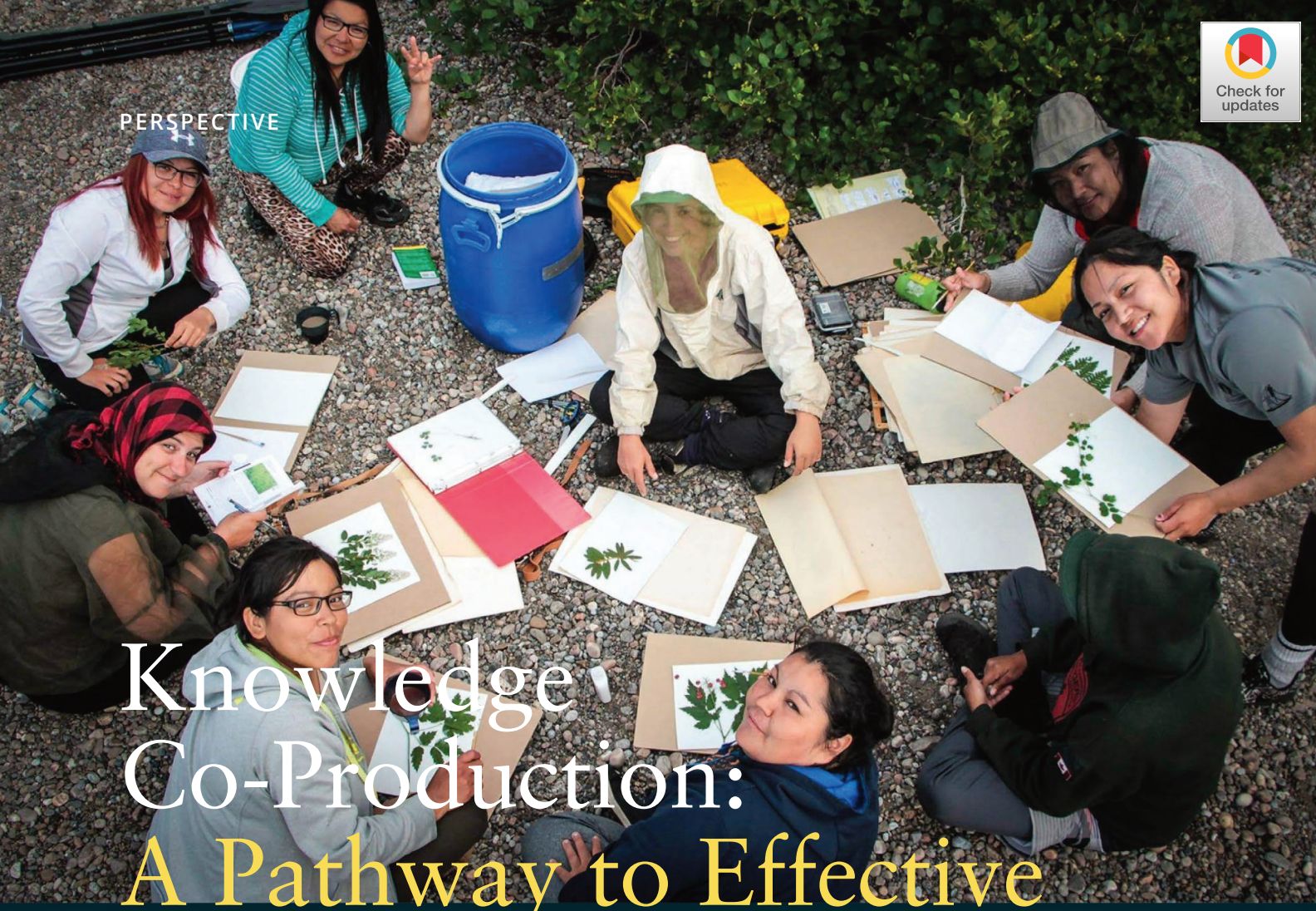

Knowledge Co-Production: A Pathway to Effective Fisheries Management, Conservation, and Governance

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Innu women building herbaria in the field with ecosystem services scientist Dalal Hanna. Photo credit: Lalo Ruiz

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Although it is assumed that the outcomes from scientific research inform management and policy, the so-called knowledge–action gap (i.e., the disconnect between scientific knowledge and its application) is a recognition that there are many reasons why new knowledge is not always embraced by knowledge users. The concept of knowledge co-production has gained popularity within the environmental and conservation research communities as a mechanism of bridging the gap between knowledge and action, but has yet to be fully embraced in fisheries research. Here we describe what co-production is, outline its benefits (relative to other approaches to research) and challenges, and provide practical guidance on how to embrace and enact knowledge co-production within fisheries research. Because co-production is an iterative and context-dependent process, there is no single way to do it, but there are best practices that can facilitate the generation of actionable research through respectful and inclusive partnerships. We present several brief case studies where we describe examples of where co-production has worked in practice and the benefits it has accrued. As more members of the fisheries science and management community effectively engage in co-production, it will be important to reflect on the processes and share lessons with others. We submit that co-production has manifold benefits for applied science and should lead to meaningful improvements in fisheries management, conservation, and governance.

