and reconstructing methods and frameworks for learning (Marie Battiste, 2002). This article documents our research story as we work to decolonize science through community-centered research methods and processes. By understanding the historical, cultural, social, and political context for the Caribbean region through the experiences and stories of community practitioners

and researchers, we form a better understanding of barriers Indigenous people face for engaging

in the sciences, as well as resources for overcoming these barriers.

3.2 Centering Community in our Research Design

In this research effort we specifically sought out a framework that centers Indigenous

community values, concerns, and contexts. Working out from this center, we drew from diverse

methods in the research process focused toward meaningful and relevant outcomes for both

Indigenous and academic communities. This process demonstrates an alternative to colonial-

driven research paradigms that have led to the current challenges for Indigenous peoples in

science research and education (Chilisa & Tsheko, 2014; Simpson, 2004).

3.2.1 Conceptual framework

The primary methodological and philosophical frameworks guiding our work include

Indigenous research methodologies, participatory action research, and constructivist grounded

theory. Across Indigenous (decolonizing) research methodologies, cultural values and protocols

explicitly built into the research design include reciprocity and a long-term responsibility to

research participants and communities (Cajete, 2015; Chilisa, 2012; Estrada, 2005; Kovach,

2010; Lambert, 2014; Menzies, 2001; Smith, 2012; Weber-Pillwax, 1999; Wilson, 2008).

Participatory action research also speaks to this model, explicitly calling for a collaborative

process of shared learning and knowledge generation (Hermes, 1999; Kindon et al., 2007).

Indigenous research methodologies and participatory action research value ongoing reflexivity,

which heightens awareness and understanding of social concepts distinct to the unique places

and worldviews from which they derive (Chilisa, 2012). These qualities work in balance with a

constructivist grounded theory approach, providing a basis for developing concepts that reflect

the participants' voices, and lived experiences as well as the researcher's subjectivity (Charmaz,

2014). In alignment with Indigenous methodologies, constructivist grounded theory creates space for researchers to engage in their work with humility, acknowledging learning potential within the research process itself (Jennings, Kensbock, Junek, Radel, & Kachel, 2010; Mills, Bonner, & Francis, 2006).

We conceptualize our research model as akin to the root and growth system of yuca/cassava (*Manihot esculenta*), an essential Indigenous food plant in the Caribbean (Figure 3.1). Casabe, a flat bread produced from yuca, for example has provided a nutritious, drought and spoil-resistant food source for centuries and yuca is still highly valued in Indigenous Caribbean communities today. Yuca provided a culturally-relevant metaphor to visualize our study as rooted in community-based, reciprocal learning and knowledge co-creation to nurture growth for praxis—transformative action-reflection, further deepening relevance between theory, research and practice (Cajete, 1994; Freire, 2000).

Figure 3.1: Conceptual Model Representing our Research Process as the Root and Growth Systems of Yuca

Our research design holds community members and their values at the center where they can inform and retain authority over the design, knowledge creation and outcomes. Both the primary researcher and the research participants in this study held dual collegial roles as collaborators, researchers, and participants throughout the process.

3.2.2 Community-based (rooted) learning: listening and guaitiao

Our early phase in the research process included listening and regenerating the Indigenous Caribbean language concept of "guaitiao" (extending community relations). During initial site visits in Kiskeya (Indigenous place name for Dominican Republic) and Borikén (Puerto Rico), we nurtured cross-community guaitiao through cultural exchanges (such as foods, gifts, song, dance, exchange of knowledge and stories), informal discussions, and meeting each

other's relatives. We listened with elders and traditional knowledge holders around the islands, and educators at Indigenous education centers.

3.2.3 Reflection and action: co-designing the inter-island knowledge exchange

Preliminary site visits and in-person informal discussions were essential for trust-building and inviting research participants to collaborate in the study. Following this, Indigenous scholars and practitioners co-designed the agenda for a two-day inter-island knowledge exchange. The practices of deep listening and guaitiao proved helpful when co-developing the agenda, identifying research questions and objectives that would be meaningful to the participants, and deciding the most effective format for the inter-island knowledge exchange. For example, we determined that it would be important to cover all costs to improve access for resource-limited practitioners working in rural areas. This process helped to enhance a sense of ownership and commitment for the knowledge exchange. These relationships also supported ongoing dialogue leading up to the event to address ethical and personal concerns between potential participants, community organizations, and academic organizations.

We designed the exchange to support a participatory format for gathering research data while also providing a means to strengthen the "coconut wireless network" (informal Caribbean network of who-knows-whom). Most planning for the event took place by phone and through a shared web platform (Google Drive) over several weeks following initial field visits. We designed our exchange to weave focus group discussions in with cultural site visits in the community to support discussions about Caribbean Indigenous knowledge and science education. An early career scholar (D. David-Chavez) in partnership with a mentor-expert in Indigenous evaluation methods (S. Valdez) led design and facilitation for data gathering.

3.3 Methods

3.3.1 Participant selection

One project goal from our primary funding grant was to create a space with opportunities to learn across communities engaged in similar practice, forming stronger relationships between Indigenous scholars and practitioners, and a formal peer support network in the process. We established our participant selection criteria to include self-identifying Indigenous scholars or education practitioners engaging with Indigenous knowledge systems and environmental science education in their work in the Caribbean islands. We focused on youth education both in school and community settings while recognizing that engaging Indigenous knowledge systems often involves bridging formal and informal educational settings, and by nature engages multiple generations within the community (Brayboy & Castagno, 2008; Cajete, 1994). We used snowball and purposive selection methods to identify potential participants (Bernard, 2011). Based on available resources, we initially focused on two islands, Borikén and Kiskeya, as geographic boundaries for the project, eventually expanding our geographic scope to include potential participants working in Cuba, Kalinago Territory in Waitukubuli (Dominica), Xaymaca (Jamaica), and Guyana. In total we included four Indigenous practitioners (3 female, 1 male) leading community-based programs that engaged Indigenous science knowledge and youth (elementary up through early-college age), and three Caribbean Indigenous scholars (2 female, 1 male) whose dissertation work with Indigenous Caribbean communities also engaged these themes. Although additional Indigenous communities live in the region, locations and participants accessed for this study remained limited mostly to Taíno and Kalinago communities due to time, funding, and access. This small sample served the need for providing contextual depth on an issue from a specific community of practitioners who maintain some connections

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through language and cultural history, however we acknowledge in limiting our participants findings may reflect inherent biases which may not generalize to a larger population.

Many of the limitations in this study reflect broader challenges we sought to address in this study. First, the difficulty of finding potential participants who identify with this research theme (due to lack of value or awareness regarding Indigenous knowledge and identity in the region). Secondly, and interrelatedly, overcoming the unique geographical, cultural, and political barriers that divide populations in this region. Although many Indigenous communities in the Caribbean share ancestral native language families and cultural knowledge, they are divided by political boundaries, geographic barriers, cultural differences, and accepted colonial paradigms. We remain aware of how these challenges prevented some participation. Additionally, most all members of Caribbean island communities hold multi-heritage ancestry, mostly Native American, African, European, and Indian. We are aware in this contemporary era many community members may not self-identify as "Indigenous" or "Native American" or recognize their cultural knowledge and practices as Indigenous knowledges, and therefore may not have been included in this study. This also speaks to the question of who has held the right to define "Indigenous" (Corntassel, 2003), and the historic influence of assimilationist education promoting the myth of extinction (Harrison, 2018). The concept of Indigenous knowledge systems must also be addressed within this ambiguous multi-heritage context. Namely, dynamic and adaptive Indigenous knowledges in practice today do not necessarily represent exact archetypes of Indigenous Caribbean practices recorded in 1492. We acknowledge inherent risk for misrepresentation within the language and definitions we use in our research study.

3.3.2   Facilitating the exchange

In May of 2016 we convened for a two-day inter-island knowledge exchange focused on the theme of Indigenous knowledge and science education in the Caribbean. We began our exchange with an informal welcome dinner in which we synthesized and shared goals for our gathering. This process drew from constructivist grounded theory generating 'sensitizing concepts' to draw the research to variables of interest and concern from the participants' perspectives (Bowen, 2006).

The two days that followed included an ethics and consent protocol, visits with local researchers and educators, visits to local farms and schools, cultural site visits, focus group discussions, and community presentations. Before beginning we discussed the purpose and goals for collecting and recording data, reviewed a confidentiality agreement developed by the Indigenous education program hosting us to protect local intellectual property rights, and provided the university institutional review board consent protocol. During the ethics protocol participants also specified how they wished to be identified for the study, including the option to remove identifiers for anonymity. Two participatory focus group discussions served as the main sources for gathering data. We also invited participants who could not physically attend to contribute their voices through phone interviews (one additional practitioner).

Focus groups and interviews centered on the following research questions: *a) What benefits do you perceive for including Indigenous knowledge in your program or research? b) What barriers or challenges do you perceive for including Indigenous knowledge in your program or research? c) What resources do you use or need to include Indigenous knowledge in your program or research?* During our last focus group, we added one additional research question: *How do you define "Indigenous science" in your Native language?* Due to acts of

genocide and discrimination, Indigenous languages in the Caribbean islands remain dormant or endangered with a rapidly decreasing population of fluent Native language speakers for most all dialects (Devonish, 2004). Bringing Indigenous language into the exchange discussion allowed us to develop place-based, culturally responsive vocabulary to describe the concepts that we were reflecting on. Previous studies recognize inclusion of Native languages as one of the most critical elements of effective practices for creating transformative informal science education programs grounded in Native ways of knowing (Mack et al., 2012), and for transmitting Indigenous knowledge (Marie Battiste, 2008).

For focus groups we used a participatory "thematic wall" activity—an Indigenous evaluation research activity developed by the Native Pathways educational consulting organization (Native Pathways, n.d.). For this activity, we asked participants to consider our gathering theme and provided materials to record responses for each of the research questions. After completing their individual responses, we invited everyone to orally contextualize their responses as a group. Fortunately, all the focus group participants shared one common language (English); however, some may have been limited in their interpretations because it was their second language. We used digital audio recorders and notetaking to record conversations, dialogue and engagement both during focus groups and community site visits. Dialectical differences also made for challenges when interpreting and recording audio transcripts. Member checking, in the form of participant-researchers reviewing transcribed quotes for accuracy proved helpful for overcoming this challenge (Lincoln & Guba, 1985).

3.3.3 Indigenous evaluation methods

Indigenous evaluation methods, as described by the American Indian Higher Education Consortium, address Indigenous community concerns for "usefulness, restoration, preservation,

and sovereignty," by remaining "grounded in Indigenous epistemologies, responsive to cultural values, and embraced by the communities…intended to serve" (J. LaFrance & Nichols, 2009, p. 16). These methods allow for an adaptive process that respects local cultural protocol, focuses research objectives to meet community needs and interests, and nurtures opportunities for building relationships (Joan LaFrance, 2004). We adapted the focus of our exchange as needed based on participant-researcher responses to an open-ended written reflection provided at the end of the first day. An open-ended post-event written reflection also helped evaluate whether and how the exchange format served our community of Indigenous education practitioners and scholars for future studies. Additionally, we included gift exchanges (a notion of reciprocity), traditional meals, and opportunities for reflection at historical cultural sites to immerse participants in the land and to honor the stories and time given for this research.

3.3.4 Participatory and grounded theory data analysis

Participatory activities served as channels for inductive thematic analysis (Braun & Clarke, 2006). During these activities we continuously compared similarities and differences in our experiences and stories connecting them to larger themes. We explored discrepancies between participant-researcher's responses on-site through discussions that further contextualized the lived experiences forming each individual's response. These in-person exchanges informed data interpretation and coding procedure led by the primary researcher (D. David-Chavez with mentorship from S. Valdez) in later analyses.

After transcribing audio from our focus groups, analysis followed a process of "listening" to the data without recording notes or coding. After this, a session of open coding included identifying actions, suggestions, potential themes, and emotions (Corbin & Strauss, 2008). During the second iteration of focused coding, comparison and analysis of differences in data

segments aided in our search for the underlying meaning within initial codes. During this phase

the focus was less on the specific emotions expressed (loneliness, frustration, etc.), than on the

circumstances and stories contextualizing them (exclusion, lack of resources, government

inaction, etc.). The third iteration of coding refined these focused codes into higher level

conceptual and theoretical categories. We adapted several names of conceptual categories

directly from the participants' voices to reflect some of the metaphorical language that they used

("crabs in the bucket," "igniting the youth"). After repeating the same process (reading,

"listening" to the data, open coding, focused coding) for the second focus group transcript, we

proceeded with axial coding—connecting, comparing, and contrasting the concepts identified in

each set of data. We elaborated on some prior categories and developed new ones as relevant for

higher level categories (Figure 3.2).

Barriers and Challenges

Support Resources

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Capacity: challenges faced by Indigenous scholars and practitioners operating within multiple cultural frameworks (such as, including spirituality, interdisciplinary or holistic concepts in their work)

"Crabs in the bucket": facing internal barriers and challenges from one's own community members (such as, competing for recognition or funding)

Resource limitations: lack of funding resources or access to them (such as, not meeting criteria for grant funding, geographic barriers, or lacking internet access)

Government inaction: instances describing lack of response or neglect on the part of government officials (such as, absence of formal recognition for Indigenous communities, lack of response to natural and human caused environmental disasters)

Historical silencing/exclusion/appropriation: making invisible, misrepresenting, and/or exploiting Indigenous knowledge and Indigenous knowledge holders (such as, perpetuating extinction myth in education system, patenting artistic designs or medicinal plant knowledge obtained from Indigenous knowledge holders)

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Methods: sharing methodological tools used in Indigenous science research and education (such as, youth and elder interviews, exploring Indigenous knowledge through place names)

Indigenous language: Indigenous language explored, expressed, and prioritized in research and education

Tech as a resource: technology for engaging youth in diverse ways of knowing and for creating support systems (such as, photo journaling, mapping technology, and social media)

Native ways of knowing: Indigenous concepts of environment, sustainability, spirituality, reciprocity, time etc.

Community action: community members taking action to address their needs and concerns (such as community clean-up events and activities promoting Indigenous knowledge and culture)

Creating Support Systems: forming partnerships, collaboration, or networking (such as, cross-community knowledge or school exchanges, collaborative grant projects)

Honoring Indigenous knowledge (and knowledge holders): giving voice, respect, safeguarding and acknowledgement to Indigenous knowledge contributions and to those peoples and practices that sustain them

"Igniting the youth": inspiring youth to engage with and care for their natural & cultural heritage resources

Building Sustainable Communities: caring for the land for future generations

</td></tr>
</table>

Figure 3.2: Conceptual Codes for Barriers and Support Resources Varying by Spatial and Temporal Scale

We applied this same coding and memo-writing process for the daily reflection and

written reflection open responses recorded immediately following the event, by recording them

into a spreadsheet and coding each individually. We also included data from one phone interview

with a practitioner unable to attend the event. Our process for data analysis provided a means to triangulate interpretations and to check for gaps, contradictions and further examples representative in our coding by using constant comparison. As described in our process for data collection and analyses, we applied multiple methods for ensuring data trustworthiness throughout the study: triangulation of methods (focus groups, surveys, participant observation), member checking and thick description for credibility; contextual data of case site and phenomenon of study to enhance transferability; detailed methodological description for dependability; transparent researcher positioning, recognition of study limitations, use of memos, and field notes for confirmability (Shenton, 2004). Given that some phases of data analysis were undertaken by the primary research facilitator (transcribing, high level coding, and visualizing the grounded theory) all data findings and publication material underwent numerous cycles of review and comment to ensure accurate interpretation and approval from all participant-researchers prior to submission for publication.

