



PRACTICE REPORT

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Special Section:

Equity in Co-Production

Key Points:

- Arctic climate information can be made *useful, useable, and used* by equitably accounting for diverse community adaptation needs through knowledge co-production
- Institutional and community capacity, including means and ability, is necessary for equitable knowledge co-production to occur
- We present an approach for co-producing knowledge with Indigenous communities that can serve as an example for other scientific efforts

Supporting Information:

Supporting Information may be found in the online version of this article.

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The Arctic Rivers Project: Using an Equitable Co-Production Framework for Integrating Meaningful Community Engagement and Science to Understand Climate Impacts

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Abstract As the Arctic and its rivers continue to warm, a better understanding of the possible future impacts on people would benefit from close partnership with Indigenous communities and scientists from diverse fields of study. We present efforts by the Arctic Rivers Project to conduct community-engaged research to increase collective understanding of the historical and potential future impacts of climate change on rivers, fish, and Indigenous communities. Working in central to northern Alaska and the Yukon Territory in Canada, the project seeks to engage with Indigenous communities in ethical and equitable ways to produce science that is useful, useable, and used that may serve as an example for future research efforts. Toward this goal, we formed an Indigenous Advisory Council and together developed project-specific knowledge co-production protocols. This paper provides a novel model of design and implementation to co-produce knowledge with communities across a large study domain.

Plain Language Summary The Arctic and rivers located in the Arctic and subarctic are warming due to climate change. To understand the impacts this warming will have on people, partnering with impacted Indigenous communities in the region is important. It is also important that these partnerships are ethical and equitable and produce science that is actionable. This paper discusses efforts undertaken by a specific project, the Arctic Rivers Project, to conduct ethical and equitable research with Indigenous communities and generate science that is useful to those communities. Through this research our goal is to better understand potential future impacts of climate change on rivers, fish, and Indigenous communities in central northern Alaska and the Yukon Territory in Canada. To achieve this goal, the project formed an Indigenous Advisory Council (IAC) and together developed guidelines for how we can work collaboratively with Indigenous communities. Our specific process of forming an IAC and guidelines is, to our knowledge, a new way to approach collaborative research when working across a large geographic area. We present our process here so that it may provide an example for other research efforts.

1. Introduction

Understanding of climate change is generally either semantic (fact-based) or episodic (event-based) (Shepherd et al., 2018). Typically, semantic knowledge is held by scientists while the public is more likely to have episodic knowledge such as memory of an impactful storm or drought event. Indigenous Knowledge is unique because it encompasses *both* episodic knowledge (i.e., past stories and qualitative observations) and semantic knowledge (i.e., quantitative observations of climate change impacts; Herman-Mercer et al. (2019)). Following the Inuit Circumpolar Council (ICC), we define Indigenous Knowledge as,

...a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multigenerational observations, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future and is passed on from generation to generation.

(Inuit Circumpolar Council [ICC], 2015, p. 15)

Indigenous Knowledge holders unite semantic and episodic knowledge to outline narratives of change and demonstrate the bio-socio-cultural impacts of environmental change. Our work operates under the understanding that Indigenous communities hold powerful knowledge and ability to (a) meaningfully contribute to qualitative and quantitative narratives of climate induced environmental change; (b) understand narratives of change in the context of impacts to nature, livelihood, and culture; and (c) use narratives to guide adaptation strategies and preparedness. Collective understanding of climate change and its socioenvironmental impacts is greatly enhanced when Indigenous Knowledge and data collected using other scientific methods are woven together through the equitable inclusion of Indigenous communities in research using a knowledge co-production framework (Ambrose et al., 2014; Beaudreau & Levin, 2014; Cuerrier et al., 2015; Herman-Mercer et al., 2020).

There are few places in the world where climate change is more pronounced than the Arctic. Arctic Indigenous residents observe changes in the timing of seasons and the freeze-thaw cycles of rivers that create dangerous conditions for travel and affect access to subsistence resources (Brubaker et al., 2014, 2015; Herman-Mercer et al., 2019; Schaeffer et al., 2019). Climate-driven changes in the magnitude, timing, and temperature of Boreal and Arctic river discharge may impact fish species of great value to northern communities and commercial ventures (Hovelsrud et al., 2011; Moerlein & Carothers, 2012; Reist et al., 2006a, 2006b). These changes may also affect river passage of critical supplies and people by barge and boat (Cold et al., 2020; Scheepers et al., 2018). Climate model projections for this century from the latest Coupled Model Intercomparison Projects (CMIP 5 and 6) simulations paint a picture of continued rapid Arctic warming (Davy & Outten, 2020; Pörtner et al., 2019). Making climate services *useful*, *useable*, and *used* (Figus et al., 2022; Findlater et al., 2021; Vincent et al., 2018) can support community-level adaptation planning and resilience in the Arctic through the more equitable accounting of diverse social structures, needs, resources, and contexts (Vincent et al., 2020).

One avenue for developing *useful*, *useable*, and *used* science is by co-producing knowledge and co-designing research priorities and projects with communities that are directly impacted by these changes (Figus et al., 2022; Nature Editorial, 2018; Naugle et al., 2020; Vincent et al., 2018, 2020). Knowledge co-production can be thought of broadly as the collaborative process of bringing several sources and types of knowledge together to address a defined problem and to build an integrated understanding of that problem (Armitage et al., 2011).