CONTEXT

For many decades, knowledge generators (e.g., researchers, scientists) operated independently from and of knowledge users (sometimes referred to as end users; e.g., managers, policymakers, user groups, industry). It was assumed that the results of scientific studies would eventually find their way into management and policy (Atkinson-Grosjean 2006). Even when managers, policymakers, or user groups were involved in identifying research needs or funding research, the researchers would operate independently during the research process and perhaps deliver findings at the end of a study. This has contributed to what has been termed the knowledge–action gap (also known as the theory–practice gap, the knowing–doing gap, or the research–implementation gap, among others) whereby there is knowledge that could be used to inform various management actions or decisions, but it is largely ignored or dismissed by knowledge users (Cook et al. 2013; Cvitanovic et al. 2015). There are many reasons for the knowledge–action gap, including communication barriers, distrust of knowledge generators, differences in cultural context between knowledge generators and users, and a failure to bridge multiple knowledge systems (Cvitanovic et al. 2016; Young et al. 2016b). Much effort has been focused on trying to bridge or close the gap informed by social science research (summarized in Nguyen et al. 2017). There have been some promising developments on improving scientific processes to generate knowledge that can be readily applied with the most notable one being the concept of knowledge co-production (Beier et al. 2017).

Here we outline the concept of knowledge co-production with a focus on how it can enhance and contribute to effective fisheries management, conservation, and governance. This topic is particularly salient to fish and fisheries given that they support livelihoods and economies (at multiple scales), have immense social and cultural value, and contribute to nutritional security. This creates a unique obligation for researchers to respectfully engage with a diverse variety of very entrenched, passionate, and at times vulnerable user groups, rights holders, and knowledge holders. We outline the benefits and challenges of co-production, provide practical guidance on how to embrace co-production in fisheries research and management, and provide several case studies that exemplify co-production done well in a fisheries context. There has been much written on co-production over the past decade, but very little that is specific to applied fisheries research. The authors (Indigenous and non-Indigenous) include scholars who study co-production as a process from an environmental social science perspective, as well as fisheries researchers who apply the co-production model to address complex and pressing research needs in the fisheries realm. Collectively, the author team has experience with co-production in partnership with governments, Indigenous communities, industry, community/special interest groups, and the environmental NGO sector.

GLOSSARY OF KEY TERMS

Knowledge co-production in the most simple terms means that research is conducted collaboratively, inclusively, and in a respectful and engaged manner—from the identification of research needs to study design, data collection, interpretation, and even application—with the idea of creating actionable science and benefits to the partners involved. It can be formally stated as the contribution of multiple knowledge sources and perspectives from different stakeholders with the goal of co-creating knowledge and information to inform fisheries management and conservation.

Knowledge co-evolution builds on the knowledge co-production literature by adding more formalized objectives of capacity building, empowerment, and self-determination as strategic endpoints of the research process. Knowledge co-evolution allows both knowledge systems to advance and evolve on their own and generates new knowledge for the benefit of Indigenous stakeholders by generating data that is meaningful for decision making and participation of Indigenous peoples in the governance of their lives and the ecosystems they rely on (Chapman and Schott 2020).

Knowledge co-assessment is an approach that may preface co-production recognizing that not all projects require generation of new knowledge. Sutherland et al. (2017) argue that co-production is expensive, time-consuming, and not always needed. After knowledge is collated (typically by experts in evidence synthesis) the knowledge is co-assessed by community members and stakeholders to assess its validity and explore how it relates to the local context. Only if there is insufficient knowledge does it make sense to engage in co-production.

Knowledge broker is a term used to describe persons that are considered intermediaries between knowledge generators (or holders) and knowledge users. They facilitate two-way or multi-way exchange of knowledge (see https://bit.ly/33nQlWY; Meyer 2010).