3.4 Findings and Discussion: Unfolding our Collective Story of Survival, Adaptation and Resilience

Within this section we describe key thematic findings constructed from the lived experiences and narrative contributions highlighted through quotes from participant-researchers. We also introduce our grounded theory for communal regeneration in the context of challenges faced by Indigenous science scholars and education practitioners through use of culturally-relevant metaphorical visual imagery. Lastly, we reflect on these findings in the context of broader research discussions and literature. Through this ongoing process of community-based learning and praxis we observed how our individual voices came together in a larger, deeply interconnected and intergenerational story. Our individual stories represent threads within this

collective history—where we have been, our current circumstances, and the futures we are

visioning. We grew in our understanding of how the unique barriers we were facing exist within

a larger socio-political and historical context. We also grew in our understanding of how barriers

and challenges manifest at different scales of space and time, and the resources to overcome

them. We used culturally-relevant visual imagery to map out how each of these concepts related

to one another on various spatial and temporal scales (Figure 3.3). Use of visual metaphor allows

for an organized structuring of data enhanced through multiple levels of representation and

meaning (Verdinelli & Scagnoli, 2013). Through each phase of the research process we observed

our collective story of survival, adaptation and resilience unfolding.
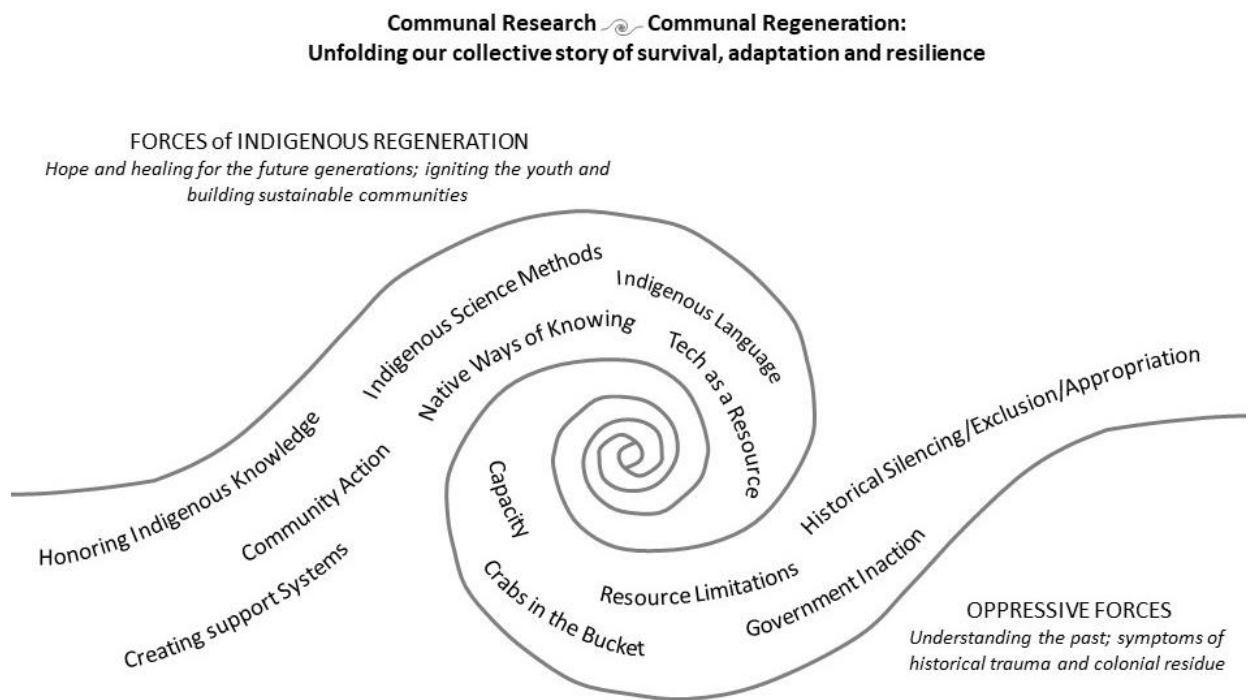
Figure 3.3: Cultural-Relevant Visual Map of Grounded Theory

3.4.1 Immediate local to regional challenges and support resources

Through the process of analyzing data findings, we identified different scales of space

and time. Looking at findings within these various scales helped us to connect immediate issues

participant-researchers were facing with deeper socio-political histories and proved helpful for

organizing thematic findings. Beginning at an immediate (temporal) and individual or local

(spatial) scale, we identified *capacity*—unique challenges faced by Indigenous scholars and

practitioners who are operating within multiple cultural frameworks—as a key barrier. Here we

share examples that informed the development of this category (please note, English may not be

speakers' first language):

> *My job that I do, geology, that's a natural science and I do ethnography which is a*
> *social science. Sometimes I'm not good enough to be a social scientist. Sometimes*
> *the work that I'm doing is not at the top to be natural science per say. So, I need to*
> *fight with that.* (Indigenous Scholar working in Borikén and Kiskeya)

> *Still I am finding methods in me, not outside…to understand that if I am not*
> *spiritually [involved] I won't be able to rescue anything. I won't be able to respect*
> *Yucahu…I won't be able to tell the kids the meaning…* (Indigenous practitioner
> working in Kiskeya)

These stories speak to personal struggles and limitations reflecting on how to honor who you are

in your practice while also meeting internal and external standards, and then learning to balance

these processes for the work to be successful. These quotes reflect challenges seen throughout

multicultural and cross-cultural circumstances as scholars and practitioners reconcile between

diverse ways of knowing that may hold fundamental differences (Aikenhead & Jegede, 1999).

Challenges born from these differences observed in our findings link back to previous research

identifying tensions between applying a holistic, interrelated and interdisciplinary scientific

understanding rather than compartmentalizing within standard disciplines (Barnhardt &

Kawagley, 2005). In addition, dominant science narratives may conflict with personal

obligations to acknowledge the spiritual and cosmological context in which Indigenous

knowledge is embedded (Aikenhead & Ogawa, 2007; Brayboy & Castagno, 2008; Little Bear,

2000). In some cases spiritually-contextualizing knowledge may result in exclusion from what is

considered legitimate "science" in mainstream culture (Snively & Corsiglia, 2001). In the process of having to face these challenges, we also recognize how they strengthen our ability to navigate and bridge multiple knowledge systems and to support others with diverse worldviews in other contexts in our lives.

We observed support mechanisms actively applied to address challenges in *capacity* at the individual and immediate scale, including *methods*, *Indigenous language*, *technology as a resource*, and *Native ways of knowing*. *Methods* referred specifically to methodological tools used to engage Indigenous science in research and practice. Throughout our exchange we shared specific research and education methods, such as youth and elder interviews, analyzing Indigenous place names, and deconstructing historical texts. Many of these methods reflect similar approaches used in other settings. For example, Mayan environmental knowledge education programs in Belize also recognize the value of methods such as youth and elder interviews for drawing out the cultural heritage along with the science (Baines & Zarger, 2012). Participants contextualized methods used within their respective areas of work such as the following example:

> *Caliche or calichi it is a Taíno word that means water coming out from the mountain…that's again how I put stuff together using toponymy. So, the place is called Caliche. The place is in the limestone is in caliza. So, water flows through the rock. But the place is called Caliche because there is a story of el niño de Caliche, the boy of the caliche, and that pinpoints in a cave that is seasonal that water comes out from the cave.* (Indigenous scholar working in Borikén and Kiskeya)

In this example, drawing from multidisciplinary methods including ethnography, geology, hydrology and toponymy (study of place names) identified in oral history and historical texts helped to deepen understanding regarding the cultural and geological significance of a field site.

This excerpt also emphasized *Indigenous language*; another significant conceptual category identified in this analysis. As McCarty and Lee affirm in their discussion on Indigenous education sovereignty, "language is vital to cultural continuity and community sustainability because it embodies both everyday and sacred knowledge and…is also significant for sustaining Indigenous knowledge systems…" (2014, p. 109). This assertion is also shared by Barnhardt and Kawagley (2005) in their work with Alaska Native ways of knowing, who observe the deep connection between Indigenous languages and knowledge systems, including unique thought processes reflected in the language. While many case studies addressing language revitalization occur in regions where fluent speakers remain, less is known about impacts of regenerating language in areas where Indigenous language has been intensively adapted with colonial language or remains "dormant" bringing up issues of ethics and a community's right to self-determination that require further attention beyond the extent of our work here (Warner, Luna, & Butler, 2007). In our study, we observed how language holds place-specific context and conceptual understandings that helped us to build our *capacity* and understanding in our own education and research work.

At this scale, we further recognize how many Indigenous scholars and practitioners use both deep, place-based, cultural knowledge and philosophy (*Native ways of knowing*) and contemporary resources (*technology*) simultaneously. In our focus group discussion, a practitioner describes these resources in her work:

> *We're also now engaging in a program to clean the rivers. Ok the kids in each school…they go out with the GPS and they identify the hotspots in each community and these hotspots have all the different contaminants…I do a map…and I send it over to the Department of Natural Resources and the Environment. Ok, do they act on it? No, unfortunately they don't, but at least we're showing [the youth] what's gonna happen to that river…for example, you are Mother Earth, and these veins that are flowing through your body, is the water of Mother Earth…What would happen if I took cement or asphalt and started covering you up? What if we are*

doing this to Mother Earth? We are suffocating her. (Indigenous practitioner working in Borikén)

In this example the practitioner and youth use both mapping technology and an Indigenous philosophical lens to learn about the environment. Geospatial science technology has served as a useful tool for other Indigenous communities, such as the Maōri as well, providing a framework for both maintaining and protecting diverse forms of knowledge (Harmsworth, 1999). Besides Indigenous communities adapting modern *technology as a resource*, we also recognized how communities have developed and utilized innovative forms of technology (as well as science, engineering, and math) since precolonial times to address their needs (A. O. Kawagley et al., 1998).

After centuries of observation of Earth's natural systems and processes, innovation and application of technology in Indigenous communities also represents *Native ways of knowing*, the final conceptual category represented in this data finding. *Native ways of knowing* include unique cultural concepts, such as our relational accountability towards Mother Earth as a living being described here. Additional studies likewise emphasize the importance of maintaining a relational understanding of the natural environment in which every aspect is alive (Aikenhead & Ogawa, 2007). Furthermore, Bang and Medin assert that "cultural practices and their connections with Native ways of knowing must be the foundation of a community-based science curriculum" (2010, p. 8).

Crabs in the bucket represents another barrier conceptualized on a local scale. This category reflects interpersonal challenges faced within one's own community. When several crabs are harvested into a bucket one crab may start to climb out, yet before achieving freedom is pulled back down by the others still in the bucket. As one participant-researcher explained:

Competition amongst groups is a big barrier for us, because we're trying to do something positive, and because we're doing it then they want to stop it. You can't be doing that because I didn't think of it…you're gonna gain recognition, you're gonna get funding. So, they'll try to stop it…that's a barrier that we're fighting against almost every month here. (Indigenous Practitioner working in Borikén)

In a research review on challenges of maintaining indigenous ecological knowledge, inequities in distribution of power proved an issue even at the local community scale, calling attention to further understanding of power dynamics when determining effective maintenance of Indigenous knowledge systems (McCarter et al., 2014a). The mention of funding in the last quote also links to the concept of *resource limitations*, which was identified in several threads of our discussion on challenges and barriers. For example, one participant-researcher noted:

Funders might not respect Indigenous knowledge. (Indigenous scholar working in Kalinago Territory)

Educators and community members both within and outside of the Caribbean note how Indigenous knowledge-related initiatives may not receive priority for government funding (Harrison, 2018; McCarter et al., 2014a). In our discussions, the related issue of whether or not funders considered Indigenous knowledge as valid also came up, paralleling previous concerns found in the literature (Snively & Corsiglia, 2001; Van Eijck & Roth, 2007). In the context of these challenges we observe how increased competition between organizations and competition for research funding can create local level barriers.

3.4.2 Regional challenges and support resources

Moving out in spatial scale, we identify *government inaction* as a barrier, with *community action* and *creating support systems* as related support mechanisms. As described earlier in the practitioner's story of the river, *government inaction* can represent instances of lack of response or neglect on the part of government officials and entities. Previous studies in Vanuatu (McCarter & Gavin, 2011) and in Borikén (Harrison, 2018) also identified lack of government

support as a barrier to including Indigenous knowledge systems in education. In these studies, as well as our own, this challenge was interlinked with *resource limitations* as programs may not receive financial support for materials, human resource needs, implementation costs etc. In our findings, we observed a counter to *government inaction* through *community action*, in which community members organize to govern over and address their own concerns. A similar response is recorded in research regarding maintenance of Indigenous ecological knowledge in Malekula Island, Vanuatu through locally-driven formation of *kastom* schools (centers for cultural knowledge and practice) (McCarter & Gavin, 2014). *Community action* may also reflect service to community, a core value, and a standard recognized for improving science education in First Nations communities living in Canada by providing opportunities for youth to apply skills and technologies in ways that enhance connections to their cultural communities (MacIver, 1995). Within this same spatial scale and context, *creating support systems* is reflected in the following example:

> *I'm strong, a strong supporter of making connections with other Indigenous communities. They are resources.* (Indigenous Scholar working in Kalinago Territory)

The emphasis on making connections also highlights the importance of building relationships through cross-community exchanges such as our research gathering. Numerous studies prior to our own recognize the value of creating and strengthening horizontal support networks bridging Indigenous scholars, educators, and knowledge keepers and also vertical networks connecting communities with external policy, funding, or research institutions that share common goals (Barnhardt & Kawagley, 2005; Marie Battiste, 2002; Berkes, 2002; McCarter et al., 2014a; Tang & Gavin, 2016). Several members of the focus group also emphasized *technology as a resource* as one of the ways that they strengthened these connections through digital communication tools

including social media. Similarly, Battiste (2002) also highlights the significance of communication technology as a resource for developing innovations and sharing across support networks. In the open coding process, we observed several participants describing feelings of loneliness in their work and feeling limited in their individual *capacity* with little local support at times. *Creating support systems* provided a path for them to find allies in this work, share effective methods, and locate funding resources. In informal discussions following the exchange, numerous participants expressed their gratitude in feeling less alone, having met others engaged in similar efforts and remained connected through social media platforms and by phone.

3.4.3 Intergenerational and large-scale challenges and support resources

Personal struggles we observed, such as loneliness and anger, also reflect symptoms from another conceptual category rooted in a larger spatial and temporal scale. Centuries of systematic oppression, misrepresentation and exploitation of Indigenous peoples and knowledge systems, along with displacement and removal from homelands, languages, and family members, and the colonial residue remaining in our current paradigm force these unique challenges into the lives of the scholars and practitioners who contributed to this studied. Other initiatives for improving Indigenous education, have recognized the need to unpack unresolved legacies colonial history inflicts upon Indigenous learners (Little Bear, 2009). In our case study, we conceptualize these circumstances as *historical silencing/exclusion/appropriation,* as noted by the following participant-researchers:

> *Even in terms of schools, a lot of Indigenous communities have to send their children to schools where they don't learn about themselves. That needs to change, because they grow up in the school system that teaches them about other people, doesn't teach them about themselves. Then they might not have access to learn about themselves at home and so you get this generation that's disconnected… when you have that disconnect, then you start breaking down, the culture starts breaking down.* (Indigenous Scholar working in Kalinago Territory)

The myth of extinction is constantly being thrown at the people …campesinos, in trying to elevate themselves, they send their kids to school. When they go into these schools, the schools tell them that [their] culture is gone…So now all these stories that were real oral traditions become more like fairytales (Practitioner working in Kiskeya and Xaymaca)

The reflections from this Indigenous scholar and practitioner link to previous research on Caribbean education describing the colonial school system as an extension of national assimilation policy in which, "school curriculum replaced community knowledge tied to the land" through systematic displacement from language and culture, and a push from rural to urban, aiming for "erasing the rural Indigenous knowledge base and identity formation" (Harrison, 2018, p. 76). In the same study effectiveness of this erasure varied across educators in the twice-colonized island of Borikén, with some holding the belief of cultural extinction and others explicitly recognizing and valuing Indigenous knowledge contributions for maintaining environmental sustainability. In recognition of these and other contributions, we observed the concept of *honoring Indigenous knowledge* as a partnering support mechanism for overcoming the barrier of historical silencing born from a colonial legacy in education in the region. This conceptual category represents the process of returning voice and respect to Indigenous knowledge holders. This category also represents a process of safeguarding and acknowledging the contributions of Indigenous knowledges. Kimmerer, an Indigenous educator and researcher, posits that "a call to introduce science students to the validity and value of traditional ecological knowledge…should be inseparable from a serious discussion of protection of traditional knowledge from exploitation" (2002, p. 437). Additional literature regarding Indigenous science knowledge and education recognizes a strong link between power distribution, self-determination, sovereignty, and sustaining knowledge for future generations (Agrawal, 1995; McCarter et al., 2014a; Simpson, 2004; Whyte, 2018). On the side of overcoming these

challenges, stories within our discussions emphasized the importance of Indigenous youth

learning about themselves to remain connected to their culture, and to enrich their learning:

> *From the perspective of including Indigenous knowledge, in the work that we do… I think that by doing that it respects Indigenous knowledge, to even have their voices be at the table, because they've been excluded. Indigenous people have been excluded for a lot. In terms of science, I think it enriches the field, and to add to that, it adds another dimension to the field.* (Indigenous Scholar working in Kalinago Territory)

As Indigenous scientists and educators, we seek to increase our understanding of the world

around us and to prepare the next generation in the best way we know how. The specific

examples demonstrated in these findings reveal how many of us work to achieve that goal in the

face of unique challenges and opportunities, often with limited resources at hand.

3.4.4   Reciprocal learning and knowledge co-creation

Our analysis also highlighted the value of the research process itself. Looking back

within this process, we observed instances, especially during the second focus group, where we

were practicing reciprocal learning and knowledge co-creation. In Tewa Indigenous scholar

Gregory Cajete's discussion extending the work of Brazilian educator and philosopher Paulo

Freire, he describes how an Indigenous model of education supports "community to become

partners in learning and becoming" through a "community-rooted approach," shifting "from an

expert-recipient relationship to a relationship of mutual and reciprocal learning and co-creation"

(2015, p. 71). In the context of our research these concepts are reflected in intentionally creating

spaces for shared learning and our process of inviting participants to generate knowledge

together through a participatory research process. Through the focus group, cultural activities,

and time spent together, we were able to build a sense of trust with each other, and to build our

own capacities to identify and explore these complexities together with vulnerability and

humility. Within the post-event written reflections, for example, one participant-researcher stated, "I think the most important outcome was the growth of ideas and sharing that occurred."

