NRC Research Press

PERSPECTIVE

# On "success" in applied environmental research — What is it, how can it be achieved, and how does one know when it has been achieved?

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**Abstract:** Environmental decision-makers and practitioners need and deserve high-quality environmental evidence for effective decision-making. We collate and share a suite of best practices for applied environmental researchers to support their capacity to inform such decision-making processes. This raises a number of important questions: What does "relevant" and informative evidence look like? How do we know when evidence has been applied? We assembled an experienced team of knowledge generators and users in Canada to identify insights that have emerged from their work and that could serve as guideposts for others who seek to apply environmental research to policy challenges. By reflecting on successes and failures, we define "success" in applied environmental science as respectfully conducted, partner-relevant research that is accessible, understandable, and shared and that can create opportunities for change (e.g., in policy, behaviour, management). Next, we generated a list of best practices for delivering "successful" applied environmental research. Our guidance emphasizes the importance of engaging early and often, in a respectful manner, with partners, generating high-quality, relevant research (which requires flexibility), having a plan for communicating and sharing outputs, and being transparent about uncertainties and limitations. Other important considerations include acknowledging partners for involvement and training early career researchers in applied partnership research. Finally, we generated a list of specific, measurable indicators for evaluating success, including quality and quantity of scientific outputs, the relationship with the partner(s), relevance and connectedness of the research, accessibility and availability of outputs to users, provision of outputs that are digestible and usable by different audiences,

Received 11 May 2020. Accepted 23 July 2020.

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*John Smol currently serves as an Editor; Jules Blais and Steven Cooke currently serve as Advisory Board members; peer review and editorial decisions regarding this manuscript were handled by Kathleen Rühland.

training and capacity building, and ultimate outcomes (e.g., including social, environmental, and economic outcomes, as well as partner satisfaction). We encourage those embarking on applied environmental research to consider embracing the strategies, to continuously reflect on progress toward shared research goals, and to be flexible. Doing so will increase the likelihood of delivering research that is "successful" and in doing so contribute to overcoming and addressing environmental issues and problems.

*Key words:* environmental science, partnership, success, funding, practitioner, decision-making, evidence, best practice, communication.

**Résumé :** Les décideurs et les praticiens de l'environnement ont besoin de données environnementales de haute qualité pour prendre des décisions efficaces et ils le méritent. Les auteurs colligent et partagent un ensemble des meilleures pratiques à l'intention des personnes qui réalisent de la recherche appliquée en environnement afin de soutenir leur capacité à éclairer la prise de décisions. Cela soulève un certain nombre de questions importantes. À quoi ressemblent une preuve « pertinente » et informative? Quand savons-nous qu'une preuve a été appliquée? Ils ont réuni une équipe expérimentée de producteurs et d'utilisateurs de connaissances au Canada afin d'identifier les idées qui ont émané de leurs travaux et qui pourraient servir de guide à d'autres qui cherchent à appliquer la recherche environnementale aux enjeux politiques. En réfléchissant sur les succès et les échecs, les auteurs définissent la notion de « succès » en science environnementale appliquée comme étant une recherche respectueuse, pertinente pour les partenaires, accessible, compréhensible et partagée, et qui peut créer des occasions de changement (par exemple en matière de politique, de comportement, de gestion). Ils ont ensuite établi une liste des meilleures pratiques pour mener à bien une recherche environnementale appliquée « réussie ». Leurs orientations soulignent l'importance de s'engager tôt et souvent, de manière respectueuse, avec les partenaires, de générer une recherche de haute qualité et pertinente (ce qui nécessite de la flexibilité), d'avoir un plan de communication et de partage des résultats, et d'être transparent sur les incertitudes et les limites. D'autres considérations importantes comprennent la reconnaissance des partenaires pour leur participation et la formation des chercheurs en début de carrière à la recherche appliquée en partenariat. Enfin, ils ont établi une liste d'indicateurs spécifiques et mesurables pour évaluer la réussite, dont : la qualité et la quantité des résultats scientifiques, la relation avec le ou les partenaires, la pertinence et la connectivité de la recherche, l'accessibilité et la disponibilité des résultats pour les utilisateurs, la diffusion de résultats digestes et utilisables par différents publics, la formation et le renforcement des capacités, et les résultats finaux (y compris les résultats sociaux, environnementaux et économiques, ainsi que la satisfaction des partenaires). Les auteurs encouragent les personnes qui se lancent dans la recherche environnementale appliquée à envisager d'adopter ces stratégies, à réfléchir en permanence aux progrès réalisés vers des objectifs de recherche communs et à faire preuve de souplesse. Cela augmentera la probabilité de mener des recherches « fructueuses » et, ce faisant, contribuera à surmonter et à traiter les questions et les problèmes environnementaux. [Traduit par la Rédaction]