Self-determination is the right of Indigenous peoples to freely determine their political status and pursue economic, social, and cultural development (definition from the UN Human Rights Office).

WHAT IS KNOWLEDGE CO-PRODUCTION?

Drawing upon key literature (e.g., Lemos and Morehouse 2005; Akpo et al. 2015; Polk 2015; Mach et al. 2020), we define knowledge co-production as "the contribution of multiple knowledge sources, ways of knowing, and perspectives from different user groups with the goal of co-creating knowledge and information to inform fisheries management and

conservation" (See Glossary). This definition is not unlike that of Wyborn et al. (2019), who eloquently define co-production as "processes that iteratively unite ways of knowing and acting—including ideas, norms, practices, and discourses—leading to mutual reinforcement and reciprocal transformation of societal outcomes." No matter which formal definition is adopted, in more simplistic terms, knowledge co-production means that research is conducted collaboratively, inclusively, and in a respectful and engaged manner—from the identification of research needs to study design, data collection, interpretation, and application—with the idea of creating actionable science (i.e., knowledge needed to enable change and that inherently links theory and practice) and benefits to the partners involved (See Figure 1 for conceptual overview of process). It is recognized that the details of co-production arrangements can vary based on the origin of the research question, the type and depth of relationship, the resources and capacity for co-production, and the level of interaction and engagement over time (Mach et al. 2020). Co-production has recently been applied to climate science (Lemos and Morehouse 2005; David-Chavez and Gavin 2018), urban forestry (Campbell et al. 2016), sustainability science (Wyborn et al. 2019), and Arctic science (Armitage et al. 2011), but has a history extending back to the 1970s (reviewed in Christenson 2013; Goodwin 2019).

BENEFITS OF CO-PRODUCTION

There are many purported benefits of adopting a co-production model relative to conventional models whereby researchers operate largely independent of knowledge users. Notably, co-production promises to increase the relevance and applicability of science for social benefit (Lemos and Morehouse 2005; Reed et al. 2014; Meadow et al. 2015; Wall et al. 2017; Lemos et al. 2018). When applied science is conducted with the premise of informing management and conservation, yet fails to do so, society experiences a loss; resources devoted to applied research that does not generate actionable knowledge is squandering resources from management-relevant work. Co-production helps mitigate the risk of loss, because it disrupts the unidirectional, linear, and isolated research practices that reinforce and broaden the knowledge–action gap (Wamsler 2017). Empirical social science research has revealed clearly that co-production is perhaps the single most effective action that researchers can take to help bridge the knowledge–action divide (Fazey et al. 2014; Cvitanovic et al. 2015, 2016). In a recent quantitative study, Nguyen et al. (2019a) revealed that altruistic, collaborative, and pro-engagement behaviors and activities positively influenced the uptake of fisheries research findings by fisheries managers. This is but one example of the ways in which co-production can transform fisheries research and management.

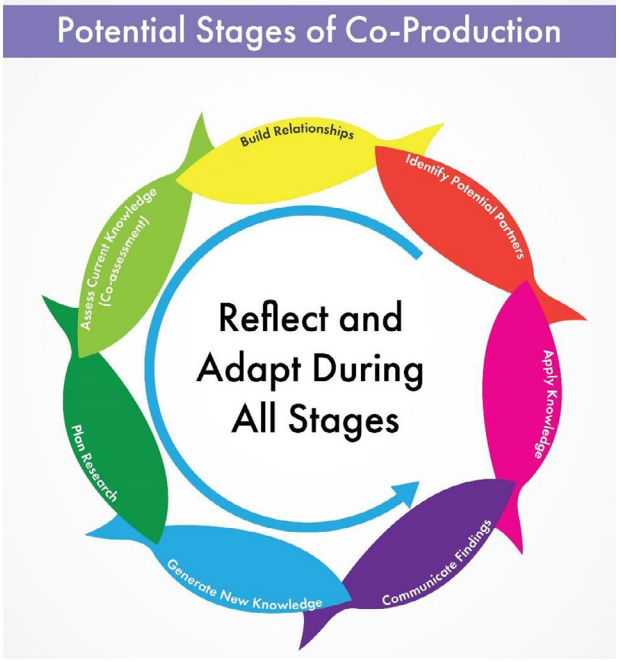

Figure 1. Potential stages of co-production emphasizing that the process is one that ideally operates in a cyclical manner and that involved continual reflection and adaptation.