3.4.5 Theoretical growth

We also reflect on how the stages in this process informed our own theory development for Indigenous science education and research in the Caribbean. In the context of historical trauma among Indigenous communities, Indigenous researchers have identified "understanding the interrelationship with our past and how it shapes our present world" as a path for healing (Yellow Horse Brave Heart & DeBruyn, 1998, p. 76). Likewise, we observed how an active process of communal research can simultaneously serve as a form of communal regeneration (growth and healing). This concept of *communal research ∿ communal regeneration* forms an overarching theme within this research (see figure 3). The symbol between (∿) is an ancient Taíno representation of huracán (hurricane). For some, this symbol represents time in a non-linear, spiral form. This symbol also represents forces of destruction and regeneration within a duality of space, time, and being. Dual forces, and concepts we identified within them, woven together in this double-armed spiral include *oppressive forces* resulting in historical trauma and the colonial residue or symptoms of oppression (barriers identified in the findings). Alternately, *forces of Indigenous regeneration* represent the hope and healing for future generations through *igniting the youth* and *building sustainable communities*.

Igniting the youth (inspiring youth to engage with and care for their natural and cultural heritage resources) and *building sustainable communities* (building communities that care for the land and future generations) are the final higher-level conceptual categories constructed from our grounded theory analysis. The concept of *igniting the youth* also serves to counter another underlying threat to Indigenous knowledge systems identified by Tang and Gavin (2016b),

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marginalization of Indigenous youth through shaming from mainstream society. Previous studies

also identified such resources for overcoming these challenges through strengthening

intergenerational knowledge sharing, supporting youth to learn from the land, and nurturing a

sense of cultural pride (Baines & Zarger, 2012; McCarter & Gavin, 2011; Simpson, 2004; Tang

& Gavin, 2016). *Building sustainable communities* relates to Indigenous worldviews described

by Kawagley and Barnhardt (1998) which emphasize a long-term, relational accountability to

both land and community. Numerous efforts from Indigenous communities in the Caribbean and

in other areas of the world recognize the need for communities to regenerate ties back to land,

language, and culture after forced displacement (Goodyear-Ka'ōpua, 2009; Harrison, 2018).

According to Goodyear-Ka'ōpua, "degradation of ecosystems and indigenous economic systems

have gone hand in hand with the decline of indigenous knowledges" and decline of relationships

to the land which nourishes us (2009, p. 50). Regeneration of Indigenous communities and

knowledge systems therefore requires interconnected goals for restoring relationships, spiritual

context, food systems, economies, governance, and livelihoods. Stories shared throughout our

exchange reflected the intergenerational nature of this work and our collective hope for the future

as we understand, interpret, and write our own story of survival, adaptation and resilience. Our

theoretical contribution, visualized in figure 3 and grounded within these stories of communal

regeneration and lived experiences, provides a recontextualized framework for enhancing

understanding and prioritizing areas for further practitioner support in the fields of Indigenous

science education and research.

3.5   Conclusion

The process and findings from this inter-island exchange led towards a deeper

understanding of the unique context for Indigenous Caribbean educators and scholars who

engage Indigenous knowledges in their practice. Understanding how the symptoms of colonization and imperialism manifest within our education systems helped us to further untangle and reweave the webs in which we learn and work. Each step of this process required meaningful reflection and action that placed the concerns and strengths of the participant community at the center. By including the languages, places, and formats for exchange that were meaningful to the community members, we were able to foster a forum for reciprocal learning and knowledge co-creation. We recognize that complexities in the process, including cultural and interpersonal diversity within the community, will require space and time for ongoing reflection and dialogue. A reflexive, adaptive and culturally responsive research protocol and timeline will support efforts like this in future research endeavors. Based on these findings, we agree with Battiste (2002), who calls for capacity building for Indigenous education and directing further support towards Indigenous scholars working within their communities. This research study serves as a means for supporting effective research and education practices known through lived experiences. Furthermore, we observed how, as Cajete explained, "researching ourselves communally through our own process, we empower ourselves to reclaim our cultures and communities" (2015, p. 219). After five centuries of imperial and colonial oppression, we recognize this is generational work. This story, and the process of bringing these voices together offers a means for helping us remember our history and for forming our own self-determined pathways forward.

Table 3.4: Glossary

Borikén	Puerto Rico (Indigenous place name)
caliche	(calichi) sedimentary rock rich in calcium carbonate
caliza	limestone
campesino	rural person
casabe	An Indigenous flat bread made from yuca (cassava)
guaitiao	extending relations through cultural exchanges
Waitukubuli	Dominica (Indigenous place name)
Kalinago	Indigenous peoples of the Lesser Antilles
Kiskeya	Dominican Republic (Indigenous place name)
niño	boy
Taíno	Indigenous peoples of the Greater Antilles and Bahamas
yuca	cassava root plant (*Manihot esculenta*)
Yúcahu	(Yocahu) spirit of the yuca
Xaymaca	Jamaica (Indigenous place name)

4. MANUSCRIPT 3: A RESEARCH MODEL FOR DECOLONIZING COMMUNITY-BASED SCIENCE RESEARCH

4.1   Introduction

Collective, and dynamic bodies of knowledge generated from centuries of observation, often referred to as "Indigenous knowledge" "Native science," "Indigenous ways of knowing" or "traditional knowledge" (Berkes, 2008, 2009b; Burkett, 2013; Cajete, 2000; International Council for Science, 2002; D. Nakashima & Roué, 2002), serve to guide a wide range of environmental practices, including sustainable agriculture (Altieri, 2004), watershed management (Kagawa & Vitousek, 2012), and intentional burning in forest management (Kimmerer & Lake, 2001). However, with the exception of a growing number of Indigenous scientists and cross-cultural collaborative research groups, environmental scientists continue working with incomplete datasets—neglecting vast and longstanding bodies of knowledge held within Indigenous knowledge systems (David-Chavez & Gavin, 2018). Effectively addressing complex social-ecological issues faced within our current and future generations, such as extreme climate variability and environmental justice, will require *all* relevant sources of knowledge and data, including and especially those held by historically marginalized communities who remain close to the land (D. J Nakashima, United Nations University, Traditional Knowledge Initiative, & Unesco, 2012). One of the greatest barriers inhibiting diverse knowledge exchanges, innovation, and problem-solving potential, is a historic, colonial-rooted imbalance in power relations (Marie Battiste, 2008; Marie Battiste & Youngblood Henderson, 2000; Simpson, 2004). We recognize the limitations set by the current dominant paradigm in scientific research and potential harmful broader impacts without continued

intervention to raise ethical standards within research practices. While some fields, such as education (Carjuzaa & Fenimore-Smith, 2010), public health (Straits et al., 2012), and geography (Grossman et al., 2010) make strides towards research protocols reflecting values such as these and improving ethical standards of practice with Indigenous communities, environmental science research requires further focus towards restoring ethics and rights to self-determination and sovereignty in research with Indigenous communities. Shortcomings in this area result in ethical violations regarding Indigenous peoples' rights and a lack of relevant and accurate research data addressing Indigenous community concerns (Harris & Jim, 2010; Quigley, 2001). To address these concerns, both researchers and community members require a comprehensive working research model that aligns cultural and institutional principles for research integrity. Potential for advancing research standards in environmental sciences (e.g., conservation, natural resource management) could be enhanced through cross-disciplinary knowledge transfer within fields of research where colonial historical legacies for Indigenous communities have received more consideration.

In our efforts to address this research gap, we draw on theoretical developments across disciplines and institutions, grounding them within experiential practice, to provide a holistic conceptual map and working research model that can be applied towards community-based research initiatives with Indigenous communities. Within this paper we seek to: (i) provide a summarized history of science research by, on, and with Indigenous communities; (ii) define and justify critical components necessary for integrity in research with Indigenous communities; (iii) highlight numerous research frameworks and concepts across disciplines as resources for improving ethical standards in environmental science research; (iv) visualize a working model that draws these resources together; and (v) present a case study field-testing this working model.

4.1.1   Historic patterns of science research in Indigenous communities

To develop a shared understanding and context across cultural communities, we recognize the importance of taking a moment to review historic patterns in scientific research by, on, and with Indigenous communities and driving paradigms underlying many of the concerns we face today. As recognized in culturally competent research, we too see how "historical views (including ignorance of history) and societal norms influence the ways researchers interact with people and their communities" (Caldwell et al., 2005, p. 5). Looking back through the record of scientific research in Indigenous communities, several patterns of inquiry and practice emerge. The first and longest-standing encompasses precolonial longitudinal studies over generations in which Indigenous communities formed, tested, adapted, and refined knowledge systems based upon careful observation of Earth's natural systems and geophysical processes (Berkes, 2008; Berkes et al., 2000; Cajete, 2000; Kawagley, 1993).

Following severe disruption to Indigenous knowledge systems and lifeways from colonial-driven genocide and oppression, and from massive loss of life due to introduced pathogens, Indigenous communities underwent traumatic changes (Stone, 2002; Yellow Horse Brave Heart & DeBruyn, 1998). Since this time, research has often shifted to colonial and academic institutions predominantly looking to Indigenous communities as populations to be studied and documented under the assumption of impending extinction, or as a source of extracting knowledge and resources (Marie Battiste & Youngblood Henderson, 2000; Smith, 2012). Many of these extractive studies frame Indigenous communities within the deficit of their symptoms without recognizing how these conditions reflect colonial history and genocide (Ermine, Sinclair, & Jeffery, 2004; Meadows, Lagendyk, Thurston, & Eisener, 2003; Simpson, 2004; Tuck, 2009; Maggie Walter & Andersen, 2013). Research driven by this paradigm allowed

for exploitative methods, such as non-consensual health studies and biopiracy, often resulting in harmful outcomes for Indigenous communities (Laird & Lisinge, 2002; Mead, 1994; Mello & Wolf, 2010; Shiva, 2016). These research practices and underlying paradigm also result in artificial binaries between what is validated as "Western" science knowledge and a multitude of diverse ways of knowing often aggregated as "ethno-" "folk" "holistic" or "traditional" knowledge (Agrawal, 1995; Kimmerer, 2002; M. Tengö, Malmer, Brondizio, Elmqvist, & Spierenburg, 2013).

In recent years, interest in science research in Indigenous communities is also driven by increasing recognition in scientific forums, including the Intergovernmental Panel on Climate Change (IPCC), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), of the value of Indigenous knowledges for addressing complex social-ecological issues such as climate change and conserving biodiversity (Adger et al., 2014; Maria Tengö, Brondizio, Elmqvist, Malmer, & Spierenburg, 2014; Thaman et al., 2013). However, evidence shows that studies engaging with Indigenous knowledge systems continue to reflect an imbalance in power distribution, often repeating the same extractive research practices (David-Chavez & Gavin, 2018). Further, research and data practices regarding Indigenous communities remain dominantly shaped by external agendas, resulting in a lack of relevant, timely, and accurate data for decision-makers within those communities (Schultz & Rainie, 2014).

In response to ongoing ethical misconduct and ineffective research standards, protocols protecting Indigenous community rights in various stages of development and formal recognition from governing bodies, continue to arise at the tribal community level (KSDPP, 2007; Kūlana Noiʻi Working Group, 2018; South African San Institute, 2017), national level (CTKW, 2014;

Rainie, Rodriguez-Lonebear, et al., 2017a), and internationally (United Nations Framework Convention on Climate Change, 2013; United Nations General Assembly, 2007). These initiatives represent an emergent pattern within science research in which Indigenous communities impacted by colonization across the world are engaging in and leading research efforts focused towards honoring and strengthening Indigenous lifeways and principles of ethics (Ermine et al., 2004). This growing movement primarily led by Indigenous scholars and researchers, many of whom represent the first generation in their families with access to leadership roles in scientific research and higher education, also focuses on honoring and strengthening inherent rights to sovereignty and Indigenous governance in the research process and data practices. Indigenous data sovereignty is defined as deriving from "the inherent right of Native nations to govern their peoples, lands, and resources" (National Congress of American Indians, 2018), and includes "the right of Native nations to govern the collection, ownership, and application of [their] own data" (Rainie, Rodriguez-Lonebear, et al., 2017a). Indigenous data governance represents the support mechanisms for upholding these rights (Rainie, Rodriguez-Lonebear, et al., 2017b).

Within this growing movement, we see a need for a transformative shift within research practice for building trust across cultural communities and an opportunity to do so through aligning cultural and institutional protocols, principles, and values. More broadly across the science community, this movement also represents an ongoing shift in the academic landscape towards research practice that is interdisciplinary (includes theory and methods from multiple disciplines) and transdisciplinary (includes community practitioners/stakeholders), bringing together strengths from across the sciences, humanities, and local/Indigenous knowledge bases for application-oriented research (Belmont Forum, 2016; Mauser et al., 2013; Palsson et al.,

2013). Within cross-cultural climate adaptation studies for example, researchers note that, "the cultural, legal, risk-benefit and governance contexts in which knowledge exchanges occur have been under-examined" (Williams & Hardison, 2013, p. 532). The following section advances these efforts through a cross-disciplinary synthesis, bridging across disciplines and cultures to form a more comprehensive understanding of opportunities for improving research standards.

4.1.2 An interdisciplinary review of relational accountability in research

Within this literature review we extend the scope beyond the environmental science discipline, linking to relevant research frameworks, best practices, approaches, and concepts applied in research with Indigenous communities. We particularly emphasize theoretical developments within Indigenous and community-based participatory research methodologies as resources to more critically and explicitly address the concerns outlined in the introduction to this paper.

Understanding the historical and cultural context previously described outlines the current need for restoring *relational accountability* in science research with Indigenous communities. Opaskwayak Cree scholar Shawn Wilson defines relational accountability in the context of research, stating that "in essence this means that the methodology needs to be based in a community context (be relational) and has to demonstrate respect, reciprocity and responsibility (be accountable as it is put into action)" (2008, p. 99). Indigenous methodologies prove helpful for this effort in that they recognize the distinct historical, colonial, place-based and socio-cultural contexts surrounding any given research study and how these contextual factors relate to the unique strengths and challenges that Indigenous community members carry into a research setting (Chilisa, 2012; Kovach, 2010; Smith, 2012). A long-term relational accountability to land and community, including non-human communities and future

generations, forms a foundational basis across Indigenous methodologies (Chilisa, 2012; Kovach, 2010; Weber-Pillwax, 1999; Wilson, 2008). Given these qualities, Indigenous, and decolonizing methodologies complement, extend and deepen the principles developed in community-based participatory research and participatory action research frameworks which aim to support collaboration with and benefit to communities as partners in the research process (P. A. Cochran et al., 2008; Fisher & Ball, 2003; Kindon et al., 2007; LaVeaux & Christopher, 2009; Smith, 2012). Across the literature, Indigenous-led initiatives for improving ethics and principles in research practice acknowledge the importance of restoring relationships. At the forefront, the Kaupapa Māori research principles developed in the 1990s, transformed and redefined research in *Aotearoa* (New Zealand) to prioritize Māori Indigenous values, beliefs, rights, and practices within the research agenda, remaining especially conscious of who benefits in the research process (G. H. Smith, 1990; L. T. Smith, 2015). The principle of *ata*—"growing respectful relationships" applied in Kaupapa Māori theory for social service practitioners (Pohatu, 2005), and the Te Mātāhauariki Methodology Creative Relationship Framework (Parr, 2002) developed for cross-cultural socio-legal research in Maori communities demonstrate innovative approaches for guiding relational accountability in practice. As developed for best practices Indigenous higher education research, the 4Rs (Respect, Relevance, Reciprocity, Responsibility) framework (Kirkness & Barnhardt, 2001) also demonstrates a shift towards improving relational accountability with Indigenous communities to foster respectful, enduring relationships and support sovereignty rights (Carjuzaa & Fenimore-Smith, 2010; Louis, 2007; Wilson, 2008). Often these frameworks use relational values to guide through ethical dimensions within cross-cultural research.

Additional concepts defining relational values and collective ethics also serve in these efforts, as in the context of the ancient grounding principles of *ubuntu* a worldview applied in Afrocentric Indigenous research methodologies (Mkabela, 2005), which "addresses researchers from all worlds to see themselves first as related and connected by the same goals of commitment to build harmony among communities they study; to reciprocate by giving back to communities for what they take; and to strive for truth justice, fairness, and inclusiveness in the construction of knowledge" (Chilisa, 2012, p. 188). These principles are carried into environmental policy and sustainability discussions in the context of restoring relational values towards our natural environment (Chan et al., 2016; Pascual et al., 2017). Biocultural approaches to conservation represented an area within environmental sciences where we identified a recognition of relational values with natural environments, while further emphasizing the value and importance of bringing together diverse ways of knowing, and prioritizing relation-building between scientists, practitioners and community members for effective decision-making in addressing complex social-ecological issues (M. C. Gavin et al., 2015; M. Gavin et al., 2018).