1.1. The Arctic Rivers Project's Approach to Knowledge Co-Production

The Arctic Rivers Project (ARP; <https://www.colorado.edu/research/arctic-rivers>), is a 5-year project that began in January 2020 and is supported by the National Science Foundation's Navigating the New Arctic (NNA) Program (<https://www.nsf.gov/geo/opp/arctic/nna/index.jsp>). The objective of the ARP is to increase collective understanding of climate change impacts on rivers, fish, and communities and co-produce this understanding with Indigenous communities (communities in the study area) and Indigenous-led boundary spanning organizations (Yukon River Inter-Tribal Watershed Council [YRITWC] and Institute for Tribal Environmental Professionals [ITEP]), Federal agencies (U.S. Geological Survey [USGS]), scientific institutions (National Center for Atmospheric Research), and U.S. and Canadian based universities (University of Colorado, Boulder; University of Saskatchewan; and University of Waterloo). The ARP research team is large and multi-disciplinary including mid and early career scientists, post-doctoral fellows, and students classically trained in the fields of social science, hydrology, climate services, and biology. While ARP collaborators, YRITWC and ITEP, count Indigenous scholars and professionals among their staff, and those staff provide support to the project, no one on the research team identifies as Indigenous to North America. The ARP study area includes the Yukon River Basin and all areas north of this basin in Alaska (Figure 1). This area is home to more than 100 Alaska Native Tribes in Alaska and First Nations representing a diversity of languages, cultures, and histories.

The ARP has, as its foundations, the tradition of knowledge co-production that is an outgrowth of sustainability science. Sustainability science was introduced in the early 2000s as a new field in environmental science focused

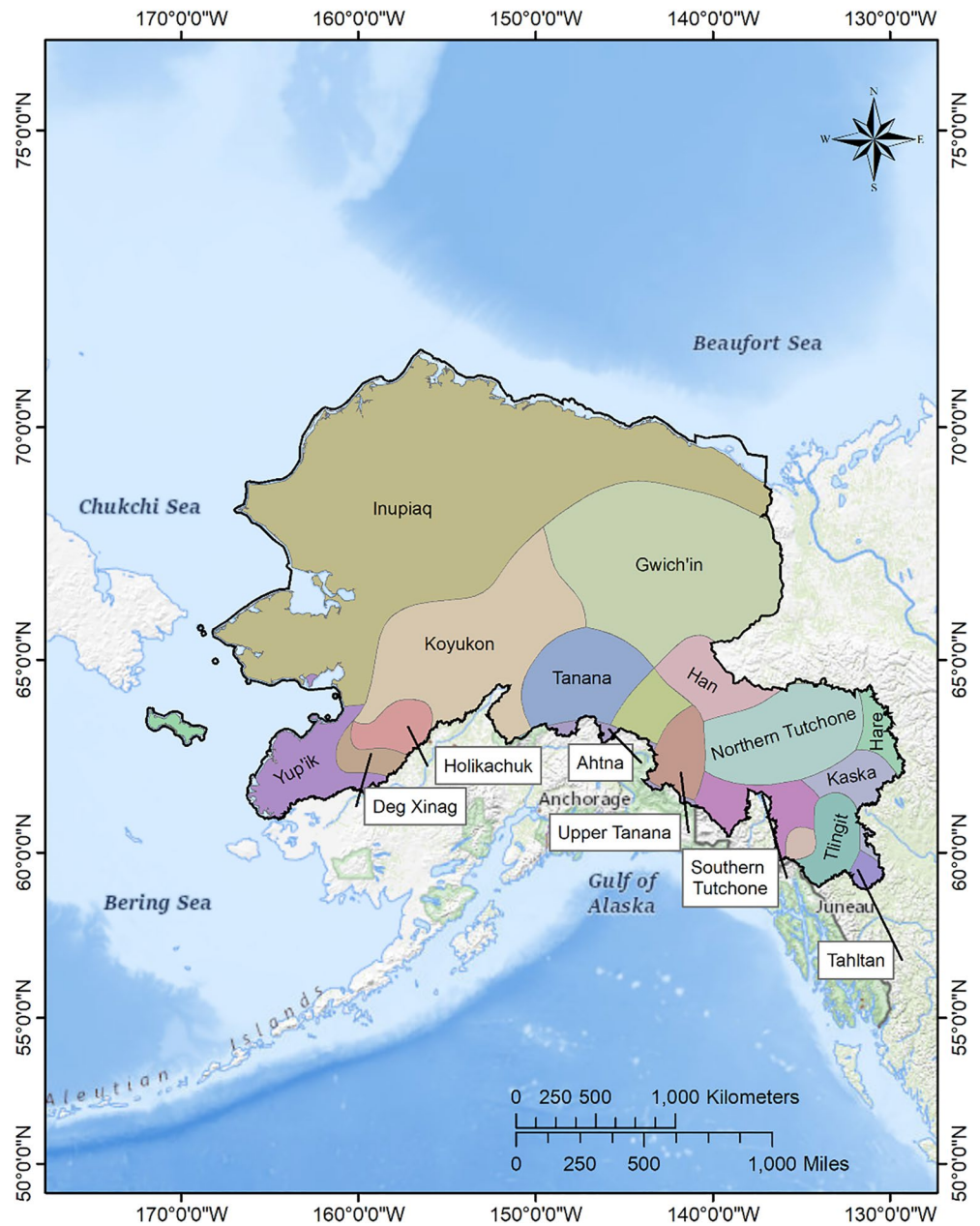


Figure 1. Study area of the Arctic Rivers Project in Alaska and Canada and the general distribution of the region's cultural and linguistic groups (Basemap from the U.S. Geological Survey National Map, 2021; Ethnolinguistic groups from Krauss et al. (2011)).

on understanding the fundamental character of interactions between nature and society to support sustainable development, defined as, “meeting fundamental human needs while preserving the life-support systems of planet Earth...” (Kates et al., 2000, p. 1). Within sustainability science, co-production has been defined as a process, “...in which scholars and stakeholders interact to define important questions, relevant evidence, and convincing forms of argument” (Kates et al., 2000, p. 2) The field of sustainability science has focused on knowledge co-production as a means of altering the practice of science through the inclusion of non-scientists (Wyborn et al., 2019).