An important aspect of co-production activities is that they have the potential to increase interpersonal trust, which is foundational to knowledge users applying new knowledge sources (Nguyen et al. 2019b). Young et al. (2016b) suggest that co-production is a way of both ensuring relevance and providing an "organizational stamp of approval" on findings, which enhances potential for new knowledge to be used in decision making. Working alongside knowledge users throughout the research process ensures project objectives remain relevant, while promoting credibility, saliency, and legitimacy (Cash et al. 2003). Co-production can also be used to enhance the ways in which science is viewed and valued by different actors, enabling science-based knowledge to be incorporated into governance of natural resources (Wyborn 2015). At the same time, scientists benefit from broadened perspectives and enriched understanding of the potential impacts of their research on their collaborators and end-users (Chapman and Schott 2020). By interacting with a wider group of people from diverse backgrounds, scientists are often forced to confront their own knowledge biases (including confirmation bias), and as a result the science itself can be more creative and objective when founded in a co-production framework.

CHALLENGES OF CO-PRODUCTION

Although there are many benefits to co-production of knowledge, there are also some inherent challenges. For example, co-production is sometimes regarded as a method that fails to be sufficiently protective of scientific inquiry and processes that impede the independence of knowledge generators (Young et al. 2016a, 2016b). This can be mitigated to some extent by ensuring that multiple end-users are engaged as partners. Nonetheless, there can be a loss of creative control and intellectual ownership on the part of the researchers in that co-production done right should reflect a democratic process. Effective co-production requires specific skills and competencies that take time to develop. Unfortunately there are relatively few formal opportunities for training on co-production, leaving one to learn through trial and error (or using resources such as this).

Another challenge is that knowledge co-production can be costly in both time and financial resources, as it requires significant long-term investments in face-to-face time and knowledge exchange. This can be overcome by budgeting appropriately for such interactions in grant applications and recognizing that relationship building takes time, particularly at the front end (Brinkerhoff 2002; Austin 2004). Sutherland et al. (2017) have argued that given the costs of co-production,

a first step should be co-assessment (See Glossary), where knowledge is collated and then co-assessed to validate knowledge and its context to a given issue. Only if knowledge is deficient or lacks relevance would it be necessary to engage in full co-production (Sutherland et al. 2017), although this can vary with context (e.g., when partnering with Indigenous rights holders where co-production is regarded as the appropriate way to conduct research in Indigenous spaces).

Funding cycles for grants are sometimes not well calibrated to the time it takes to develop relationships and engage in co-production. The deadline-driven culture of science (e.g., in academic or government environments) and funders may not align well with the time constraints, capacity, or interests of co-producers, especially in Indigenous communities. Moreover, incentive structures (e.g., tenure and promotion) for knowledge generators are often not optimized for researchers who wish to meaningfully engage in co-production.

Practically, there can also be challenges in ensuring that power is shared in a research project so that all participants have a voice and are respected and engaged (Hickey et al. 2018). This can certainly be done, but takes care and effort (Chapman and Schott 2020). Co-production can also be unexpectedly costly to knowledge users or stakeholders given that they may feel pressure from their respective communities to represent their groups interests in a specific way (Young et al. 2020). In addition, we know that women are under-represented in fisheries research (Moffitt 2012; Arismendi and Penaluna 2016), and this can contribute to power imbalances between researchers and knowledge holders or users.

Although co-production can increase the likelihood that new knowledge is used by managers and decision makers, other factors come into play. For example, the sociopolitical, cultural, and economic impact of decisions will dictate the quantity and quality of evidence needed to enable change (Nguyen et al. 2019a,b). Those issues, however, are outside the control of the knowledge generator. Even when co-production is done "right" it will not always bridge the knowledge–action gap in the way that one might hope or expect (Mach et al. 2020). Decision making is a complex and multifaceted human process such that there is no single formula for success.