Beyond biocultural approaches, we identified a handful of approaches within environmental sciences working towards addressing power imbalances and restoring relational accountability across cultural communities including place-based learning communities, in which researchers observe their protocol as "a site-specific expression of a process of relationship building" (Davidson-Hunt & Michael O'Flaherty, 2007, p. 298), Indigenous-driven co-governance (Hill et al., 2012), and co-management approaches (Berkes, 2009a). In place-based learning communities a focus on cross-cultural understanding and relationships lays the groundwork for locally-led research and capacity building (Davidson-Hunt & Michael O'Flaherty, 2007). Indigenous-driven co-governance maintains an intercultural purpose,

intentional in "Indigenous centred holistic community planning," "reconciliation, long-term, lasting resolution of issues," "Indigenous empowerment and community development," and capacity-building for both Indigenous and non-Indigenous community members (Hill et al., 2012). Co-management approaches, based on building trust between community members and scientists and sharing of power also demonstrate potential for improving environmental science research and practice (Fernandez-Gimenez et al., 2006). Originating in *Oglála Lakȟóta Oyáte* (Oglala Sioux Tribal Nation) in the United States, the Indigenous Stewardship Model, for example guides an Indigenous-led process for collaborative natural resource management through developing a shared language based on local cultural values and inclusive of diverse scientific ways of knowing (Ross, Sherman, Snodgrass, Delcore, & Sherman, 2011). A valuable recent development specifically applicable to environmental science research, the Kūlana Noiʻi Working guiding framework (2018), also provides detailed best practices for decision-making in natural resource management that focus on relational accountability between communities and researchers.

An aspect within relational accountability we highlight as relevant to ethical conduct in environmental science research, that intersects with many of the previous concepts and approaches discussed here, can be described as *cultural competence*, a concept developed from social science health research and applied in participatory research with tribal communities (Caldwell et al., 2005). Cultural competence defines the role, responsibilities and the commitment of the researcher, including maintaining an understanding of sovereignty, self-determination, and the unique historical context surrounding issues within each respective Indigenous nation and community.

Within this brief literature review, we also highlight the critical importance of *grounded* models that bridge theory into actionable methods and practice. The Tribal Participatory Research Model (Fisher & Ball, 2003) serves as an effective example of this as a collaborative research model presented through specific operational mechanisms (e.g., "tribal oversight," "training and employing of community members as project staff," "culturally specific assessment"). The emphasis on *praxis* articulated by Brazilian philosopher and educator Paulo Freire as "reflection and action upon the world in order to transform it" (Freire, 2000, p. 51), is also applicable to this discussion for bridging theory into practice.

Finally, many of these approaches and frameworks speak towards a goal for *sustainability*. Through terminology such as sustainability, and resilience may be relatively young to the sciences, they speak to ancient philosophies for intergenerational stewardship represented across Indigenous knowledge systems and practices—explicitly, providing for the needs of the current generation while considering for the needs of future generations (Haudenosaunee Environmental Task Force, 1992; M. K. Nelson, 2008; Whyte, 2018). As Tewa scholar and educator Dr. Gregory Cajete describes, "we are realizing that the conceptual framework of sustainability—so fundamental to our philosophies and sciences—is giving us the greatest opportunity to apply and even evolve Indigenous sciences" (2015, p. 133).

As practitioners and scientists restore contextual understanding of Indigenous concepts and philosophies of ethics disrupted by colonization, they continue to seek pathways for more socially just and effective research practice. To further facilitate and guide this continual growth in scientific practice, we require research models centered in *relational* values, that require *culturally competent* intentional commitments on the part of the researchers (especially in terms of understanding and upholding inherent Indigenous rights to sovereignty), and that map out

grounded actionable methods to reach outcomes that maintain both cultural and scientific

integrity. While each of the contributions summarized here hold immense value, we recognized a

remaining need for cross-disciplinary knowledge transfer to carry into environmental science

research and other disciplines engaging Indigenous communities and colonial historical contexts

in research. Much of the literature to date remains limited to specific fields or is developed for a

specific cultural community project. To enhance this knowledge transfer, and to fill persisting

gaps between theoretical developments, principles for research integrity, and current dominant

practices, we synthesize and translate the values, concepts and methodologies presented here and

acquired through our own experience and practice into a comprehensive interdisciplinary

conceptual synthesis and visual map to guide research design and process.

4.2   Conceptual Working Model

A shared foundational thread we identified across disciplines and cultural communities is

the intentional need for identifying and centering relational values and principles to guide

balanced and respectful interactions and engagement between cultural communities and in

interactions between humans and nature (Borraz et al., 2012; Chan et al., 2016; L. T. Smith,

2007). In this section we present a model for decolonizing science research that considers both

institutional and cultural aspects regarding research within Indigenous communities through the

basis of relational values of *integrity, respect, humility,* and *reciprocity* (Figure 4.1). We selected

these four core values based on their frequency and relevance across cultural and disciplinary

contexts both in the literature reviewed for this study and in the experiential practice and

language of the researchers working in community settings. We define each of these values in

the context of science research in Indigenous communities working out from these central values

through culturally-competent commitments and grounded actionable methods to bridge them into

practice. In our development of the model and identification of these values, we recognized that within some cultural contexts additional values and terms (including Indigenous language concepts) may better serve varying community contexts than the four values centering this model. Therefore, we present this as a working model, with an understanding that the numerous emerging movements and innovations generating from Indigenous communities and cross-cultural collaborations will continue to inform and refine what we've developed here.

Figure 4.1: A Working Model for Decolonizing Science Research

Integrity as a research value, is demonstrated through a researcher's personal

commitment for understanding and honoring moral and ethical responsibilities to the

communities impacted by their work. However, in order to uphold this commitment and

underlying value of ethical integrity, it is necessary for researchers to first hold a clear

understanding and recognition of the rights and responsibilities that come with research practice

(OFIFC, 2016). These understandings may come from pre-existing documents or governing

bodies, such as tribal research consultation frameworks, or tribal institutional review

boards/research ethics boards (IRBs/REBs), which may be in various stages of formal

development and recognition (Kelley, Belcourt-Dittloff, Belcourt, & Belcourt, 2013; Sahota,

2007).

Among foundational responsibilities in research, Free, Prior and Informed Consent

(FPIC) ensures communities retain access to information that they deem necessary for decision-

making regarding proposed research or developments within their communities (Forest

Stewardship Council, 2012; United Nations General Assembly, 2007). Understanding consent

can also be complicated depending on what level of representation researchers and community

members aim to achieve. For example, Bantu scholar Bagele Chilisa observes four levels of

consent, including "individual consent, community consent, group consent, and collective

consent" (2012, p. 196). Issues within levels of consent can occur when authority is placed in

governing bodies that are geographically removed from research sites. For example, as

conservation scientist Anne Toomey noted, "official approval as authorized by an indigenous

leadership council to conduct their research does not ensure local support" (2016).

Another foundational principle, the commitment to "cause no harm" remains essential for

reducing instances of risk and harm, including those associated with Indigenous intellectual

property (P. A. Cochran et al., 2008; CTKW, 2014). The United Nations Declaration on the Rights of Indigenous Peoples (UN DRIP) Article 31 states that, "Indigenous peoples… have the right to maintain, control, protect and develop their intellectual property," including "traditional knowledge…manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, [and] oral traditions…" (2007, p. 9). This responsibility also includes respecting community-determined restrictions on when and where sensitive knowledge should and should not be shared (Marie Battiste, 2008). Williams and Hardison further illustrate this sense of integrity through an understanding that, "when traditional knowledge is shared, it is often accompanied by stewardship obligations within communities with expectations that outsiders also carry these obligations when knowledge is shared" (2013, p. 534). One of our most valuable resources for addressing these concerns is under development in the rapidly growing field of Indigenous data sovereignty. Through applying an Indigenous data sovereignty framework, Indigenous scholars, researchers and allies are transforming both qualitative and quantitative research data practices to center the inherent rights of Indigenous peoples to govern data stewardship in their communities (Kukutai & Taylor, 2016; Maggie Walter & Suina, 2018)

Laws and protocols such as these, governing Indigenous knowledge systems and data generated from them vary from community to community. Researchers should seek a detailed understanding of the background context on what governance mechanisms and protocols already exist, and at what levels for each distinct community that researchers engage with. In some instances, ethical responsibilities in regard to Indigenous community rights are formally and clearly defined for both community members and researchers, whereas in others they are not. Even with access to principles for conduct, such as those defined in the UN DRIP, countries may

not be legally bound nor have existing protections or resources for enforcing ethical protocols for research (Kinnison, 2011). For example, in the U.S., even for federally-enforced consultation policies relevant to environmental science research, such as the National Environmental Policy Act of 1969 (NEPA) and the National Historic Preservation Act of 1966 (NHPA), "agencies are required only to conduct consultations and take them into account, but their decision-making is not necessarily constrained by the feedback received during these consultations" (Kinnison, 2011, p. 1310). In the instances where formal protocols for ethical research integrity have not yet been defined, we emphasize the importance that these be developed and formalized under the authority of the Indigenous communities in which the research will take place (Lambert, 2014). In some instances, researchers and community members formalize their commitment to ethical integrity through establishing memorandums of agreement or understanding (Ball & Janyst, 2008; Cummins et al., 2010; Morton Ninomiya & Pollock, 2017). In addition to tribal IRBs or formal governing councils, research integrity may also be guided through forming community advisory groups, boards or steering councils to oversee and approve the research process (KSDPP, 2007; Sahota, 2007).

Respect, as an underlying research value, requires a commitment on the part of researchers towards restoring Indigenous governance of research and data impacting Indigenous communities. The Native Nations Institute's policy brief on *Data Governance for Native Nation Rebuilding* (Rainie, Rodriguez-Lonebear, et al., 2017b) asserts the importance of data governance as a mechanism for upholding Indigenous data sovereignty, which is necessary for supporting self-determination and capacity for effective decision-making. Addressing respect within the research process requires listening, observing, and responding to unique strengths, challenges, and needs that communities hold in the context of the research. Potawatomi scholar,

Kyle Powys Whyte for example, maintains that "scientists who seek to exchange knowledge with Indigenous peoples should not only understand what Indigenous knowledge systems can do for them, but also have a sense of the significance of these knowledge systems for Indigenous governance today" (2018, p. 57). Demonstrating the value of respect within these contexts also requires developing a space and format where Indigenous governance remains supported in terms of the research design, goals and objectives, and project evaluation, both during and after a research project occurs.

Humility as a research value, acknowledges the underlying premise that all those engaged in the research bring unique strengths, expertise, and experiential insights through prior knowledge and that we have opportunities to learn and generate new knowledge together. This holds contrast to longstanding academic science methods in which "we are told what to know and how to know it, unrelated to our lives and of the knowledge we have gained from our experiences" (Cajete, 2015, p. 68). Long-held assumptions that one way of knowing science, as developed from the dominant colonial paradigm was somehow superior to Indigenous knowledge systems, challenged opportunities for these exchanges for centuries (Cajete, 2015; Smith, 2012). Following a systematic review of challenges for maintaining Indigenous ecological knowledge, researchers recognize how "maintenance of [this knowledge] has, at its heart, issues of rights and power" (McCarter, Gavin, Baereleo, & Love, 2014). Multiple critiques also highlight a persistent barrier for shared learning born from these assumptions in the form of forcing integration of Indigenous knowledge systems and perspectives into dominant colonial ways of knowing science (Nadasdy, 1999). In the same vein, many researchers and educators continually stress a need to validate Indigenous knowledge systems through external criteria to accept them as a form of "science" without recognizing these knowledge systems as scientific

ways of knowing within their own context (Aikenhead & Jegede, 1999; Van Eijck & Roth, 2007). Alternately, engaging multiple ways of knowing through processes that enhance balanced, respectful exchanges can lead to improved data interpretation and understanding (Parrado-Rosselli, 2007). In the health sciences, some researchers are looking to participatory research processes as a means of restoring trust, recognizing that "mutual learning is essential to acknowledging and reconciling past abuses inflicted upon tribal communities by researchers" (Christopher, Watts, McCormick, & Young, 2008, p. 1404). The Multiple Evidence Base framework, originating from the United Nations Intergovernmental Science-Policy Platform on Biodiversity, asserts that various knowledge systems represent "different manifestations of equally valid and useful knowledge systems which generate complementary evidence for interpreting conditions, change, trajectories, and causal relationships relevant to sustainable governance of ecosystems and biodiversity" (M. Tengö et al., 2013). This framework stands in contrast to the dominant paradigm in academic research in which one knowledge system is used to validate all others and recognizes pre-existing power dynamics that may influence and inhibit synergy between diverse knowledge systems (Maria Tengö et al., 2014). Through this approach, the Multiple Evidence Base approach is also described as a process for building trust and respect across cultures. In a parallel thread the multiple epistemologies approach developed in science education research, also provides methods for integrating diverse ways of knowing without delegitimizing one over another, and overcoming cultural barriers that suppress contributions from marginalized cultural communities (Balgopal, Wallace, & Dahlberg, 2017; Bang & Medin, 2010). Seemingly different forms of knowing may be complementary and valued across diverse communities given opportunity for these exchanges. Further, when complementary threads of knowledge weave together, innovation through shared knowledge generation may follow. These

exchanges require overcoming inherent biases and assumptions about the "other." When successfully supported, knowledge exchanges support capacity-building in multiple directions (Toomey, 2016). Shared knowledge generation, also commonly referenced as co-production of knowledge, can be described as "working from the premise that knowledge is a dynamic process," and is deemed as "vital to indigenous community-based natural resource management" (Davidson-Hunt & Michael O'Flaherty, 2007, p. 293).

Reciprocity as a research value focuses on how researchers will ensure Indigenous community members can access benefits from research outputs and outcomes. In the colonial paradigm, extractive research methods focused on providing benefits and credits to external institutions and peoples, often overlooking broader impacts on Indigenous communities (Smith, 2012). In our model for decolonizing science research we look to multiple forms of reciprocity occurring between researchers and Indigenous communities both during the process and after research takes place. In terms of research impacts, reciprocity involves both present and future generations. For example, in the Kūlana Noiʻi Working Group's (2018) recently released guide for best practices there is a clear recognition that research decisions have long-term impacts in the communities where they take place given they will eventually impact the descendants of the community members there today. Looking critically within the research process, we identify pathways beyond the dominant model of extraction and non-binding consultation, to research that gives due credit and honors rights for inherent stewards of Indigenous knowledge systems and resources. In agreement with the Indigenous Stewardship Model, we emphasize the importance of building capacity in local youth to understand and draw from their Indigenous knowledge systems, and other relevant diverse ways of knowing as "ultimately, children will become the stewards of the land" (Ross et al., 2011, p. 254). Findings from additional studies in

environmental change, stewardship, and conservation research also highlight the importance of engaging local youth in the research, especially opportunities for strengthening relationships and pathways for knowledge sharing between Indigenous knowledge keepers and youth (C. G. Flint et al., 2011; Gill et al., 2014; Reo, Whyte, McGregor, Smith, & Jenkins, 2017; Tang & Gavin, 2016). Further, in a more direct assertion of the rights of Indigenous community members, the Mataatua Declaration on Cultural and Intellectual Property Rights of Indigenous Peoples affirms that, "the first beneficiaries of indigenous knowledge (cultural and intellectual property rights) must be the direct indigenous descendants of such knowledge" (1993, p. 2).

The holistic working model presented here centers scientific research within these four values to generate research initiatives that remain intentional aware of commitments necessary for addressing colonial legacies, and that remain relationally accountable to the impacted communities throughout the entirety of the research process. An important part of the theoretical development of this working model, besides the conceptual synthesis outlined here, is ensuring that the model can be applied through grounded methods. The case study to follow summarizes our experience field-testing the model, detailing the actionable methods and resources we found useful, along with lessons learned from the research process applied in practice.