Despite this recent adoption of knowledge co-production by the environmental sciences through the field of sustainability science, the concept of co-production first appeared in scientific scholarship in the 1970s

(Jasanoff, 1996, 2004; Ostrom et al., 1978) in the field of public administration. Public administration studies focus on understanding how citizens and public institutions (e.g., police departments, public schools) work together, amicably or not, to *co-produce* the ways in which these institutions operate in the public sphere (Brudney & England, 1983). The concept of knowledge co-production has also been prominent in the field of science and technology studies. Broadly defined, science and technology studies compose an interdisciplinary field that examines the creation, development, and consequences of science and technology in their historical, cultural, and social contexts (Hackett et al., 2007). The focus is on how knowledge is produced, validated, and used as an integral part of social dynamics, emerging from and, in turn, shaping social processes and arrangements (Wyborn et al., 2019).

Public administration literature provides substantial insights into the processes, means, and capacities required to bring multiple knowledges, perspectives, and actors into action by creating rules, incentives, and other social institutions (Voorberg et al., 2015; Wyborn et al., 2019). The field of sustainability science, however, has been accused of ignoring power dynamics embedded in knowledge co-production, focusing more on the outcomes of co-production (i.e., useable science) than the process of co-production (institutional transformation) (Löwbrand, 2011; Wyborn et al., 2019). Within the field of science and technology studies, co-production explains the idea that scientific knowledge is a product of socially distributed work and is therefore a theoretical lens to understand interactions between scientists and non-scientists as opposed to these interactions being an intentional outcome of the work as is the case in sustainability science and the field of public administration (Wyborn et al., 2019). These framings are not mutually exclusive (Wyborn et al., 2019) and each is useful when striving to successfully co-produce knowledge of climate impacts across multiple institutions, organizations, disciplines, and Indigenous communities as the ARP seeks to do.

Recent scholarship led by Indigenous scholars and organizations and coming primarily out of the Arctic have highlighted equity as the most important feature of successful knowledge co-production (Behe et al., 2018; Bering Sea Elders Group, 2019; Climate and Traditional Knowledges Workgroup, 2014; David-Chavez & Gavin, 2018; Inuit Circumpolar Council Alaska, 2020; Ikaarvik Youth, 2018; U.S. Interagency Arctic Research Policy Committee, 2018; Yua et al., 2022). These scholars also emphasize that what constitutes appropriate knowledge co-production is up to the discretion of the communities and researchers and must be continually negotiated throughout the co-production process (Yua et al., 2022). Communities and researchers must develop processes that are appropriate and be intentional and deliberate about what is collectively needed and desired (Yua et al., 2022) for successful co-production to occur. Knowledge co-production between western institutions and Indigenous communities is value laden (Daly & Dilling, 2019), often fraught with uneven power dynamics (Daly & Dilling, 2019; Vincent et al., 2020; Wyborn et al., 2019), and lacks universal metrics by which to evaluate success (Wall et al., 2017). In response to these factors and drawing on the work of Wyborn et al. (2019), the ARP seeks to draw together the foundations of knowledge co-production theories (sustainability science, public administration, and science and technology studies) to develop an approach for the ARP that is deliberate, reflexive, and co-designed and values both processes and outcomes (Miller & Wyborn, 2020). During the creation of the research proposal for the ARP, two strategies were used: (a) developing a broad research question with partners representing Indigenous communities in our study area, and (b) forming an Indigenous Advisory Council (IAC) as key project co-designers and essential piece of the project. The IAC was envisioned as a group that the ARP western research team would co-produce project components with, as well as develop the process of knowledge co-production that ARP would follow. The idea for the IAC is based on a long history of Indigenous advisory bodies in national and Indigenous governments and is a growing approach for including Indigenous perspectives and voices in research based in knowledge co-production (e.g., see Ikaagvik Sikukun at ikaagviksikukun.org).

This article presents details of developing a research proposal, forming an IAC, and the first years of working with the IAC in a large U.S. Federally funded, multiyear, multinational project focused on the impacts of climate change on rivers and communities. We will discuss the role of the IAC in the ARP in the context of attempting to co-produce knowledge across a large study domain including the development of a project specific definition of knowledge co-production and protocols to guide our efforts and allow us to measure success. We present reflections and guidance from the IAC and the research team about adding a formal, structured IAC to support a research project based in knowledge co-production.

2. Methods

2.1. Developing a Proposal

Many Indigenous community advocates (United Nations Framework Convention on Climate Change, 2013), Indigenous communities and organizations (ICC, 2022; Inuit Tapiriit Kanatami, 2018), and scholars of knowledge co-production (Behe et al., 2018; David-Chavez & Gavin, 2018; Yua et al., 2022) assert that knowledge co-production can only take place when the communities affected by the research process or research outcomes are involved in problem identification and the development of the research question. When working across a large study domain as the ARP is, it is challenging to work directly with each community to develop a research question for a grant proposal. To meet this challenge, the research team relied on an existing relationship between the USGS and the YRITWC. The YRITWC is an International Indigenous non-profit organization representing 73 Tribes and First Nations of the Yukon River Basin in Alaska and Canada and composed of several departments working toward the goal of protecting and preserving the Yukon River for present and future generations. The USGS, a science bureau within the Department of the Interior, has been collaborating with the YRITWC since 2006 on a community-based environmental monitoring program called the Indigenous Observation Network (Herman-Mercer et al., 2018; Schuster & Maracle, 2010; Schuster & Thomas, 2011). This partnership between the USGS, YRITWC, and Yukon River Basin communities facilitated co-produced projects in the past (Herman-Mercer & Schuster, 2014; Herman-Mercer et al., 2020) built on the same foundations of knowledge co-production as the ARP.