INDIGENOUS AND LOCAL KNOWLEDGE MEETS CO-PRODUCTION

Many areas of conservation and management interest in fisheries can be found within Indigenous territories. After enduring exploitive and paternalistic research practices involving Indigenous communities (Smith 2013), Indigenous sovereignty in research and management is becoming solidified, making respectful and reciprocal co-production in research a moral and ethical obligation (Wilson 2008; Reid et al., in press). Researchers have great opportunity to improve on conventional research practices by applying co-production given that it acknowledges that (1) any undertaken research must be done with Indigenous consent and partnership (ideally undertaken in response to a community-identified need and desire and always with free, prior, and informed consent; Artelle et al. 2019; also see the UN Declaration on the Rights of Indigenous Peoples; available: https://bit.ly/3fqyXsn), and (2) Indigenous communities are not considered stakeholders, but self-determining nations with their own research leadership (Latulippe and Klenk 2020). Engaging diverse knowledge users and knowledge holders in research can empower individuals and groups that have been traditionally marginalized (Berkes 2009), help address long-standing conflict (Young et al. 2016a), and create more inclusive processes that ensure better collective outcomes (Chapman and Schott 2020). Knowledge co-production involving Indigenous communities should be centered on the defining objective of enhancing local capacity for self-determination in research and resource management (Chapman and Schott 2020). Given that all participants are simultaneously exchanging and producing new knowledge, the term "knowledge co-evolution" (see Glossary) has been used in recognition of the iterative nature of interactions among different knowledge holders, recognizing the enrichment of knowledge for all parties involved (Chapman and Schott 2020). Additionally, Indigenous knowledge (which is not a single unified perspective, but rather a plurality of perspectives reflecting the diversity of Indigenous peoples and communities) are inseparable from socio-cultural, political, and legal values that give rise to knowledge systems, and therefore engaging with it requires a shift away from knowledge extraction to collaboration, partnership, as well as Indigenous research leadership (Latulippe and Klenk 2020) and the use of Indigenous research methodologies (Kovach 2010). In some regions formal co-production processes are required to obtain social and legal licenses to operate (see Arctic case study for example).

CASE STUDIES

We present several case studies that emphasize the different ways in which co-authors of this paper have engaged in co-production. Each case study followed a different path and involved different user groups and partners ranging from Indigenous communities to recreational anglers to policymakers. We share these case studies to highlight where co-production has worked in practice and the benefits it has accrued.

Emerging Fisheries in the Arctic

The Government of Nunavut (GN) has recently enhanced focus on inshore fisheries development (GN 2016). The community of Gjoa Haven, Nunavut, having experienced several failed commercial fisheries in the past, wanted to better characterize potential fisheries sustainability from ecological, economical, and cultural perspectives before additional development. The local Hunters and Trappers Association reached out to researchers known in the community to initiate collaboration, culminating in successful application to the Genome Canada Large Scale Applied Research Project competition for the Towards a Sustainable Fishery for Nunavummiut (TSFN) project. The research team included the Association's board of directors, academics, students, local knowledge holders, technicians, and project facilitators, and federal and territorial government representatives. The project was designed collaboratively from the ground up using a "knowledge co-evolution" (an advancement of co-production) framework (Chapman and Schott 2020), and included steering committees that ensured community objectives remained central to all research activities, questions of intellectual property and data ownership were addressed, and interpretation of results aligned with local knowledge (for detailed descriptions see Chapman and Schott 2020; Schott et al. 2020). The final objectives were to better understand population structures of Arctic Char *Salvelinus alpinus* (*Iqaluk*) and whitefish (Coregoninae; *Kavihilik*) species to assess and balance subsistence and commercial harvesting opportunities. During the project, it became clear that knowledge co-production was not sufficient

Figure 2. Researchers checking in with Gjoa Haven Indigenous hunter and fisher, Abel Tavalok (left), on his test fishery sites, illustrating part of their ongoing knowledge co-evolution practices. Photo Credit: TSFN Project.

to meaningfully connect and strengthen distinct knowledge systems. Community partners were purposefully involved in stages relevant for fisheries monitoring and research (e.g. data recording and sample collection; Figure 2). The research team facilitated the opening of new test fisheries, working with GN and Fisheries and Oceans Canada to guide local fishers through the process. This was not envisioned as a part of the research, however, the research team was positioned to bridge gaps between managers and community members and, in doing so, enhanced self-determination, while strengthening relationships among researchers and local collaborators. As a result of this effort, local test fisheries are collecting samples and data and providing Arctic Char to a food program for pregnant and nursing mothers in the community. Throughout the project, workshops were held twice a year to present and interpret preliminary data with collaborators. From this, the community's objectives expanded to include concerns tangential to the TSFN project objectives, including questions on local food security and economic barriers to harvest. Inherent flexibility in the research plan, continuous collective reassessment of knowledge gaps, and trust were central pillars of the TSFN project and led to additional funding and collaborations that will continue for many years to come.