4.3   Case Study: Field Testing a Model for Decolonizing Science Research Through an Indigenous Community-Based Climate Study in the Caribbean

4.3.1   Background

The working model for decolonizing science research presented and field-tested here developed from experiential practice and theoretical growth to form a process for aligning cultural and academic institutional protocols. This model grew out of necessity, as identified by the primary researcher (D. M. David-Chavez), who sought a higher standard of ethical and

relational practice in climate and science education research within her own Indigenous

Caribbean (*Taíno*) community. One of the core questions asked is these efforts was, *how could*

we bring the values in which Indigenous knowledge systems are embedded into the research

process itself? Specifically, how could these values serve to guide and define the methods and

research agenda? While a researcher's beliefs and value paradigms remain underlying any

methods applied in research, they are not always explicit, nor acknowledged in the dominant

models applied in scientific research. The values centering the base of this research model—

integrity, respect, humility, and *reciprocity*—emphasize long-term relational accountability

between researchers and communities. They also represent the ongoing transformational shift

from the dominant science paradigm to a new paradigm re-centering research in value systems

that support balanced knowledge exchanges and sovereign rights for Indigenous governance and

lifeways (Louis, 2007; Smith, 2012). Although David-Chavez developed the initial model for a

specific place and context, we emphasize that the language, processes, and methods developed

here can be adapted to numerous contexts and places. In developing and refining this research

model we draw from Indigenous, constructivist grounded theory, community-based participatory

methodologies in research, as well as the ongoing discourse and relevant contributions of

numerous Indigenous, cross-cultural, and intercultural scientific working groups and

organizations (e.g., National Center for Atmospheric Research's Rising Voices: Collaborative

Science with Indigenous Knowledge for Climate Solutions Working Group, the Indigenous

Phenology Network, National Aeronautics and Space Administration's American Indian/Alaska

Native Education Working Group, and the U.S. Indigenous Data Sovereignty Network).

Our case study takes place within the two neighboring rural agricultural communities of Cidra and Comerío, in the mountainous central region of a twice-colonized island originally known as *Borikén*, and more recently as the United States territory of Puerto Rico (Figure 4.2).

(field site locations indicated with ✦)
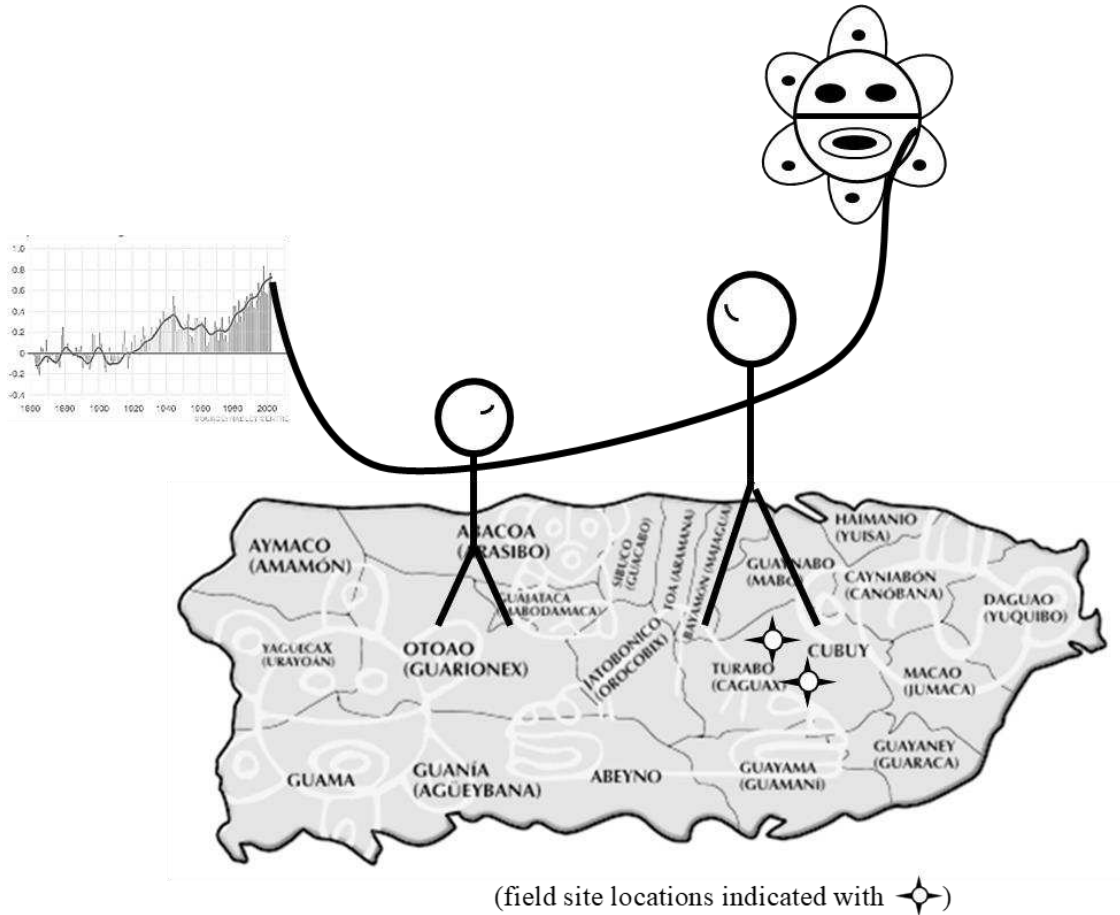
Figure 4.2: Intergenerational Study Field Site Map

Since the time of colonial impact, Caribbean Indigenous descendent communities have had little say in how research is conducted with their lands and peoples, and remain especially marginalized within the U.S. Caribbean, lacking formal recognition and accompanying political protections at the state or federal level (Borrero, 2017). Over five centuries of systematic silencing, exclusion, exploitation, and appropriation in the region present complex and unique challenges and barriers for those practitioners and community members who wish to sustain Indigenous knowledge systems for future generations (David-Chavez et al., n.d.). Despite these

challenges, grassroots initiatives for restoring rights for protection of Indigenous lands, histories, and lifeways endure (Taboas Cruz, 2017). The Caribbean Indigenous Legacies Project (CILP), an ethnographic research collaboration between the Smithsonian National Museum of the American Indian and Latino Center, has been documenting such initiatives since 2016 (Smithsonian Institution, n.d.). One of the few self-identifying Indigenous Caribbean ethnographic researchers working with the CILP, Jorge Baracutei Estevez (*Taíno*), provided mentorship during preliminary fieldwork and introduced the primary researcher to several community leaders and organizations who informed the focus and design of the field study presented here.

Facilitation of the research project was led and implemented by two of the authors of this paper who are both Indigenous Caribbean community members, the primary researcher (D. M. David-Chavez), whose maternal family is from a nearby rural community in the region, and the community research partner (N. Ortiz), a retired school counselor and grandmother from one of the field sites who continues to holds strong social ties within the community. Based on the prior expertise of the primary researcher (climate, geoscience, and Indigenous science), current environmental concerns within the island communities regarding extreme climate events identified during preliminary fieldwork, and topics aligned with available funding opportunities, the research project planned to broadly address the themes of Indigenous knowledge systems in the Caribbean, climate, and youth science education. Due to its tropical climate and geography, this region is deeply familiar with the impacts of extreme climate events. For instance, the term "hurricane" originated from the Indigenous name *Huracán,* depicted in ancient cosmology stories describing the interaction of atmospheric and oceanic processes (Pané, 1999). Growing concerns with social and environmental impacts relating to drought, flooding, increase in

hurricane frequency and intensity, fresh water availability, soil quality, and food security serve as constant reminders of the importance of maintaining all necessary resources for mitigating and adapting to climate change in the region (David-Chavez & Ortiz, 2018; W.A. Gould, Diaz, Álvarez-Berríos, Aponte-González, & Et al., 2018). Working within these broader themes, the research facilitators explicitly designed the project to be led and adapted by the needs and interests of the community at every stage of the research process—initiation, design, implementation, analysis, and dissemination.

4.3.2 Research design and summary

Our research design drew from Indigenous and community-based participatory research methodologies and guidelines as described in the development of the working model for decolonizing science research. These included recommendations developed for climate research with Indigenous communities with an emphasis on community-led decision-making in every stage of the research (CTKW, 2014; David-Chavez & Gavin, 2018). This case study was also informed by findings from a previous grounded theory study and knowledge exchange facilitated by two of the authors (D. M. David-Chavez and S. Valdez), in which Indigenous Caribbean educators and researchers identified benefits, barriers, and resources for Indigenous science education and research (David-Chavez et al., n.d.). The invitation to conduct this field study along with determination of the field site locations and selection of research participant groups resulted from relationships formed in a regional Indigenous scholar-practitioner network that grew from this exchange. One practitioner partner from the exchange, Carlalynne Yarey Melendez Martinez was serving as director for the Naguake Community-School Survival Program in Borikén. Naguake works with public schools and communities with a mission "dedicated to the preservation, protection and management of the natural and cultural heritage of

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eastern and east central Boriken (Puerto Rico)" (Naguake Community School Survival Center, n.d.). Upon invitation from the Naguake program, the primary researcher (D. M. David-Chavez) collaborated with community members from Cidra and Comerío to facilitate a community-based participatory climate research project as a means of further ground-truthing the working model for decolonizing science research.

We recognized the importance of grounding the model through meaningful praxis to test the usefulness and value, while also observing challenges and lessons learned through the process of applying it. Based on current needs and interests within the Naguake program communities, we were invited by the Naguake program director and educational partners to facilitate the study with 5th and 6th grade youth (ages 9-12) in two rural public schools. Members of the administration and families at these schools had expressed an interest in further developing Indigenous education programs and saw this as an opportunity to provide research that could inform youth and community educational resources.

Along with the school sites, based on community interests and invitations, several parts of the study took place at various locations in the community, including family-managed sites that hosted workshops and culturally significant rural field sites within Cidra, Comerío, and the southeast neighboring municipalities of Cayey and Salinas. We identified initial community collaborators using culturally-sensitive snowball and purposive recruitment methods for hard-to-reach populations (Bernard, 2011; Sadler, Lee, Lim, & Fullerton, 2010). In total, study participants included 44 youth, ages 9-14 years and 44 older youth, adults and elders, ages 18-104 years, including some elders and educators working in *Kiskeya* (Dominican Republic) and Kalinago Territory in *Waitukubuli* (Dominica) who informed preliminary fieldwork for this study. Initial community workshops and a community field hike coordinated in collaboration

with the Naguake organization, provided on-site locations to discuss the background context and interests of researchers, funding organizations, and community members and to assess local interest in supporting a community-based research study.

To ensure sustained accountability, scientific rigor, and empower local governance in the research process, we also used the first workshop discussions to form a community advisory group to oversee all aspects of the project (Ermine et al., 2004). Members of the advisory group were based upon local recommendations and selected to represent diverse perspectives and experiences from various genders and roles within the community, including youth, parents, farmers, conservation practitioners, educators, and elder knowledge keepers (16 members total, with 6-11 physically attending each advisory group workshop; 5 female elders, 5 male elders, 2 female youth, 1 male youth, 2 female educators, and 1 mother of an elementary age youth).

Working closely with the community advisory group provided a consistent format for determining where and how to effectively apply responsible practices in our work. Throughout this process we referenced guiding frameworks for responsible research engagement previously developed by the research facilitator into a series of reflective questions to guide responsible research practice with Indigenous communities which ask: "*Are Indigenous community members included in the decision to initiate the study? To what level do Indigenous community members have authority in the research design… (None or Contractual (employment-related), Consultative, Collaborative, Collegial, Indigenous)? To what level do Indigenous community members have authority regarding the implementation of the research? To what level do Indigenous community members have authority regarding the analysis of the research? Are findings accessible to Indigenous community members? Are findings reported in the context of concerns, issues or interests defined by Indigenous community members? How were Indigenous*

community members credited for their knowledge contributions and efforts (i.e.

acknowledgement, co-authorship)? Did the study report ethical guidelines followed, such as

Free Prior and Informed Consent? Did the study address intellectual property rights or risks for

Indigenous communities? Did the study report any outputs or outcomes for the Indigenous

community?" (David-Chavez & Gavin, 2018). From these guiding questions and data generated

from the community advisory group, we were able to determine the format both for the field

project, and for realizing the broader research impacts for the community.

The format for our study, detailed in the following sections included: a series of

community workshops, a youth survey (pre- and post-test), youth workshops, a science and

culture field camp, youth-led presentations, a participatory analysis workshop with the

community advisory group elders, and a final community workshop reviewing and developing

outputs for the study. For the purpose of this paper the primary focus is on the research process

rather than the research project and data specifically. The broad goal of the study was to build an

understanding of how diverse ways of knowing are applied towards climate adaptation and

resilience, while also assessing youth interest and attitudes towards science and Indigenous

knowledge in their community. This focus emerged from community interests and also reflects

key gaps highlighted in the literature by many scholars and international agreements (Adger et

al., 2014; Maldonado et al., 2015; Maynard, 2014; D. J Nakashima et al., 2012). We intentionally

maintained an intergenerational research design to allow us to bridge the widening gap between

elder knowledge keepers and Indigenous youth with potential to be future environmental leaders.

This included facilitating opportunities for youth to observe and interpret connections regarding

Indigenous climate science concepts within the context of their own community. Both our pre-

and post-survey results and findings from participatory data analysis workshops indicated that

youth interest in learning about environmental science increased when they were learning through culturally contextualized knowledge and experiences, especially "learning by doing" in the field and engaging with their Indigenous language. We observed an extensive oral history record reaching back several generations of interruption and shifts in seasonal cycles and increase in extreme weather events (heavy rain, drought, and hurricanes). We observed distinct parallels between traditional rain-fed rural agricultural practices passed down through countless generations and agricultural techniques identified by scientists for climate change adaptation and mitigation (David-Chavez & Ortiz, 2018; William A. Gould et al., 2015). Lastly, we observed climate resilience in rural communities through exercising food sovereignty—"the right of peoples to healthy and culturally appropriate food" (Huambachano, 2018, p. 1022). Specifically, a strong extended community social network serving to increase access to a variety of nutritious, climate resilient Indigenous food crops whose surplus were frequently shared across families. Additional outcomes from the research project included technical contributions for the fourth National Climate Assessment Caribbean regional chapter representing the first Indigenous community contribution for the Caribbean region (W.A. Gould et al., 2018), capacity-building (both for local community, and for scientists who they presented to) through a youth presentation at the International Institute of Tropical Forestry and a professional research presentation by the community research partner (N. Ortiz) at the American Geophysical Union fall meeting. The following sections outline how our research process exemplified the values centering this working research model through detailing methods and resources applied along with lessons learned.

4.3.3 Integrity: understanding and honoring moral and ethical responsibilities to community

Our most useful format for facilitating integrity in the research process, required preliminary onsite discussions via community-based organizations and community workshops held at a local public school. This began early-on with informal discussions with regional and local leaders of Indigenous community organizations who helped to identify existing cultural and institutional research protocols. Also, prior to beginning our study, the first author reviewed the UN DRIP (United Nations General Assembly, 2007) and the principles set forth in the ISE Code of Ethics (2006) to build an understanding of integrity and rights for Indigenous nations and communities at the international scale. The ISE Code of Ethics explains that it "recognizes and honors traditional and customary laws, protocols, and methodologies extant within the communities where collaborative research is proposed" and emphasizes to "support and enable but not override such community-level processes and decision-making structures" (2006, pp. 4–5). A critical step we recognized for enabling this standard of integrity was early and ongoing local community review and co-design of protocols and workshops, both in terms of the format and the materials. During workshops, we were then able to account for multiple levels of protocols for consent (individual, institutional, community, state) and formalize the community advisory group to guide cultural protocols for the research. For each community workshop, we invited participants to individually decline or accept invitation to engage in the study via an oral or written consent protocol according to their preference. An oral consent protocol helped to overcome varying levels of comfort with literacy. During this process we also determined how community members wished to be identified, and what levels of anonymity they preferred for any research outputs. Community advisory group discussions also served to support Indigenous data sovereignty and Indigenous data governance through early on determining how, for what purpose, and with whom data would be shared. This process required us to adapt numerous

revisions and additions for the university IRB protocol of the funding institution to align

community and institutional needs for research integrity.

At the community and state scale we used a confidentiality agreement developed by the

Naguake program designed for protecting local intellectual property rights (Melendez Martinez,

2016). In addition, because portions of our study occurred within the public-school system, we

were required to use consent protocols developed by the Puerto Rico Department of Education

for teachers, youth, and families participating in the study. We noted a difference between

institutional protocols developed outside the community (the university and Department of

Education forms) versus community developed protocols. Namely, institutional protocols

contained a language and format that proved challenging, and anxiety-provoking for some rural

families who wondered if the project would require money or resources from their families for

example. With support from the community research partner, we developed a language and

format to translate between rural community members and institutional requirements. This

included writing a more concise cover letter to accompany the five-page Department of

Education consent form packet for youth and their families. The letter introduced the project

facilitator including her cultural background and local family ties within the study area,

described what activities youth and family members were invited to participate in if they chose

to engage in the project, noted that there were no costs to participate, noted that transportation

and food were provided, and included a local phone number and familiar community contact for

any additional questions or concerns. These methods helped to maintain a sense of trust and

open, accessible pathways for ongoing communication. Challenges regarding use of institutional

processes in local cultural context have arisen in similar studies as well, including reference to

the additional amount of time and labor necessary for codesigning and adapting effective and ethical institutional consent protocols (Riddell, Salamanca, Pepler, Cardinal, & McIvor, 2017).