Directives for scientific projects undertaken by the YRITWC are formulated based on adopted resolutions by Alaska Tribal and First Nation representatives during YRITWC biennial summit meetings. At the eleventh biennial summit held in 2019 in Fairbanks, Alaska, the leadership passed a resolution directing the YRITWC science department to address concerns of Yukon River Basin communities related to local, regional, and watershed wide impacts of climate change on water quantity, quality, and salmon habitat. The YRITWC science staff collaborated with the rest of ARP research team to formulate research questions and develop a research proposal to implement these directives. The question the ARP seeks to address is,

How will societally important fish habitat and river-ice transportation corridors along Arctic rivers be impacted by climate change including permafrost degradation, transformed groundwater dynamics, shifts in streamflow, and altered river temperatures?

This question was made intentionally broad to allow for flexibility as communication and collaboration from the project increases beyond the YRITWC's stakeholders to the IAC and communities allowing for methods and specific questions to be more fully co-produced.

2.2. Forming an Indigenous Advisory Council

The IAC was formed through an open application process in the first year of the ARP. An application was developed by a subset of the larger project team which included Co-PI (social scientist), PI (hydrologist), and project collaborator (representing an Indigenous non-profit organization) for interested and eligible individuals to apply. Eligibility required an individual to be an enrolled member of Alaska Native Tribe or Yukon First Nation or work for organizations representing or serving Alaska Native Tribes or Yukon First Nations (e.g., a regional Indigenous organization). Applicants were asked to describe previous experience representing their community, experience, or interest in helping their community plan for change, and to describe why they were interested in being an IAC member.

Project outreach, including an introduction to the IAC concept, was conducted during a well-attended session at the Alaska Forum on the Environment conference held in Anchorage, Alaska, in February 2020. In addition to presentations and a question-and-answer session, a project fact sheet was distributed. The fact sheet described the objective of the IAC as helping the project team members make decisions about research design, analysis, and deliverables with a focus on ensuring that Indigenous Knowledge and Indigenous perspectives are included, valued, and protected in the ARP. Attendees were also invited to sign up for the ARP email listserv. Outreach to First Nations in Canada was facilitated by the YRITWC through their email listserv. To advertise the IAC application further, a webinar was held in May 2020 and was attended by more than 80 people representing a wide variety of organizations and institutions from both the United States and Canada. An invitation to apply was then

circulated to members of the ARP listserv as well as other Arctic and Indigenous focused listservs and information boards (e.g., Rising Voices, ITEP, Arctic Research Consortium of the United States, YRITWC).

Overall, 18 IAC applications were received. To select IAC members from the applicant pool, a review panel consisting of two Indigenous leaders and scholars of knowledge co-production from the region, the ARP Principal Investigator, and a Tribal liaison from a U.S. federal agency convened to review the applications and make recommendations to guide the selection of IAC members. Review panel members were recruited based on their experience in and understanding of knowledge co-production research in the Arctic or working with Indigenous communities based on their publication records, job title and affiliation, and engagement on the topic of knowledge co-production. The decision was made to skew the review panel toward members outside of the research team to ensure that the selection of Council members was not unduly influenced by the research team.

The review panel evaluated the applicants based on their responses to the application questions, with regard to the applicant's (a) experience living in a community relying on rivers for transportation, subsistence, or culture; (b) experience representing their community or group; (c) experience planning for change; (d) if serving on the IAC would be an opportunity to grow applicant or community capacity; (e) self-identification as Indigenous; and (f) representation of a community or organization within the ARP project domain. A scoring matrix was provided to each reviewer with a possible score of 0–10 for each of the six categories described above. The scoring matrix also provided space for the reviewer to indicate whether they recommended the applicant or not based on these criteria. The lowest scoring applicants and those not recommended by any of the reviewers were eliminated from further consideration, while the rest of the applicants were discussed further during a virtual meeting. Final decisions were made during this meeting. The review panel was encouraged to keep the ARP goal of forming an IAC that was diverse and representative in terms of gender, age, and geography in mind during their final selections. Ultimately, nine applicants were selected based on the recommendations of the review panel. To increase representation from Canada, which encompasses about one-quarter of the ARP study area, Canadian applicants were recruited to fill two additional council seats—a youth and an elder representative for a total of 11 members. Eleven individuals were expected to be a group small enough to be productive and able to reach decisions while also allowing for enough individuals that the cultural and geographic diversity of the study area would be represented. Additionally, although the IAC was invited to determine its own decision-making process during the first IAC meeting (see Section 3.1), an odd number of IAC members was chosen to avoid tie votes if a voting based decision-making process was chosen by the IAC.

3. Results: Guiding the Project

The IAC officially convened in October 2020, 10 months after the project began. All members of the IAC are Indigenous and include Elders, students, scholars, and leaders from across Alaska and the Yukon Territory in Canada. IAC members serve a voluntary 2-year term with the options to reapply when their term is up and to vacate their position at any time. IAC meetings take place virtually using an online video conferencing platform for 2 hr. Meetings were held on a roughly monthly basis at the beginning of the term and moved to bi-monthly with 14 meetings held as of this writing. Meetings are attended by a core subset of three members of the research team who serve as facilitators and liaisons between the research team and IAC. Other members of the research team attend as needed depending on the project elements under discussion. Agendas are circulated at least 2 days prior to the meeting with topics focusing on knowledge co-production, advice on science directions, and developing the Arctic Rivers Summit, thus far. Meeting notes are distributed a week later via email and stored in a shared cloud-based file directory. Council members are paid project consultants and are compensated \$135 USD for each meeting they attend.