Muskellunge Catch-and-Release Research

Angling for Muskellunge *Esox masquinongy* is a sport dominated by specialized anglers who practice catch-and-release (C&R). The Muskellunge angling community has worked diligently to develop a set of best handling practices, but for years C&R mortality cited by management agencies was often based on data from Beggs et al. (1980) that indicated a 30% mortality rate. The Muskellunge angling community vehemently opposed the use of this figure, citing significant advancements in handling practices (e.g., specialized nets, use of 80–130 lb test braided fishing line, Muskellunge-specific rods and reels). In 2009, a university-based research team set out to test the veracity of modern-day Muskellunge C&R practices through a collaborative effort with Muskies Canada, Inc. (MCI; Landsman et al. 2011). The process began by distributing an informal survey to local Muskellunge anglers to assess current handling practices and incorporate their feedback into a study design. In addition, the lead researcher on the study presented an overview of the project to the local Ottawa MCI chapter, which also included a call for project participation by chapter members. There was significant support from this group of anglers and many volunteered their time (Figure 3). One of the veteran anglers from the Ottawa MCI chapter would become the primary field assistant to the lead researcher, whose expertise and assistance was invaluable during the study and earned him co-authorship. Each volunteer provided local expertise on the best locations to capture fish, knowledge that was required to make the project a success. Knowledge co-production created an inclusive environment for local anglers to become involved in data collection and enriched their learning experience. Researchers gave frequent presentations to MCI chapters across Ontario as well as other community angling groups to present preliminary data. The resulting collaboration ultimately produced two peer-reviewed publications (Landsman et al. 2011; Landsman et al. 2015) and provided a much-needed update to Muskellunge C&R science that better reflected modern-day handling procedures. The research confirmed the veracity of specialized muskellunge angler perspectives and emphasized the importance of scientists and anglers working together. Perhaps most importantly, the collaboration has formed a strong connection between the university research team and the local Muskellunge angling community, a relationship that continues to produce fruitful collaborations. Engaging early and often, facilitating opportunities for involvement in research, remaining accessible and approachable throughout the research process, and deferring to local expertise as a way to build trust were critical elements to the success of this collaborative project. In recognition of and appreciation for the exceptional engagement of MCI, the academic partners nominated MCI for a Fisheries Conservation Award from the American Fisheries Society (which they were awarded).

Applied Pacific Salmon Research

For the past 20 + years some of our team members have been involved in applied research in British Columbia focused on the migration biology of Pacific salmon *Oncorhynchus* spp. The research team included students and professors from

Figure 3. Volunteer anglers like Muskies Canada, Inc. member Ed Sanford were integrated into the research process by enlisting their help with capturing and tagging fish as well as recording data. Photo Credit: Sean Landsman.

several academic institutions, Indigenous communities, government (including science and management/policy staff), NGOs, and industry (e.g., commercial fishers) with diverse expertise. The team has worked collaboratively to understand how to reduce bycatch/release mortality of non-target species and to understand the effects of climate change on salmon migration behaviour (reviewed in Cooke et al. 2012; Hinch et al. 2012; Patterson et al. 2016). The level of engagement extended beyond individual projects to a cohesive research program with continual interaction among all parties. In that sense, the team has fully embraced co-production where there was constant feedback and interaction regarding identifying key research needs, developing research projects, exchanging knowledge, and thinking about how findings are applied. There is an immense amount of trust and mutual respect that has taken time to foster. One of the presumed enablers in this scenario is the conflict (e.g., among different fishing sectors and government) that has existed in the system (Nguyen et al. 2016)—to the point where Pacific salmon management represents a "wicked problem" (Young et al. 2016a). As academics, the goal of the team was to generate science to help support decision making and to do that well, we needed to work closely with all parties. This process developed organically given the need to engage with diverse users. Central to this were annual workshops (Figure 4) where research questions were jointly formulated, leading to collaborative field work. In some cases the knowledge users have contributed resources (cash or in kind) to projects. More recently, the fisheries scientists have worked with social scientists to study the processes that we use and the perspectives of knowledge users, which has further refined how, in practice, we implement co-production and generated lessons that we have shared with others (see Young et al. 2016b). If co-production had not been embraced, funding would have been much more difficult to obtain, trainees would not have learned about how to conduct engaged science, and the diverse resource users would not have had the opportunity to become fully engaged in research to the point where the science is actionable (see Patterson et al. 2016 for examples of specific management benefits).