One other challenge that arose early on in the research process involved the need to understand and address diversity and power imbalances within the community. We were explicit and transparent in our efforts to identify women and youth for the community advisory group, recognizing that their voices are often excluded or marginalized in scientific research studies (Hitomi & Loring, 2018; Toomey, 2016). We were also explicit in prioritizing access for those community members working and interacting at the most local level—farmers, educators, and conservation practitioners who had grown and worked within the area, along with youth who had grown up in the community—even though individuals from outside the community were sometimes deemed as the "experts" on topics we were addressing in the project. In their research on forming place-based learning communities Davidson-Hunt and O'Flaherty describe how, "in any community there will be numerous layers of power, and successful negotiation with the preeminent public authority does not do away with the responsibility of outside researchers to be sensitive to community divisions" (2007, p. 294). We observed and remained attentive to varying power dynamics during workshops, discussions, field-site activities, and within the broader community. For example, one outcome of the process that we observed within this context, was a shift towards increased acknowledgement and valuing of local elders and knowledge-keepers, rather than external academic researchers, as the experts towards the end of the project. For all of the concerns summarized here, we found it helpful to be available for on-site discussions (most often held at the two school sites or at the homes or farms of local elders), to listen for local interests, to address any questions or concerns as they arose, and to otherwise engage in participant observation (Glesne, 2015).

4.3.4 Respect: ensuring Indigenous governance in the research process

In the research design, we argue that the methods, whether quantitative, qualitative, or mixed, should represent those tools and methodologies that are most culturally-responsive and best-suited to meet the needs of the community (Kindon et al., 2007). Broadly speaking, effective methods applied in our research entailed processes for listening to, observing and respecting local interests and concerns. These served as the basis for determining a mixed-methods format for our study, including co-designing survey instruments, and deciding on the format and outlets for disseminating findings. During meetings with the community advisory group, we drew from Indigenous evaluation methods (J. LaFrance & Nichols, 2009), constructivist grounded theory (Charmaz, 2014), and participatory decision-making (Kaner, 2014) to facilitate activities that allowed marginalized voices to be heard and centered in the research design. Up front, the research facilitators shared that the goal of our first workshop was to co-create a research design that was appropriate and relevant to the needs of the local community. Preliminary discussions focused on finding a shared terminology for concepts related to Indigenous science knowledge to form the broader focus of our study regarding Indigenous knowledge, climate and youth science education in the Caribbean.

For focus group discussions during the design phase of the research, we used a participatory Indigenous evaluation activity, a 'thematic wall,' developed by one of the authors (S. Valdez). To identify priority topics for the research project we asked community members to respond to the following prompt, *Please take a moment to share an example of Indigenous science knowledge or a traditional activity that you believe is important for our future generations*. Each member attending the community workshop was invited to write or voice their response. We posted all responses up to the wall where they could be shared out again to the

group and then invited all the members to rank their top four themes of interest for the project by applying various-colored stickers. In addition to community responses, we included several culturally-relevant, informal science learning target areas identified in previous studies from Native Science Field Centers in the ranking activity (Augare et al., 2017; Valdez, 2012). These facilitation methods focused the research to prioritize concerns that were relevant to the community, a key principle for ethical and effective research with Indigenous communities emphasized across numerous research guidelines (Riddell et al., 2017).

Based on data generated during the first two community workshops, we determined the focus for our youth-led study—Indigenous Caribbean knowledge regarding traditional cycles (lunar and seasonal) for planting and harvesting Indigenous plants in the context of climate resilience. We included plants harvested for medicinal, food, and utilitarian purposes with an emphasis on two important Indigenous food crops, *yuca* (*Manihot esculenta*), and *maíz* (*Zea mays*). This theme and additional target areas identified in the participatory ranking activity also provided relevant data to form survey questions for gathering pre and post-data concerning youth interest and attitudes towards science and towards Indigenous knowledge in their communities. Prior to beginning the youth study, community advisory group members reviewed and approved the project design and materials. We also extended an invitation for all community advisory group members to continue engaging with the next phase of the study to the extent that they wished. During the youth workshops, we also facilitated activities for youth to determine their own research questions within the community-generated theme and identify potential data sources for youth-elder interviews held within their families or their community.

We found community and youth workshops a useful format for listening and responding to community needs and interests and supporting Indigenous governance in the research process.

Facilitating this process required extra considerations in terms of access, intercommunity dynamics, and adapting protocols to shift external data governance to the community. In terms of access, keeping a responsive and flexible timeline allowed us to respect the time and needs of community members. This was important considering the potential for overburdening community members during the research process, noting past concerns in research with "research fatigue" or "consultation fatigue" (J. D. Ford, Stephenson, et al., 2016). The community research partner's prior experience working as a school counselor, proved especially valuable in helping us to adjust the times and locations to best accommodate community advisory group members. Phone calls to connect with each advisory group member helped us to coordinate transportation if needed and encouraged those who knew one another to reach out and remind each other of meeting times and places. In planning all activities, we remained aware of what factors (e.g., location, time, providing food etc.) increase access, and help to not overburden community members.

During community workshops, we also focused on designing and facilitating activities to draw out more marginalized voices and buffer more dominant voices as they emerged within the community. We drew from Indigenous evaluation frameworks (J. LaFrance & Nichols, 2009) along with participatory decision-making (Kaner, 2014) to guide these interactions. Interpersonal dynamics proved challenging at times between community members, however maintaining a shared and culturally grounded focus on the youth during community advisory group meetings proved helpful in overcoming minor personal disputes and disagreements as they arose. We also found it helpful to invite early college-age youth from the community to help facilitate and assist elders during community workshops by synthesizing oral contributions into text and visual depictions during workshops, and college-age youth joined us during field visits assisting with

informal interviews with elders. Additionally, for the youth workshops at each of the two schools, elementary age youth collaboratively defined what our research values should be during our project. We found it helpful to have this visual reminder to reference at the beginning of each workshop and as needed throughout our discussions.

Lastly, beyond these onsite methods that we applied, we found external institutional protocols challenging when co-designing the research. Specifically, the funding agency and university IRB centered governance over the research process and data within the external institution or researcher who predetermines the study procedures and instruments for gathering data (Cross, Pickering, & Hickey, 2015; Riddell et al., 2017; Sabati, 2018; Sherman et al., 2012). Institutional ethics review boards have received critique regarding Indigenous research ethics, due to their emphasis on protecting the liability of external institutions without adequately addressing collaborative relational aspects regarding the research process (Grossman et al., 2010). To overcome this challenge the research facilitator, worked closely with the principal investigator advising the project, and with the university IRB coordinator, describing cultural considerations and findings as they were observed, and submitting numerous protocol revisions following community review of research design and data. The on-site discussions and participatory activities during community workshops helped to align the needs of the community, the research facilitators, and the funding grants and also provided a format for review, feedback and approval for all research instruments and protocols for gathering data.

4.3.5 Humility: supporting opportunities for shared learning

Allowing for humility in our research process required intentionally designing opportunities for shared learning and capacity building (NCAI, 2012). We explored numerous methods often used in community-based participatory and Indigenous research methodologies to foster knowledge exchange, innovation, and community ownership, such as place-based education methods, community field hikes, focus groups, participatory mapping, and Photovoice (documentary photography) (Castleden, Garvin, & First Nation, 2008; Little Bear, 2009; Semken & Freeman, 2008). At the most basic level, we recognized the importance of maintaining an adaptive and reflexive research timeline and design. Maintaining an adaptive research design allowed us to engage in field-based, experiential learning opportunities as they arose. These included invitations for members of the community advisory group to hike together to ancient and remote places of cultural and ecological value. Guided by the machetes and memories of local land stewards, we travelled through the dense jungle, up rivers, and along long-worn Indigenous trail systems. During our time together on the land, members of our research team formed stronger relationships, sharing stories and further knowledge exchange inspired by the landscape and experiences we were sharing. Collaborative science field projects in Arctic Native communities likewise emphasize the important of providing time for informal exchanges and participation in local seasonal activities as a means for building a common experience and reference points (Huntington, Gearheard, Mahoney, & Salomon, 2011). To gather data during informal exchanges, we used audio recorders, photos, handheld GPS units, and field notes. The research facilitators also took time to visit members of the community who may have had more limited access to physically attend workshops.

Building a shared language represented another useful method for supporting humility in the research process. In our case study community, a *Jibaro* dialect formed through an Taíno (Island Arawakan) mother language woven with Spanish, African, Mayan and English language contributions reflects the complex history of the region (Shaffer, 1971). During preliminary informal community discussions, workshops and field hikes we noted how scientific processes were described within the local language and prioritized these terms and concepts before introducing academic terminology. Indigenous language reflects different philosophies and concepts than those that may be represented in colonial and academic languages (Little Bear, 2000). In addition to increasing access to these deep-place based knowledge systems through language, these methods also highlighted where knowledge systems overlapped (Berkes, 2009a). The research facilitators used field journals to memo and reflect on local concepts and knowledge learned throughout the process.

Humility also formed the basis for the youth workshops and field camp. Capacity building workshops for youth included first honoring culturally embedded Indigenous science knowledge from their own families and community, and then following with related academic and technical science terminology and understanding. This method, identified in previous literature (Mack et al., 2012), supports culturally-relevant informal science learning grounded in Native ways of knowing. For example, we shared stories regarding animal behavior as an indicator for weather patterns commonly referenced in Indigenous-descendant families in the region as a point of inquiry to explore how knowledge about the environment is held in our communities and what scientific elements are contained in these stories. During their field study, the youth applied multiple methods for recording diverse forms of data, including field

notebooks, a GPS unit, audio recorders, a video camera, a tablet, and hand drawn seasonal diagrams.

Photovoice images, and transcripts from youth-elder interviews and onsite informal interviews with elder knowledge keepers also provided data for a participatory analysis workshop held with the community advisory group. During this workshop they engaged in qualitative research methods that supported participatory data analysis and interpretation included pile sorting with youth-selected Photovoice images (Weller & Romney, 1988) and constant comparison with interview transcript text (Corbin & Strauss, 2008). To record community-generated interpretive data, we provide pen and paper for notetaking and set-up video and audio recording devices to allow for storytelling. These methods provided for participation by overcoming literacy limitations.

At times we observed a hesitation in engaging with and discussing Indigenous knowledge from the community members. From our own family histories and contexts, both research facilitators recognize a longstanding stigma regarding Indigenous knowledge and peoples on the island in which negative stereotypes of being uncivilized, uneducated and poor are often associated with being *Indio(a)*or *Jibaro(a)* (commonly used terms describing Indigenous peoples in Borikén). We also observed community members at times deferring to those who had received some college education or held positions of leadership for their knowledge expertise. Several creative methods helped us to remain sensitive to and work through these challenges. When facilitating our early community workshops, where we were seeking out a shared terminology around the concept of Indigenous knowledge systems we started with place-based knowledge regarding familiar place names. After this initial discussion, community advisory group members seemed more confident to discuss other areas of knowledge they held and found important for

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the research. The research facilitators recognized additional contexts where negative stigma regarding Indigenous knowledge systems occurred throughout the project. For example, while attending a regional stakeholder meeting for the fourth national climate assessment, the research facilitators spoke briefly with one of the only rural smallholder farmers in attendance. He remarked that he didn't feel Indigenous agricultural knowledge was respected by the federal agency and academic scientists, that they looked down on it as "folk knowledge." A young woman in attendance overheard and joined the conversation. She shared that she was excited to hear us talking about Indigenous knowledge and shared her frustration with the science experts and with her college degree program where they continually dismissed and looked down on Indigenous knowledge regarding lunar cycles for guiding planting, harvesting, and pruning practices that she had learned and respected growing up in a rural agricultural community. Previous studies regarding threats to sustaining Indigenous knowledge identify marginalization and social racism as factors resulting in further loss of knowledge transmission between knowledge keepers and youth, who turn instead to mainstream knowledge and values (Tang & Gavin, 2016). Keeping these cultural sensitivities in mind we used the research process itself, specifically valuing and centering local community members as primary knowledge sources to challenge colonial legacies and stigma.

An outcome that we observed during the course of our project was renewed recognition and valuing of Indigenous knowledge, including language, and of practices that sustain that knowledge, such as farming. This recognition was reflected, for example, in the elders' interpretation of the youth Photovoice images (some quotes translated from Caribbean Spanish):

They are learning an inheritance. (Socorro Diaz Rosario, Cidra)

It's good that they are transmitting a seed that our ancestors transmitted to us. (Nilda Santiago, Comerío)

The power of healing comes from wisdom. (Emilia Santiago, Cidra)

These findings support the conclusions of prior intergenerational research studies. For example, in Parrado-Roselli's (2007) collaborative study, the research process itself, including dialogue between youth and elders, resulted in outcomes such as regeneration of Indigenous knowledge, improved data interpretation, and increasing connections between generations.

Holding a workshop where we could facilitate participatory data analysis and interpretation with elders from the study communities provided opportunities for what Kendrick and Manseau (2008) refer to as "culturally appropriate peer review processes." The research facilitators reviewed, questioned, and deepened their preliminary findings by comparing them to the elders' interpretations from the Photovoice images and interview transcripts. For example, both the research facilitators and the community advisory group members recognized the thematic significance of "learning by doing" as demonstrated in the following quote:

For the children to learn Indigenous [practices], they must be…in the field. Planting the plants...they connect with nature…they see the development, the growth, the crop. These are important things for them, so it stays in their mind. That is what we want. (Enrique Rivera, Comerío)

The concept of "learning by doing" also mirrored findings in research regarding effective co-management (Berkes, 2009a). Likewise, this finding represents an alternative path away from a known threat to conserving Indigenous ecological knowledge stemming from colonial-driven education systems in which, "children learn knowledge from school in abstract, but not "learning by doing" from their own community" (Tang & Gavin, 2016, p. 60)

Throughout the project, community members often reflected on remembering and reawakening knowledge that they thought was forgotten, such as in the following quote from the

community research facilitator just following a field visit with one of the elder, knowledge keepers in the community:

> *It happened to me when I was at Randal's farm, I remember all the things that I forgot…I refresh with Randal.* (Norma Ortiz, Cidra)

Knowledge exchanges out on the land both strengthened relationships between community members and became reference points for future discussions regarding Indigenous knowledge concepts.

Lastly, through our process of listening, recording, transcribing, note-taking and then reviewing and coding transcripts using constructivist grounded theory methods, the research facilitators, who are both Indigenous to the area as well, were surprised to learn the extent of living Indigenous language regarding the environment, including place names, plants, animals, and domestic products formed from naturally-sourced materials that had survived the past five centuries. Often, academic texts and community members erroneously referred to the Indigenous language as Spanish. Similarly, the vast majority of youth in the pre- and post-survey expressed substantial interest in learning more of their Indigenous language, yet in a free listing question did not recognize the extent of Indigenous language that they already knew. Within a deeper context, these observations reflect the history of erasure designed through the colonial education systems and assimilation policy on the island (Harrison, 2018).

4.3.6   Reciprocity: ensuring benefit to community

Methods we applied for ensuring reciprocity in the research also aligned with methods for ensuring data quality standards in qualitative research methods, and for supporting Indigenous data governance. These included community review of data (Photovoice images, transcripts), providing due credit for knowledge contributions, and building direct long-term community benefits into the research process and goals. We used member checking, in which

researchers engage community members in review of raw data and interpretive themes, to improve accuracy and validity of qualitative findings (Creswell & Miller, 2000; Lincoln & Guba, 1985). Workshops and focus group discussions with the community advisory group members, provided time for review and approval of research findings and products, while also sharing out more broadly what we were learning in the process. With one of the community members serving in a key research leadership role and as co-author on publications and presentations (N. Ortiz), this research study also benefited from continual member checking (via the community advisory group), and critical review in every phase of the study through a locally accountable and culturally grounded perspective. We also shared preliminary findings and data during our field visits with elder knowledge keepers, providing additional opportunities for culturally-relevant review and verification of outputs and findings from the project. During these visits, we made efforts to reciprocate the time and knowledge shared, through gifts, such as solar lanterns and emergency supply donations to assist with hurricane recovery.