3.1. Working Together: Developing a Charter

To guide the internal workings of the IAC, as well as their interactions with the research team, a charter was developed. An initial draft IAC charter was created by the IAC facilitators for consideration by the IAC. The draft charter was based on a review of charters and bylaws of other Indigenous advisory groups that advise U.S. federal agencies (e.g., U.S. Environmental Protection Agency [USEPA], Centers for Disease Control and Prevention, and the U.S. Department of Health and Human Services). The charter (summarized in Table 1 and provided in full as

Table 1
Indigenous Advisory Council Charter Sections and Descriptions of Each Section (Supporting Information S1)

Charter section	Purpose of section
Introduction	Defines project member roles
Purposes and tasks of the council	Defines the purpose of the Council and describes the various tasks of the council
Membership guidelines	Describes qualifications, number of members, terms of office, resignation guidelines, guidelines on filling vacancies, and removal of research or Council members from participation
Meetings and participation	Describes minimum participation requirements, provision of meeting summaries, and setting up a shared cloud-based file directory
Decision making	Describes the process by which the Council makes decisions with respect to project methods and inclusion of Indigenous Knowledge
Guidelines for engagement	Confirms the commitment of the project team to create a safe, respectful, and collaborative environment for all team members, and describes values and practices for team members to adhere to do so
Charter review and amendment	Describes the process for reviewing and amending the charter as needed
Certification of adoption	Records the date and Council vote by which the charter was adopted

a Supporting Information S1 to this manuscript) was developed and refined in deliberation with the IAC over the course of two IAC meetings after which it was unanimously adopted.

The charter defines the project team and its roles and responsibilities (research team, IAC facilitators, the IAC, and the Project team). The project team consists of the IAC plus the research team.

The purpose of the IAC and intended tasks are outlined in the charter and include providing guidance on: (a) the ethical and equitable co-production of knowledge, (b) protection of Indigenous Knowledge, (c) research design, analysis, and deliverables to ensure that research is relevant, understandable, and useable by the Indigenous communities it is intended to serve, (d) best communication pathways to distribute project information and products, (e) identifying proper channels of consent and authorization before conducting any field work in Indigenous communities and best methods for engaging communities, and (f) leading the design of an Arctic Rivers Summit bringing together Indigenous leaders, knowledge holders, and western trained scientists and land managers to discuss the current and potential future of Alaskan and Yukon rivers and how we can adapt.

In addition to the tasks described above, involvement in ARP decision-making processes is a key role of the IAC. Decision-making is composed of two-parts: (a) how the IAC makes decisions amongst itself (i.e., internally) and (b) how the research team shares decision-making with the IAC. Internal decisions are made by consensus, defined as a decision that is reached without dissent. Consensus decision-making was deemed by IAC members to be a hallmark of traditional Indigenous decision-making and therefore the process they chose during the development of the IAC charter. In the case that consensus cannot be reached, decisions are determined by a simple majority vote. The idea of having a Council chair was discussed; however, the IAC decided against this to ensure that all voices were considered equal and to avoid a hierarchical structure.

Decisions related to the project's research methods and analysis are made iteratively with the research team. The research team brings methodological questions to the IAC for input, advice, and to make decisions. Advice is given and recorded during each meeting when decisions are sought and, if possible, decisions are reached. Occasionally, votes and other input are recorded outside of the meeting using polls, emails, or phone calls. Questions or concerns on the part of the research team about IAC decisions are discussed, with the IAC and research team representatives proposing solutions, until a consensus on how to proceed is reached. When bringing questions to the IAC, care is taken to present research project decisions in a way that is both meaningful in terms of informing the project direction and deliverables and being understandable by IAC members. We strive to avoid scientific jargon at IAC meetings and bring higher-level decisions that are most relevant to the IAC as opposed to the many detailed decisions that are made throughout a project (e.g., which streams to place sensors in but not which sensor to purchase). The IAC also helps the research team interpret input from the broader Indigenous communities. For example, to inform project decisions related to climate and land surface model configurations, we surveyed Indigenous decision-makers across the study area using a survey that was co-developed with the

IAC (Herman-Mercer, 2021). Co-developing the survey with the IAC ensured that the survey questions were culturally appropriate. For example, with guidance from IAC members, questions were revised from asking about “the most important subsistence resources” to all subsistence resources, acknowledging that “all resources are equally important” (Buschman, V. Iñupiaq, Utqiagvik, Alaska. Lives in Nuuk, Greenland. Oral teaching. Personal Communication. 7 April 2021). The IAC helped us to interpret the results of this climate information survey and make final climate modeling decisions. The IAC has final say on all decisions made with respect to Indigenous Knowledge.

The charter outlines *Guidelines for Engagement* developed based on a review of values and practices embodied by other Indigenous working groups including the YRITWC (yritwc.org), Rising Voices Center for Indigenous and Earth Science (<https://risingvoices.ucar.edu/>), the USEPA Tribal Science Council (<https://www.epa.gov/healthresearch/tribal-science-council>), and the ITEP's Status of Tribes and Climate Change Steering Committee (<https://www7.nau.edu/itep/main/Home/>). These guidelines include being honest, inclusive, patient, solution-oriented, and good listeners; interacting with the spirit of being a good relative and ancestor; and being generous in spirit and heart with one another's experiences and points of view. Explicit guidelines keep us grounded in our engagement with one-another and remind us to be empathetic and caring in the important work we conduct together.

3.2. Working With Communities: Developing Knowledge Co-Production Protocols

The ARP project team (which includes the IAC) also developed and adopted knowledge co-production protocols to guide our future work with communities. The protocols outline how the research team co-produces knowledge and co-designs processes with the IAC with specific actions that can be taken at regional, local, or community scales. The key objective was to ensure that protocols for knowledge co-production were guided by Indigenous community representatives, not driven exclusively by the research team. After developing a charter, the subsequent three IAC meetings (7 December 2020; 4 January 2021, and 3 February 2021) were dedicated to the development of project-specific co-production of knowledge protocols.