Binational Ecological Risk Assessments of Asian Carps

The Asian carp invasion currently plaguing the Mississippi Basin continues to threaten the Laurentian Great Lakes through artificial connections between Lake Michigan and the waterways where invasive carp populations are established (Mandrak and Cudmore 2004). Early risk assessments indicated that the species would have substantial negative impacts on aquatic ecosystems in Canada (Mandrak and Cudmore 2004) and the United States (Nico et al. 2005; Kolar et al. 2007), however more comprehensive assessments were necessary to inform binational management actions specific to the Great Lakes. The Great Lakes straddle the international border between the United States and Canada, presenting unique resource management challenges involving federal, provincial, and state agencies. The federal governments decided to conduct a binational risk assessment, initially for the bigheaded carps (Silver Carp *Hypopthalmichthys molitrix* and Bighead Carp *H. nobilis*), completed by a binational team of 5 experts (Cudmore et al. 2012) and peer reviewed by 25 experts (DFO 2012). Despite being rigorously peer reviewed, the ecological risk assessment was deemed inadequate by certain end-users as it did not address the needs of managers or agencies conducting socio-economic risk assessments. In retrospect, this was the result of lack of co-production. In response, subsequent binational risk assessment for Grass Carp *Ctenopharyngodon idella* (Cudmore et al. 2017; DFO 2017) adopted a co-production approach. Researchers, resource managers, and Indigenous leaders were invited to a 2-day workshop to scope the risk assessment during the problem formulation stage. On the first day, participants outlined the questions that they and their stakeholders and community members wanted answered from the risk assessments. On the second day, researchers discussed the analyses required to answer the questions, provided information for the socio-economic analysis, and conducted the risk assessment. Workshop attendees re-convened 6 months later to ensure that their needs were being met, and a peer-review meeting was held 6 months after. At the meeting, the risk assessment was peer reviewed, and the results were mapped against the managers' questions, which was included in the proceedings document (DFO 2017). Following the meeting, original workshop participants were re-convened to explain the outcome of the risk assessment and how it addressed their questions and information needs. The results of the risk assessment that adopted a co-production approach was deemed superior (by all parties) to conventional methods, and has been subsequently used to guide and coordinate management responses to the threat of Grass Carp to the Great Lakes basin.

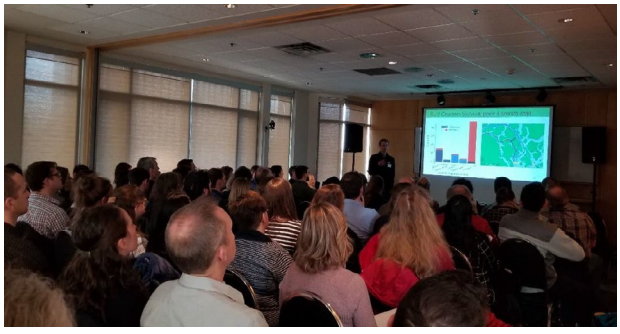

Figure 4. Annual workshops on Pacific salmon migration biology are held at the University of British Columbia, where researchers share findings with diverse knowledge holders and users while brainstorming future research needs and developing new projects. Photo Credit: Steven Cooke.

Guidance for Engaging in Co-Production of Knowledge

There is no single recipe for effective and successful co-production (as evident with case studies presented above) but there is some guidance that should be considered (for more detail see Beier et al. 2017; Reed and Abernathy 2018; Hickey et al. 2018; Mach et al. 2020; and specifically for working in Indigenous knowledge contexts, Latulippe and Klenk 2020 is a strongly recommended read). We also encourage readers to consult some of the materials developed for co-production in healthcare research and, in fact, suggest that the guiding principles for co-production shared by the UK National Institute for Health Research (2018) are particularly salient (i.e., sharing of power; including all perspectives and skills; respecting and valuing the knowledge of all participants; reciprocity; building and maintaining relationships; see Figure 5). We also want to draw attention to a toolkit developed by Westwood et al. (2020) for application to bird conservation and management where specific worksheets were provided to aid in facilitating knowledge exchange by building respectful and sincere relationships. Based on individual but shared experiences, the

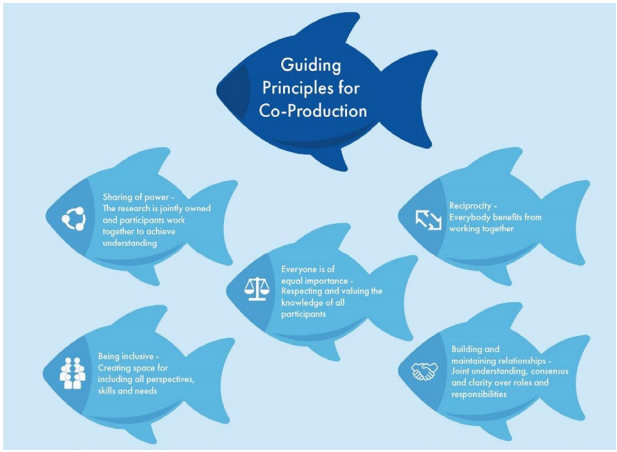

Figure 5. Guiding principles for co-production. Adapted from principles developed for the health care realm (UK National Institute of Health Research 2018).

author team has compiled a list of best practices that have led to more effective co-production and improved collective outcomes (each anchored with at least one key reference and relevant resources; See Table 1).