When other opportunities to give back time and effort on behalf of the community presented themselves, we made our best effort to reciprocate the benefits that we were receiving from the research. For example, one elder during the first community workshop emphasized the importance of strengthening connections between the youth and their grandparents. He requested that we begin the project with an intergenerational planting of the *yuca* and *maíz* in the garden of the public school where we held our workshops. We worked to prepare a new garden plot and during our last community workshop meeting before beginning the youth-led study, grandparents and their grandchildren planted seeds and cuttings supplied from the farm of another member of the community advisory group. This planting and other cultural considerations, including a blessing for our work provided by another member of the advisory group, also served as a means

of honoring local cultural protocols. For all necessary supplies for the garden, meals, and workshop materials we invested in local family businesses when available. We reached out for municipal support and to local research agencies as well, to provide transportation and resource materials as needed for all activities. Through another opportunity that arose during the course of the study, the research facilitators attended and contributed to the regional stakeholder meeting for the fourth U. S. National Climate Assessment. Their participation resulted in a technical contribution for the Caribbean regional chapter, and a report in response to recent calls for representation of Indigenous communities in this comprehensive climate report (W.A. Gould et al., 2018; Maldonado et al., 2015)

Lastly, energy and efforts towards producing outputs from our study centered interests and access concerns identified by the community advisory group. For our last workshop held with the community advisory group, in addition to providing a traditional meal, gifts, and hurricane relief supplies to give thanks for the time and efforts, we focused on co-designing educational resources based on our study findings. Prior to the workshop, we worked with a local artist and Indigenous scholar to visualize our data. Use of visual metaphor can enhance data through drawing together multiple levels of meaning (Verdinelli & Scagnoli, 2013). We drew from Jibaro and Indigenous Caribbean language and visual symbols to identify cultural visual metaphors that hold relevance within the local community context. With review from this last community workshop we are now in the process of refining these materials, Indigenous calendar rounds representing lunar cycles, in relation to agricultural, biological, and hydrological systems and annual seasonal cycles in relation to atmospheric changes and traditional agricultural practices and obtaining grant funding and support to print hardcopies for distribution in local schools and community centers. When the resources become available, we also aim to complete

a locally produced short film. We based our decision to prioritize the calendars over other potential outputs, such as the film or informational brochures, based on community concerns with internet access and literacy (primarily among rural elders). During the final workshop, we also shared copies of the study summary that served as the technical contribution for the fourth national climate assessment with photos, and orally reviewed all of the findings that will be provided in a formal report advocating for Indigenous education for the state-level department of education.

Throughout this study we looked to how we could support reciprocal relationships. These included relationships with each other, potential collaborators and participants, as well as reciprocal relationships within the land and places where we held the research study. In terms of long-term goals identified by community members, we recognized within this process an opportunity for reciprocity in addressing two critical concerns faced by the community: 1) loss of Indigenous knowledge between elder generations and youth, and 2) ensuring that current and future generations have all the resources they can access to address environmental challenges they may face into the future. As in many similar studies, we observed a disconnect and disruption between youth and Indigenous knowledge keepers that, at least in part was widened through the influence of the colonial education system (Harrison, 2018; McCarter et al., 2014b; Tang & Gavin, 2016). We also observed the differences in the dominant narratives between those presented in the educational system by Indigenous knowledge keepers, regarding cross-cultural exchanges in the island, as reflected in the following quote from an elder farmer during the final community advisory group workshop:

> *The colonizers brought seeds, but they also took away. They took more than they brought.* (Luis Vidal Amaro, Cidra)

Throughout our study, we sought opportunities to center narratives such as these, which have remained largely underrepresented in the region. In sharing out our research findings, we specifically centered youth and community voices in presentations. These included, youth presentations at the two field study school sites (one for their classmates, and one for their families), a presentation by youth nominated by their peers for research scientists at the U.S. Forest Service International Institute of Tropical Forestry (IITF), and numerous conference presentations provided by the research facilitators. At the IITF presentation we observed some researchers in the audience remarking with surprise at the descriptions of Indigenous science knowledge the youth had obtained from elders in their community. Some remarked on the under-recognized value and relevance of what the youth were sharing, and for some this included knowledge from their own grandparents that they had overlooked in the past.

For the national and international presentations, we noted challenges for providing access for community participation as well as resources for overcoming these. A severe hurricane season partway through the study resulted in loss of power and school closures for months in both rural field site communities. By providing a solar battery charger the community research partner was able to co-present study findings via webinar platform for the NASA American Indian/Alaska Native Education Working Group. We also obtained funding support for the community research partner to present at the American Geophysical Union's international science conference, where attendees remarked on the value of the unique perspective and context that she was able to provide. In turn, the community research partner remarked on the value of what she learned, the resources that she obtained to bring to her home community (including hardcopies of the National Climate Assessment that she had contributed to), and the connections made while attending the conference. Although, we were able to obtain travel support for the

community research partner to be represented in these spaces, we were limited in providing

monetary compensation to all project participants based on funding restrictions of the research

grant. Also, within the cultural context, providing monetary gifts was not always considered as

appropriate as providing meals and more personalized gifts. However, in the future we will

resource more flexible funding options that will allow provisions for community members,

especially early-college age youth, to attend trainings, professional development opportunities,

and to hold paid research positions on projects such as these.

Through overcoming social stigma and accessing both local and external support

resources, we were able to set on a pathway for more balanced relations and knowledge

exchange than we have witnessed in past scientific research. One of the key factors was

developing methods to restore intergenerational connectivity, and how the research itself can be

a method for decolonizing transmission pathways. Previous research observes challenges related

to disruption of Indigenous knowledge transmission brought on by colonial impacts on economic

and education systems (McCarter et al., 2014b; Tang & Gavin, 2016), and alternately the

potential for biodiversity conservation through strengthening intergenerational communication

(Fernández-Llamazares & Cabeza, 2018). By searching out ways of strengthening

intergenerational knowledge transmission in the research process itself, we redefined and

centered youth and community knowledge keepers as the researchers and experts. We also

centered local community as the primary beneficiaries of the research outputs and outcomes.

4.4   Discussion and Conclusion

Based on our findings from applying and ground-truthing this working model for

decolonizing science research, we recognize further potential for engaging in cross-cultural

research that enhances rather than erodes Indigenous sovereignty, governance, and maintenance

of Indigenous knowledge systems and lifeways. One of the most important impacts identified by participants, whether academic or community researchers, elders or youth, was that the research process itself ignited a renewed interest and valuing towards Indigenous identity and knowledge systems. This renewed interest supported our efforts in overcoming challenges associated with negative social stigma and power imbalances between authorities of learning and rural knowledge keepers. Through this process, as observed in similar studies, we also recognized the importance of engaging youth and elders in the research process to strengthen intergenerational pathways for knowledge transmission (Parrado-Rosselli, 2007; Reo et al., 2017; Ross et al., 2011; Tang & Gavin, 2016). Further, we acknowledge that science research is also inherently a vehicle for science education wherever it occurs and especially within experiential settings out on the land through participatory community-based processes (Kūlana Noiʻi Working Group, 2018). Therefore, we see applications for this research informing educational settings working towards inclusion of diverse ways of knowing and experiences.

This research study also brought to light several areas that still require further development and research. First, we observe ongoing challenges associated with colonial assimilation and Indigenous erasure in the school curriculum. While we find research on language policy in education for Borikén (Harrison, 2018), and are aware of one Indigenous education programs in the region, we recognize that in the Caribbean and across countless other Indigenous communities impacted by colonization, youth continue to learn in institutions where, as described by a Kalinago linguist Keisha Josephs in our preliminary study informing this work, "they don't learn about themselves…they grow up in the school system that teaches them about other people, doesn't teach them about themselves… so you get this generation that's disconnected [and] the culture starts breaking down" (David-Chavez et al., n.d.). Relatedly,

reconciling past research and "authorities" on Indigenous community knowledge and history that perpetuate misinformation and harmful racially driven stereotypes remains a challenge in this work. The Canadian Royal Commission on Aboriginal Peoples' document outlining ethical guidelines in research noted, for example that with the majority of past research initiated and implemented by non-Indigenous researchers, "Aboriginal people have had almost no opportunity to correct misinformation or to challenge ethnocentric and racist interpretations" (1993, p. 1). One of the key areas requiring further attention towards addressing these challenges is raising awareness among non-Indigenous communities regarding Indigenous rights to sovereignty and self-determination. In the context of this research, we emphasize the right to environmental self-determination in environmental justice (Tsosie, 2007), and as applied towards "restorative justice… for the longstanding environmental and cultural damage from a history of colonialism" (Sproat, 2016, p. 160). We likewise recognize the need for awareness regarding sovereignty within colonial educational systems (Brayboy, Faircloth, Lee, Maaka, & Richardson, 2015). Lastly, we advocate for focusing additional resources and funding support towards building Indigenous capacity and leadership opportunities in research. The purpose that this model serves is to map out a potential path towards restoring and sustaining relational accountability, one of the key components necessary for effective and ethical partnerships between research institutions and cultural communities.

In this article, we detailed some of the opportunities and insights available when applying values such as *integrity*, *respect*, *humility*, and *reciprocity* to restore long-term relational accountability towards Indigenous communities, lands and futures. The value of the model presented here is that it synthesizes across disciplines, bringing together theory and practice regarding research ethics in Indigenous communities for a holistic working model that can be

adapted for multiple disciplines and research contexts. This model provides a comprehensive visual map to guide responsible research integrity and praxis with Indigenous nations and communities, while the case study provides examples of specific actionable methods that can be used in implementing the model. With the vast majority of researchers in fields such as climate research continuing extractive research practices in Indigenous communities (David-Chavez & Gavin, 2018), what's needed now is further accountability and support towards normalizing higher ethical standards in research practice. Among the many areas where these efforts could be immediately applied include support for Indigenous communities to develop and implement formal research protocols and codes of ethics where they are not currently available, to define data practices that enhance tribal capacity for Indigenous data sovereignty and Indigenous data governance, and to advocate for greater support in terms of funding and capacity for Indigenous-led research and authorship. We also assert in the areas, both disciplinary and geographically, where Indigenous communities have already developed research principles and codes of ethics, as synthesized in this paper, may be useful starting points. One of the common threads within this and similar studies, is the need for research regarding Indigenous communities to be led and designed by members of those communities (Hepi, Foote, Marino, Rogers, & Taimona, 2007). Addressing the issue of incomplete datasets in science requires creating space for the primary sources of that data—the Indigenous communities who hold the untold narratives, deep place-based concepts, and relevant research questions. We look forward to the innovation and problem-solving potential that has not yet had opportunity to grow from beneath the thick colonial residue that has settled into the science community for so long. We also reflect back on the youth who participated and led this study, as they seamlessly wove together diverse knowledge systems and languages from their ancestors, grandparents, and scientific trainings.

Within the spark of these youth we hold great hope and anticipation for the future of scientific research under the leadership of a new generation of environmental leaders, deeply rooted and culturally grounded within their Indigenous communities.

5. COMMUNITY OUTPUTS

Within the working model for decolonizing science research that I present in my dissertation work, the value of *reciprocity* emphasizes an intentional commitment on the part of researchers to ensure that the community benefits from the research process, outputs, and outcomes. I am aware that the vast majority of Indigenous and rural community members I work with may have limited access to directly benefit from the manuscript publications required to fulfill my academic commitments. Therefore, this body of work includes numerous community outputs and outcomes, representative of my time, efforts, and dedication towards restoring relational accountability within my own PhD process through capacity-building, advocacy, and providing accessible materials to share project findings, including:

1) A resource database and social media platform produced from the inter-island knowledge exchange case study described in the 2nd manuscript, developed to nurture a sustained support network for Caribbean Indigenous scholars, educators, and conservation practitioners. Following this event, two practitioners began planning for an inter-island youth exchange program to be held between Indigenous education programs in Kiskeya (Dominican Republic) and Borikén (Puerto Rico), and scholar participants continue to support each other through providing peer review, collaborative authorship, and through sharing information regarding relevant conferences and funding opportunities.

2) For the case study described in the 3rd manuscript, I supported three youth nominated by their peers, by providing a capacity-building workshop to develop their presentation skills. These youth and one older brother, age 14 who had volunteered for the field camp in a mentoring role, successfully presented their climate research project, designing their

own format using PowerPoint, mapping technology, and interactive activities, for professional scientists at the U.S. Forest Service International Institute of Tropical Forestry.

3) I invited and provided transportation for my community research partner (Norma Ortiz) to attend the regional stakeholder meeting for the 4th National Climate Assessment (NCA4) where we shared preliminary findings to inform the Caribbean regional assessment. Following this meeting I wrote a report for the Indigenous Peoples' chapter of NCA4 regarding climate impacts and Indigenous communities in the Caribbean in response to a series of questions and concerns they posed at the stakeholder meeting, in which they noted census data for Indigenous populations for which they had no data regarding climate impacts and unique historical factors, such as land tenure and climate impacts regarding culturally-specific natural resource use.

4) Working with my community research partner, we produced a bilingual blog article summarizing our field study (David-Chavez & Ortiz, 2018). We provided hardcopies of this summary article for review and distribution to all community advisory group members.

5) We also submitted a technical contribution for the NCA4 based on the youth-led climate project summarized in the 3rd manuscript in this dissertation that is included in the Caribbean chapter (W.A. Gould et al., 2018), representing the first contribution documenting climate concerns for Indigenous communities in the region. My community research partner (N. Ortiz) returned to her community with a Spanish language hardcopy of the NCA4 report to share. Our field study is also included in the NCA4 Indigenous People's Resilience Actions map, an online learning resource where students and

community members can link to the project blog summary and see their efforts represented in a national context.

6) I obtained funding support (provided through NASA and NSF) and registration assistance to provide access for my community research partner (N. Ortiz) to attend the American Geophysical Union fall meeting in Washington D.C. and present our field study in a professional poster presentation. Following a power outage lasting several months as a result of severe hurricane damage, I provided a solar charging device to ensure that my community research partner could continue collaborating. She was able to co-present our work for a webinar hosted by the NASA American/Indian Alaska Native Education Workgroup for over 100 attendees.

7) In collaboration with a Caribbean Indigenous artist and scholar (Liliana Taboas Cruz) and the community advisory group we are currently working on visualizing data findings from our climate project in an series of Indigenous calendars (annual seasonal and lunar), documenting Indigenous cycles of planting and harvesting, seasonal shifts recorded in oral history records, and interconnected observations of biological, hydrological, and atmospheric cycles. I am working on obtaining funding support to distribute these calendars for youth and community education on the islands.

8) Lastly, I worked with the community advisory group to develop a report for the Puerto Rico Department of Education that will be submitted upon final community review.

6. CONCLUSION AND DISCUSSION

The manuscripts contained in this dissertation contain detailed discussions and conclusive remarks respective to each independent study. Here I present a synthesis of ideas focused more broadly across the overall body of dissertation work.

6.1   Emergent Themes

The main theme emerging from this dissertation work regards understanding how the research process itself, rather than the customary focus on research outputs, can serve a critical role in decolonizing research, enhancing Indigenous sovereignty, and regenerating Indigenous lifeways sustained by Indigenous knowledge systems. The research process can serve as a vehicle for building capacity, both for the researchers and for the research communities while also strengthening long-term relationships (Kūlana Noiʻi Working Group, 2018). Similar studies note the importance of processes that promote shared learning (also see, "social learning" Berkes, 2009a) by strengthening partnerships across communities facing similar challenges and partnerships between communities with research and policy-oriented institutions (McCarter et al., 2014a; Tang & Gavin, 2016). Through the body of evidence presented in this dissertation, numerous opportunities for raising ethical standards in research surfaced. For example, findings in this work highlighted how Indigenous knowledge contributions to climate research studies rarely received credit beyond an acknowledgement. Among academic scientists this could be considered ethical misconduct, yet these practices persist in studies initiated by outside researchers accessing Indigenous knowledge for research. As Kimmerer asserts, in studies such as these, "the identity of the practitioners, informants, and the community should always be fully referenced and acknowledged with the same diligence that scientists apply to the contributions

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of their academic colleagues" (2002, p. 437). Through an Indigenous data sovereignty framework, this dissertation work demonstrated a means to shift away from the dominant extractive model within scientific research restoring respectful relations between researchers and Indigenous communities. The analytical framework and findings from this research and the literature informing it also hold relevance for research with non-Indigenous, local communities in some contexts and in settings beyond the environmental science discipline, such as in various educational settings when engaging with deep place-based knowledge.

In a similar thread this research identified numerous remaining barriers within academic institutions and dominant research practices inhibiting cross-cultural knowledge exchange. For example, this research revealed how Indigenous principles for research integrity, along with some foundational scientific standards for research integrity remain absent from reported data on research methods applied in a majority of case studies. As Kawagley and Barnhardt describe, "when examining educational issues in indigenous settings, we must consider the cultural and historical context, particularly in terms of who is determining what the rules of engagement are to be, and how those rules are to be implemented" (1998, p. 15). Until such rules of engagement in academia undergo refinement and improvement, these barriers remain. The work synthesized within this dissertation in the 3rd manuscript reaches back decades, producing numerous research frameworks and codes of ethics available to the larger scientific and academic community, yet we see little evidence of these developments influencing academic norms as evidenced in findings from the 1st manuscript. As researchers, communities, and institutions grow on their paths to reconciliation and genuine inclusion, a critical part of this effort will be determining how to effectively operationalize principles for integrity in research practice. In my development of a working model for decolonizing science research, I identified how cross-disciplinary knowledge

transfer (as presented through the synthesis in the 3rd manuscript), along with Indigenous, community-based, participatory action research, and qualitative methodologies (as applied in case studies in the 2nd and 3rd manuscripts) can support these efforts. This research also identified specific areas, such as IRB/REB protocols (Brant Castellano, 2004; Cross et al., 2015; Flicker et al., 2007; Riddell et al., 2017) and data stewardship practices (Kukutai & Taylor, 2016; Schultz & Rainie, 2014) where institutions can immediately enact improvements in research standards with Indigenous communities (detailed in the 3rd manuscript and "actionable methods and resources" within the working model). In terms of academic research, two specific areas in need of continued improvement include revising IRB/REB protocol requirements and grant funding timelines to more effectively support community-driven and designed research protocols that respect the needs of Indigenous communities. Although conflicts are noted and recommendations provided for improving accountability in the IRB process (Cross et al., 2015; Flicker, Travers, Guta, McDonald, & Meagher, 2007), academic institutions have yet to fully address these concerns. We identify a need for seed grant funding and adaptive research timelines to support the preliminary work that is necessary for effective, relationally accountable community-based research projects. Further, an emphasis across this body of work, is that these initiatives be led by those Indigenous and tribal community members whose lands, lifeways, and families are most directly impacted by such research.