Starting with a review of existing peer-reviewed literature and other published resources on the topic of knowledge co-production (Bering Sea Elders Group, 2019; Behe et al., 2018; Climate and Traditional Knowledges Workgroup, 2014; David-Chavez & Gavin, 2018; Inuit Circumpolar Council Alaska, 2020; Ikaarvik Youth, 2018; U.S. Interagency Arctic Research Policy Committee, 2018), particularly from Indigenous scholars and experts, a summary document for review and feedback and a companion presentation to facilitate discussion were developed. The presentation provided background on the qualities of co-production emphasized in best practices documents and provided a summarized list of practices that could be used by the project. After the presentation, an interactive activity using an online whiteboard took place where IAC members and IAC facilitators considered additional practices and offered ways in which the project could operationalize the practices through specific actions.

The IAC developed the following statement to be included in the ARP knowledge co-production protocols and serves as the ARP definition of knowledge co-production,

This project recognizes the rights of Indigenous communities to shape the research that occurs in our homelands, to assert our knowledge as a valid way of knowing. Co-production of knowledge involves the contribution and equal distribution of power between Indigenous stakeholders, researchers, and project members, in a manner that integrates the various knowledge systems present and informs the guidelines, goals, and expectations of the project.

Protocols developed with the IAC were divided into *qualities* and *practices*. The *qualities* of knowledge co-production transcend the project and emphasize the necessity of framing equity throughout all stages of the research process (Behe et al., 2018), whereas the *practices* of knowledge co-production may be subjective and are specific to our project. The qualities (Table 2) were based primarily on a review of the literature (Behe et al., 2018; Bering Sea Elders Group, 2019; Climate and Traditional Knowledges Workgroup, 2014; David-Chavez & Gavin, 2018; Inuit Circumpolar Council Alaska, 2020; Ikaarvik Youth, 2018; U.S. Interagency Arctic Research Policy Committee, 2018), whereas the development of practices (Figure 2) was driven by the IAC and research team using project-specific measures and needs. The resulting protocols define each practice and outline how the project team will implement that practice through specific actions. The protocol (Co-production protocols provided as Supporting Information S2) outlines how the ARP implements and embodies knowledge

Table 2
Qualities of Knowledge Co-Production From the Arctic Rivers Project Knowledge Co-Production Protocols

Quality	Meaning or significance
Trust	Trust Indigenous voices and Knowledge. Believe Indigenous experiences. Make the process iterative
Respect	In all actions and interactions, exercise thoughtfulness and recognize the value of all people, land, animals, cultures, and the environment
Warmth	Operate in a way that leads to friendship and mutual understanding. Humor is essential in creating a warm, relaxed environment where everyone is comfortable
Gratitude	Be thankful and express appreciation for the time, efforts, and energy of all participants
Holistic	Nothing can be singled out. The world operates as a whole with many different components and Indigenous Knowledge is guided by this holistic approach. Interdisciplinarity
Accountable	Be consistent and dependable
Open-minded	De-center western notions and thoughts and be willing to engage other perspectives. Actively listen
Adaptive	Be flexible, innovative, cooperative, and have patience
Honest and transparent	Actively communicate—use language and forms that are understandable. Never deceive or omit information
Humility	Be humble and work to equalize recognition and importance
Avoid being individualistic or hierarchical	Shift away from western ideas of individualism and acknowledge Indigenous values of community prioritization and unity. Reject social hierarchies and do not reproduce common power dynamics. Avoid paternalism and attitudes that depreciate Indigenous Knowledge and practices
Fair and just	Strive for equity and work to reproduce fairness and justice

co-production and creates metrics to hold the project team accountable and allow the team to continually reflect upon and reevaluate the mission, goals, and intentions of the project.

3.3. The Council's Perspective

After working together for just over a year, the IAC was asked (a) to provide their perspective on how they see the role of the IAC, (b) if being a member has been what they expected it to be, and (c) to provide suggestions for improvement as we move forward for inclusion in this paper.

Members of the IAC primarily reported that they viewed their role as ensuring that local and Indigenous Knowledge and perspectives are included in the ARP through their participation in the IAC meetings. As one IAC member put it,

I see the IAC as being involved as a partner to guide the science component of the Arctic Rivers Project. As an equal partner, we carry and share our Indigenous Knowledge about the land, associated teachings and practices related to rivers, fish and climate change that helps to validate the scientific findings. The end result is a balanced approach.

(Anonymous IAC member)

IAC members also saw their role as advising on direction, relevancy, and utility of the project, in addition to guiding community engagement efforts. Although members of the IAC saw one of their roles as helping the project connect and engage with communities, this engagement was characterized as one-way communication with IAC members only able to provide information out to the communities they represent as opposed to bringing information from the communities into the project. Members also highlighted the vast geography and cultural groups in the study domain, while stating that the IAC could not replace the work that a dedicated, paid, community liaison could do. Some IAC members were unsure of what to expect before joining the council, while others expected it to be like other committees, councils, and boards they have served on in the past. One member relayed that they were pleasantly surprised at the level of involvement the IAC had in shaping the ARP's research. Suggestions for improvement were directed primarily at the project overall as opposed to the functioning of the IAC. These improvements included more targeted outreach to communities in the study domain, and to review the project goal to ensure that we understand what it means to “weave knowledge together.”