CONCLUSION

Knowledge co-production is a reasonably novel and transformative research framework for any researcher who strives to have their findings embraced by knowledge users (Renn 2020). Although there have been many papers on the topic of co-production, there are still relatively few examples of co-production in the context of fisheries management and conservation that have been shared and celebrated. Recent articles in *Nature and Environmental Research Letters* suggest that co-production done well generates outcomes that extend well beyond the tangible to include many things that are intangible (see Willyard et al. 2018; David-Chavez and Gavin 2018), which makes the concept extremely appealing. There is increasing recognition of a moral obligation for researchers working on species or systems that have economic, societal, cultural, and nutritional value to include user groups and rights holders in their work to ensure that the knowledge and concerns of all relevant parties are understood and respected (Gibbs 2001). Fortunately, co-production as a research approach is being incorporated into undergraduate and graduate training in environmental programs (see Bieluch et al. 2019), such that there is hope that this approach will be normalized within the next generation of fisheries and natural resource science and management professionals.

It is well established that there is a knowledge–action gap in most applied environmental disciplines including fisheries, which is a major justification for engaging in co-production. Moreover, co-production makes the entire process of research more open and transparent (Chapman and Schott 2020), which increases trust and is consistent with contemporary best practices in research (e.g., open science; Kulczycki 2016). Because co-production is a process, there is no single way to do so, but there are some best practices summarized in this Perspective.

Table 1. Best practices for co-production with associated key references and resources.

Best Practices for Co-Production	Key References and Resources
Read key papers on the topic of co-production and seek training and guidance from others who have been involved in co-produced knowledge projects	Beier et al. 2017; Reed and Abernathy 2018; Hickey et al. 2018; Mach et al. 2020 See blog: https://bit.ly/2BWgTIU
Build strong and lasting relationships with partners as that is a prerequisite for co-production—it takes time and effort	Wilson 2008; Kovach 2010
Agree upon guiding principles for co-production—it is important to be working from a common playbook and to agree to data sharing terms from the outset	Mach et al. 2020 OCAP® Principles for data sharing See https://fnigc.ca/ocap
Discuss the goals and perspectives of all parties involved to help develop understanding of context (e.g., cultural, institutional, socioeconomic)	Djenontin and Meadow 2018; Westwood et al. 2020
Engage in explicit discussions about shared power, responsibility, and ownership	Chapman and Schott 2020
Initiate co-production at the earliest possible phase of research (i.e., problem identification) and ensure that it is sustained throughout given that co-production is only truly achieved when done throughout the entirety of the process	Reed and Abernathy 2018 https://bit.ly/3gz6WQY
Engage in exceptional and sustained bi-directional communication	Li 2020; Mach et al. 2020
Be transparent and clarify the nature of co-production relationships for partners and external parties	Young et al. 2016a, 2016b
Consider employing a knowledge broker (See Glossary) to help orchestrate interactions among partners	Young et al. 2016b https://bit.ly/3kbGfnu https://bit.ly/31drcRw
Respect and value the knowledge of all those working together on a given project recognizing that everyone is of equal importance	Hickey et al. 2018 https://bit.ly/3i7FGt3 https://bit.ly/2DmaveP
Reflect on the process (with partners and stakeholders) at key points during a project and refine accordingly	Chapman and Schott 2020
Explicitly recognize and value the different capacities and priorities of various parties and partners	Crompton 2019 https://bit.ly/3i7FGt3
Create culturally relevant, appropriate, and safe spaces for Indigenous research to flourish within existing knowledge production infrastructure	Latulippe and Klenk 2020
Support Indigenous research leadership and governance-value: value for data sovereignty, stewardship and dissemination in Indigenous communities	Whyte 2017

As more members of the fisheries science and management community engage in co-production, it will be important to reflect on the processes and share lessons with others (see Cooke 2019 for example). It is our hope that this article will inspire and challenge researchers and their partners to engage collaboratively in co-production—as doing so should lead to meaningful improvements in collaborative, evidence-based fisheries management, conservation, and co-governance.

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