In a related theme, this research identified the need to continue to disrupt presumed binaries between ways of knowing generated by the dominant academic institutions (i.e., Western/colonial knowledge systems which disproportionately empower a small handful of worldviews) and historically marginalized ways of knowing (e.g., Indigenous knowledge systems generated from thousands of diverse worldviews over extended timescales). This

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research highlighted the link between these oppressive binaries which validate one scientific way of knowing over others, vastly ignoring numerous contributions from diverse ways of knowing appropriated to inform the academic scientific body of knowledge to-date, and the historic political context that manifests through persisting power imbalances. This dissertation work also highlights numerous theoretical developments to assist this needed intellectual growth, such as the Multiple Evidence Base framework (M. Tengö et al., 2013), and presents a working model rooted in the values of *integrity, respect, reciprocity*, and *humility* in which researchers can support opportunities for innovation through shared learning and knowledge generation.

Lastly, this body of work highlighted the critical need for intergenerational research methods and commitments in environmental and natural resource science research. By engaging youth in the research process, and strengthening opportunities for knowledge sharing between youth and elder knowledge keepers, the research process can serve a critical role in sustaining Indigenous knowledge systems, and their natural pathways for knowledge transmission that have been threatened by loss via a widening generation gap (Fernández-Llamazares & Cabeza, 2018; Gill et al., 2014; McCarter et al., 2014a; Reo et al., 2017; Tang & Gavin, 2016). Further, restoring connections between Indigenous community knowledge-keepers and youth, and inviting opportunities for place-based, culturally-relevant and informal science learning throughout the research process, opened pathways for addressing the systematic displacement from community knowledge sources, language, and culture inflicted on Indigenous youth through colonial education policies. Among all of the lifeways threatened and disrupted by the legacies of colonial-driven genocide, oppression, and assimilation policies, this objective towards restoring intergenerational relationships arguably holds the greatest potential for our future. Through learning by doing, out on the land, under the guidance of those who've

maintained Indigenous knowledge systems and related practices, Indigenous youth can inherit the skills and capacity necessary to continue to refine and carry this knowledge forward.

6.2   Research limitations and future research

I acknowledge that the literature informing my dissertation work was limited in terms of language and access, and also due to the interdisciplinary scope of this work. Data presented in my findings most accurately reflect English language resources and are more heavily representative of an American geographic and historical context. Further, I am aware that notable and valuable efforts led by on-the-ground community activists and leaders, whose work is not recorded within academic literature or within the government and tribal community project reports that I had access to for these studies, remain underrepresented. Given these limitations, I emphasize that the theoretical developments presented here represent working models, for successive generations to adapt and refine as necessary. To enhance access for this, all publications resulting from this work will be open-access and I have put forth my best efforts to use inclusive language to cross transdisciplinary boundaries that more discipline-specific and abstract theoretical terminology may have limited. Further research overcoming these limitations could best be supported through developing capacity and increasing access for Indigenous scholars and practitioners from underrepresented regions of the world, and underrepresented roles outside of academia to join and lead the discussions regarding best practices in environmental and natural resource science research within their respective communities. In transforming our current systems of education, Mi'kmaq scholar Marie Battiste recommends support for professional capacity-building focused towards "students who develop a consciousness of developing their credentials to benefit First Nations people and to contribute to First Nations development…individuals working with communities, not careerists or remote

academics" (2002, p. 36). I also advocate for more support from the research community towards existing efforts for Native nation-building, such as within the Indigenous data sovereignty movement (Rainie, Rodriguez-Lonebear, et al., 2017a, 2017b; Te Mana Raraunga Māori Data Sovereignty Network, 2018; M Walter, Lovett, Bodkin Andrews, & Lee, 2018).

This research focused within the context and history of Indigenous communities, yet in defining this scope I acknowledge that criteria for determining who represents "Indigenous" peoples and communities is inherently complicated by political tensions varying based on regional and historical context (Corntassel, 2003; Xaxa, 1999). Such complexities and the power dynamics therein that may serve to empower or disempower rights of community members require further consideration than afforded within this body of work. For the context of this study I drew more heavily from U.S. and Caribbean contexts and also from international Indigenous peoples' working groups (e.g., United Nations Working Group on Indigenous Populations), following fluid working definitions based on characteristics that may vary by regional context and that are at the highest level based upon self-determination and community acceptance according to each unique community. Future research, generated from communities in different areas of the world, such as African, Asian, and South American colonized regions will likely reveal deeper political and historical threads and understandings that my dissertation work was not able to address.

Lastly, due to limited scope and time, there were also concerns regarding power imbalances, diverse ways of knowing, and marginalization *within* Indigenous communities I was not able to sufficiently address. Understanding additional barriers and support mechanisms for inclusion of underrepresented populations within Indigenous communities, such those marginalized by gender, ethnicity (including mixed-heritage), ability, and socio-economic status

will also hold relevance for Indigenous communities and standards of practice in environmental science research (Agrawal & Gibson, 1999; United Nations Framework Convention on Climate Change, 2013). For example, not all community members may have an interest in or access to higher levels of engagement in research studies and participating in various aspects of the research may place disproportionate burden on certain community members, especially in the case of marginalized populations (Agarwal, 2001). United Nations' best practices for use of Indigenous knowledges in climate adaptation emphasizes the need for further understanding regarding "not only how different social groups are affected but also how different groups can bring vital resources to the adaptation process" (2013, p. 5). Concerns regarding mistrust, historical trauma and exploitation in Indigenous communities may also present differently across communities and require further consideration in this research. These concerns likewise highlight the problems and complexities within defining boundaries to the concept of community, given the various conceptualizations of "community" and the heterogenous and dynamic nature of human populations (C. Flint, Luloff, & Finley, 2008; Kumar, 2005).

6.3 Final thoughts and a call to action

Through this body of work, I followed numerous threads connecting symptoms (e.g., underrepresented knowledge systems and communities, cultural biases, and extractive research practices) inhibiting growth and integrity in the sciences to their deeper origins rooted in histories of colonization and oppression. In a way I saw my research process untangling and reweaving these threads into new patterns informed through the guidance of my community research partners, practitioners, mentors, and from the ever-growing body of work generated from Indigenous scholars and cross-cultural collaborations around the world. Within these patterns I recognized how regeneration of Indigenous knowledge systems requires

interconnected goals for restoring relationships, sovereignty, cultural context, food systems, governance, and livelihoods. This process, involving synthesis across knowledge systems and academic disciplines, helped me to identify and map out a pathway forward for restoring relational accountability and disrupting colonial agendas and narratives in the sciences. This body of work also provides an evidence-base to inform higher standards of integrity and responsible research practices.

In order to continue towards collective growth and innovation in the scientific community, I propose a call to action on the part of researchers, academic institutions, funding agencies, proposal reviewers, and publishers, to acknowledge their role in reconciling and healing our histories, and their intergenerational role in regard to the collective stewardship of the Earth and all our relations. Over my course of time completing my doctoral degree here at Colorado State University, the administration formally adopted an Indigenous land acknowledgement, for the first time in history formally addressing the colonial legacy with which the land grant institution was founded upon (Frank, 2018). Even within our own institution we have a considerable amount of work to do to beyond this first step, to acknowledge and honor the countless contributions and sacrifices Indigenous and marginalized communities have provided to the growth and benefit of society at large. We cannot unwrite the harmful stereotypes or erase the racially charged and inaccurately bias datasets, just as we cannot un-see the atrocities of genocide, oppression, and slavery that are valorized in so many aspects of our learning institutions (curriculum, data, symbolism, naming, etc.). What we can do is fill and balance these incomplete and radically skewed datasets with the unspoken narratives, the unasked questions, and the longitudinal findings and knowledge carried forward and transmitted against great odds by our ancestors and elders.

Rather than continuing the dominant models of extracting or taking intellectual ownership over Indigenous knowledge systems, I call for researchers to support the rightful inheritors of such knowledge—Indigenous youth—to build their capacity as data stewards and leaders of their lands and lifeways. As increasing numbers of youth from marginalized backgrounds gain access to institutions of higher learning and to forums for policy and governance, they carry their diverse knowledges and perspectives with them enhancing the potential for problem-solving capacity and innovation that is generated from knowledge-exchange within these spaces. I call for each of us to make an intergenerational commitment to support these efforts, to ensure that future generations of all backgrounds have access to all the resources that we can offer them to face the challenges ahead. It is with great hope and excitement that I offer this work as my contribution to the body of knowledge that future generations will carry with them. In doing so, I envision a new generation of leaders in environmental and natural resource sciences, deeply rooted and culturally grounded within their communities, seamlessly weaving tradition and innovation towards a more hopeful future.

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APPENDICES

Appendix A. Colorado State University IRB Approval

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 eprotocol
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	July 07, 2016
TO:	Gavin, Michael, 1480 Hmn Dim Ntrl Rsrc
	David-Chavez, Dominique, 1480 Hmn Dim Ntrl Rsrc, Manfredo, Michael, 1480 Hmn Dim Ntrl Rsrc
FROM:	Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE:	Indigenous Knowledge and Science Education in the Caribbean
FUNDING SOURCE:	Funding - Fellowships
PROTOCOL NUMBER:	15-5987H
APPROVAL PERIOD:	Approval Date: July 22, 2016 Expiration Date: July 21, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Indigenous Knowledge and Science Education in the Caribbean. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu
Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu
Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu

Evelyn Swiss

Swiss, Evelyn

Approval to recruit the remaining 45 participants with the approved recruitment and consent procedures. Because of the nature of this research, it will not be necessary to obtain a signed consent form. However, all subjects must be consented using the approved verbal script. The requirement of documentation of a consent form is waived under § _ _.117(c)(2).

Approval Period:	July 22, 2016 through July 21, 2017
Review Type:	EXPEDITED
IRB Number:	00000202
Funding:	NSF,

Appendix B. Study Attributes, Descriptions and Codes (1st Manuscript)

	Label	Description	Variable type
Demographic data	Article #	1-3 digit unique identifier	numeric
	Author(s)	Last name, First Name	text
	Year	year of publication	numeric
	Title	publication title	text
	Journal/Host Pub.	title of journal or host publication	text
	Geographic Area	location of study (country/territory/region)	text
	Context of Study	key research question/intervention, theme of study etc.	text
	Community/ participant population	Indigenous community(ies), tribe(s), village(s) etc.	text
Levels of participation by research stage	Project initiated by	*Are Indigenous community members included in the decision to initiate the study?* A = Academic researchers initiate study (unless researcher is from study community & working on behalf of community needs, then code as C) M = Mutual agreement b/w community partners & researchers C = Community members/groups initiate study O = Other (listed under 'Notes') NR = not reported	categorical
	Design notes & methods	Evidential notes describing methods & processes regarding community participation in research design stage (w/pg. numbers cited) or 'NR'	open text
	Participation in design stage	*To what level do Indigenous community members have authority in the research design (proposal development, defining goals & objectives, defining research Qs etc.)?* 0 = Contractual/no community participation (researchers make all decisions, may employ community to perform tasks; tasks are defined by the academic researcher) 1 = Consultative (community members consulted by asking for opinions/feedback/recommendations, decisions made by scientists) 2 = Collaborative (community members & researchers work together, researchers have primary authority and make decisions about/facilitate the process for collaboration) 3 = Collegial (researchers & community members work together, local community members have primary authority and make decisions about/facilitate the process for collaboration) 4 = Indigenous (community members make all decisions and have authority over all research aspects in every stage of the process)	ordinal

		Label	Description	Variable type
			NR = not reported (if there is no reported data regarding this research stage, otherwise code as 0 if described & no community pt. is recorded)	
		Implementation notes & methods	Evidential notes describing methods & processes regarding community participation in implementation stage (w/pg. numbers cited) or 'NR'	open text
		Participation in implementation stage	*To what level do Indigenous community members have authority regarding the implementation of the research (fieldwork, sampling, data collection, monitoring etc.)?* 0 = Contractual/No participation; 1 = Consultative; 2 = Collaborative; 3 = Collegial; 4 = Indigenous; NR	ordinal
		Analysis notes & methods	Evidential notes describing methods & processes regarding community participation in analysis stage of research (w/pg. numbers cited) or 'NR'	open text
		Participation in analysis stage	*To what level do Indigenous community members have authority regarding the analysis of the research (data interpretation, evaluation etc.)?* 0 = Contractual/No participation; 1 = Consultative; 2 = Collaborative; 3 = Collegial; 4 = Indigenous; NR	ordinal
Quality indicators		Dissemination notes & methods	Evidential notes describing community considerations in dissemination (authorship, acknowledgement, use of findings) stage of research (w/pg. numbers cited) or 'NR'	open text
		Accessibility	*Are findings accessible to Indigenous community members?* 0 = not reported 1 = accessibility is directly addressed (e.g., findings shared with community, data available to/stored with community members, local publications produced, disseminated in local language etc.)	binary
		Relevance	*Are findings reported in the context of concerns, issues or interests defined by Indigenous community members?* 0 = relevance for community not directly addressed 1 = relevance for community is directly addressed	binary
		Credit	*How were Indigenous community members credited for their knowledge contributions and efforts?* 0 = no acknowledgement 1 = acknowledgement only 2 = co-authorship (contributing member of community/community itself)	ordinal
		Ethics notes	Evidential notes describing ethics & guidelines reported in the research process, such as Free Prior and Informed Consent (FPIC), guidelines for addressing cultural sensitivity & researcher bias, assessment of risks & protection of intellectual property regarding Indigenous traditional knowledge, etc. (w/pg. numbers cited) or 'NR'	open text

	Label	Description	Variable type
	Ethics/FPIC	*Did the study report ethical guidelines followed, such as Free Prior and informed Consent?* 0 = not reported 1 = some form of ethical guidelines/consent process reported	binary
	Cause no harm	*Did the study address intellectual property rights or risks for Indigenous communities?* 0 = not reported 1 = intellectual property rights/risks addressed	binary
	Outputs & Outcomes notes	Evidential notes describing outputs or outcomes (e.g., did project lead to any action/changes within or by the community such as capacity building, or produce something for the community such as curriculum materials, maps etc.) (w/pg. numbers cited) or 'NR'	open text
	Outputs & Outcomes	*Did the study report any outputs or outcomes for the Indigenous community?* 0 = not reported 1 = proposed 2 = actual, specific outputs/outcomes reported	ordinal
Additional notes	Conceptual status	Qualitative assessment whether study is 'on' 'for' 'with' or 'by' the Indigenous community. Can also be in combination (on/for; on/with etc.)	categorical
	Notes	Any additional notes relevant to this systematic literature review	open text
	Total # lit	Recording number of publications incl. in analysis for aggregated analyses (multiple publications describing the same field study)	numeric
	Discipline	Discipline(s) of author(s): AGRI = Agricultural sciences, ENGI = Engineering, ENVI = Environment/ecology, SOCI = Social sciences, INDI = Interdisciplinary (represents a group/single author from one interdisciplinary field), MDNS = Multidisciplinary (team of authors) natural sciences, MDSS = Multidisciplinary (team of authors) social sciences, MDMX = Multidisciplinary (team of authors) natural & social sciences (could also include interdisciplinary fields), TRDI = Transdisciplinary with Indigenous practitioners, TRDN = Transdisciplinary non-Indigenous practitioners	categorical

Appendix C. Literature Included in Data Analyses for Review (1ˢᵗ Manuscript)

Articles in **bold** represent high levels of responsible community engagement

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14. Boillat, S., & Berkes, F. (2013). Perception and Interpretation of Climate Change among Quechua Farmers of Bolivia: Indigenous Knowledge as a Resource for Adaptive Capacity. *Ecology and Society*, *18*(4). https://doi.org/10.5751/ES-05894-180421

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45. **Gadamus, L. (2013). Linkages between human health and ocean health: a participatory climate change vulnerability assessment for marine mammal harvesters.** *International Journal of Circumpolar Health*, *72*(1), 20715.

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