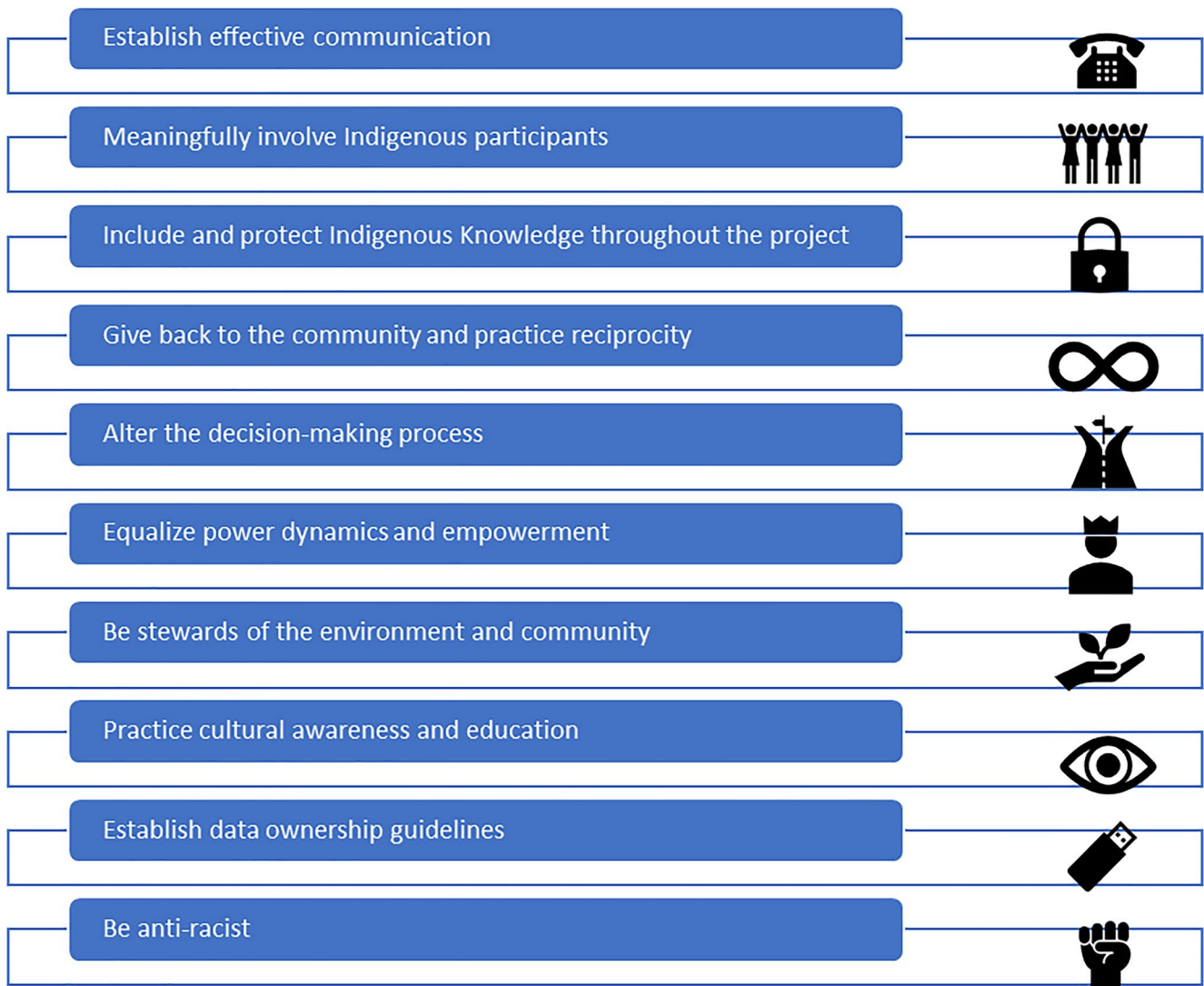


Figure 2. Practices of knowledge co-production from the Arctic Rivers Project knowledge co-production protocols.

4. Discussion: Guidelines Based on What We Have Learned So Far

Equity, typically conceived of as fairness or justice in the way people are treated (Merriam-Webster, 2022), is a key piece of knowledge co-production (Yua et al., 2022). To achieve equity, it ideally would be deliberately strived for in all aspects of a project and integrated into all project processes through the removal of barriers to participation (Yua et al., 2022). To identify and remove barriers, the non-Indigenous members of the research team ideally would practice active empathy throughout the research process, attempting to place themselves in the position of their Indigenous counterparts and identify ways in which the research process makes participation uneven, difficult, or impossible for Indigenous project members and take steps to rectify this. Identifying and removing barriers is one of the key reasons to plan the research process in direct consultation with Indigenous partners. Involving Indigenous partners at the proposal stage or earlier would allow sufficient time for the identification of barriers and the development of solutions that are agreed upon by all involved. For the ARP research team, the perspectives, feedback, and suggestions for improvement from the IAC are important to consider as we move into years 3–5 of the project to ensure that we are functioning as a cohesive team, removing barriers, and that the objectives of the IAC are attainable.

The ARP is in the early stages of practicing knowledge co-production that includes the formation of an advisory council and development of protocols and charters. Through this process the authors—representing

western-trained researchers, Indigenous leaders, and community members—have identified institutional and community capacity as the main resources needed for equitable knowledge co-production supporting the findings of Yua et al. (2022). Scientific organizations and communities must have the capacity to work together to co-produce science (Kūlana Noi'i Working Group, 2021). If institutional and community capacity to work together is uneven, it can be difficult to co-produce knowledge (Wyborn et al., 2019). One piece of capacity is the institutional support and funding to build and maintain relationships (Yua et al., 2022). To equitably develop relevant research questions with communities, relationships ideally would exist prior to developing a proposal for funding or beginning data collection (U.S. Interagency Arctic Research Policy Committee, 2018). Institutional and agency support (e.g., financial, temporal, and in performance evaluations) is important for the time to build relationships and processes for working together. Although the research team was able to collaborate with our partners at the YRITWC to develop the research proposal, forming the IAC and its charter outlining the cooperation were not complete until nearly a year into the project. Building relationships takes time and this time is often not adequately rewarded in the current scientific system, which still prioritizes publications and citation counts (Davies et al., 2021). There is evidence that this is changing with community relationships identified as a key piece of National Science Foundation - NNA Program proposals in the United States with a specific proposal type geared at funding the work to develop relationships (i.e., NNA Incubator Grants). Similarly, there is a broadening of evaluation criteria for researchers to include connections to communities in the United Kingdom (e.g., Research Excellence Framework) and Canada (Natural Sciences and Engineering Research Council) (Davies et al., 2021). For scientists to successfully build relationships, and for Indigenous communities to be equitable partners in the research process, creating institutional space that responds to the needs and priorities of Indigenous researchers, students, and communities is important (Latulippe & Klenk, 2020). This includes expanding the evaluation criteria, timelines, and resources associated with research grants to accommodate the governance structures of Indigenous communities (Latulippe & Klenk, 2020).

Capacity for western-trained researchers and Indigenous communities includes the staff to carry out the work, from scientists to administrative staff, and all other roles in between that are necessary to complete the project. In the experience of the authors, on both the research side and the community side, one individual often takes on the role of managing community-researcher relationships. These individuals are boundary spanners, working at the intersection of two different worlds (DeCrapeo et al., 2018; Goodrich et al., 2020): science and communities or science and decision-makers (Bednarek et al., 2018). Boundary spanners are very important in helping scientists and communities find one another, establish relationships, and work together. In the case of the ARP, organizations such as the YRITWC and ITEP spanned the divide between Indigenous and scientific communities. The goal of the IAC is to serve as a boundary organization as well with its members spanning the boundary between the ARP and the communities they represent.

Despite the interest in, and usefulness of, boundary spanning, particularly in the knowledge co-production domain, the role of boundary spanners is often not fully understood or legitimized (Bednarek et al., 2018; Goodrich et al., 2020). Furthermore, these individuals often fill the boundary role out of necessity and passion and as collateral duties, rather than as the primary duties of their position in federal and academic scientific positions. This limits their capacity to manage relationships, requests, and balance the work of the research project itself. In the experience of the authors, in the Indigenous Alaskan context within the environmental research field, boundary spanning on behalf of communities is often undertaken by individuals working in the environmental department of a Tribal government. These positions are typically funded by the USEPA through Indian General Assistance Program (IGAP) funds and thus are often referred to as IGAP coordinators, or IGAP assistants. In our experience, these individuals often are overburdened with requests from researchers to play the role of connecting researchers with communities. To equitably co-produce knowledge with communities, it is essential that both the community and the researchers have the capacity to contribute to relationship building and the research process (Kūlana Noi'i Working Group, 2021). As suggested by an IAC member, a community liaison employed by the project, or a funded Tribal research coordinator within the community, may increase capacity and facilitate knowledge co-production.

Capacity also encompasses means and ability; *means* refers to having the necessary resources and *ability* speaks to having the appropriate tools and proficiencies (Yua et al., 2022). For non-Indigenous western-trained scientists, *ability* includes having appropriate education and training regarding Indigenous Peoples, including Indigenous rights, cosmologies, histories, values, methodologies, and concerns (Yua et al., 2022). For Indigenous communities, which may include Indigenous scholars and western-trained Indigenous scientists, *ability* includes

the appropriate technology, tools, and training to fully participate in a research project (Inuit Circumpolar Council Alaska, 2022; Yua et al., 2022). Ability can also include the power to share decision-making authority as a key piece of knowledge co-production is sharing power and decision-making authority among researchers and communities. Research teams that work to understand the governance processes, including who can and cannot make decisions on behalf of the community, can avoid missteps in the decision-making process. This is also true for research institutions. When in the academy or the federal government, research institutions and funders often have their own scientific objectives and agendas that may constrain the ability of a research team to share decision-making. Research teams should be transparent with communities regarding these constraints and make clear what decisions the communities will have the ability to participate in and in what decisions they may not be involved or risk misunderstandings that can affect trust. It is important that decision-sharing frameworks such as those outlined here are established well ahead of a need to make decisions.

For Indigenous communities to have the capacity to co-produce with western-trained scientists, having the means to participate is essential—sharing the work means sharing the funding. We have found increasing the acceptance for compensation of non-traditional research partners (e.g., IAC members) for their expertise by funding organizations and federal agencies is needed. Also important is the existence of simpler institutional mechanisms through which the grantee organization or government agency can pay non-traditional research partners for their contributions. The established ways of recognizing community contributions to research as *human subjects research participants* or as *citizen scientists* fail to capture how communities participate in knowledge co-production. Indigenous Knowledge holders are not citizen scientists or human subjects as they themselves are experts in their own knowledge, understandings, and competencies (Wong et al., 2020) - they are research associates, collaborators, and partners and deserve the same measure of respect and level of compensation as western-trained researchers (U.S. Interagency Arctic Research Policy Committee, 2018; Kūlana Noi'i Working Group, 2021).

5. Conclusion

Co-producing knowledge with Indigenous communities provides a pathway to transition science from “demand-relevant” research toward “demand-driven” research that provides *useful*, *useable*, and *used* data (Findlater et al., 2021). Demand-driven research undertaken using knowledge co-production can help effectively address the problem of climate change in an equitable way that not only weaves together Indigenous Knowledge and other scientific approaches, but also weaves Indigenous morals, beliefs, and governance into the research process—acknowledging that all of our interactions produce a new convergent knowledge, not just the outcomes of our research or equal to the sum of its parts (Miller & Wyborn, 2020). Increasing capacity through relationships, training, and resources, as well as taking time to build relationships and identify research questions with communities, can increase productivity (defined as useful, useable, and used research results) while increasing equity.

The ARP strives to co-produce knowledge with Indigenous communities in our study region as informed by our work with an IAC. Although not intended to be an exhaustive list of steps that western-trained researchers could take to co-produce knowledge with Indigenous communities, we have described our process for forming the IAC and knowledge co-production protocols and provided guidance for others seeking to co-produce knowledge with Indigenous communities based on what we have learned along the way.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

No data was collected or created as part of this work. All materials used in the development of this paper (Indigenous Advisory Council Charter and Knowledge Co-Production Protocols) are available as Supporting Information.

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