*Mots-clés :* science de l'environnement, partenariat, succès, financement, praticien, prise de décision, preuve, pratique exemplaire, communication.



## Introduction

Applied environmental research is critical for understanding and solving the complex environmental problems of the Anthropocene (Crutzen 2006). From reducing carbon emissions to developing sustainable fish harvesting methods to restoring degraded habitats, decision-makers and environmental practitioners can struggle to make good decisions (Costanza and Jorgensen 2002). Some challenges are truly global (consider the UN Sustainable Development Goals), while others are specific to a taxon (e.g., how to recover an endangered frog population), issue (e.g., where to site wind turbines to reduce impacts on wildlife), or location (e.g., what is the trajectory of permafrost near a given mine site). No matter the scale of the problem, it is difficult to make effective decisions without using evidence (Dicks et al. 2014). To that end, researchers in academia, government, industry, and nonprofit organizations conduct studies that aim to generate new knowledge and deepen our understanding of environmental issues and problems.

Given that financial and logistical resources for conducting research are normally limited, applied research must generate information and knowledge that is truly relevant and useful to decision-makers and practitioners and thus leads to more effective outcomes (Milner-Gulland et al. 2012). Moreover, because evidence demonstrates that many current environmental issues are crises (e.g., climate change, biodiversity loss, plastic pollution; see Ripple et al. 2017), delivering actionable science is urgent. Although fundamental research plays a crucial role in understanding environmental problems and identifying solutions and can sometimes be applied in unexpected, immediate ways (Lederman 1984), actionable findings generally arise from research with the explicit goal of informing policy and practice (see Littlewood et al. (2012) for an example of fundamental science contributing to improved management of grasslands or Burnett et al. (2017) for an example of how the fundamental concept of carryover effects was used in an adaptive management study to benefit salmon passage at a dam). As such, applied environmental research that aims to inform policy or practice but fails to do so is a waste of resources and may put species, ecosystems, or people at risk. Quite simply, environmental decision-makers and practitioners need and deserve high-quality, applicable environmental evidence. Evidence can take many forms, but for the purpose of this paper, we focus on scientific knowledge, using the term broadly to span the social and natural sciences. We acknowledge and respect the role of other ways of knowing (e.g., Indigenous knowledge, local knowledge), but here we focus on knowledge generation that uses the scientific method or other forms of "western" scholarship — whether qualitative or quantitative, experimental or observational, empirical, or modeling. Indeed, this may involve social science or ethnographic studies of other knowledge holders. Other ways of knowing are beyond the scope of our collective expertise; we encourage decision-makers to engage with experts in those fields.

Although most environmental researchers spend many years in university, formal training for environmental researchers to apply their skills in applied ways are scarce (Touval and Dietz 1994; Zhao et al. 2020; Young et al. 2016*b*). Informal training opportunities can include mentoring by those working on policy development (see Chapman et al. 2015) and formal training programs also exist, such as the Leopold Leadership Program (https://www.earthleadership.org/) or the Mitacs Canadian Science Policy Fellowship (https://www.mitacs.ca/en/programs/canadian-science-policy-fellowship). There is also a growing number of funding opportunities for those working on applied environmental issues, and certainly one of the best ways to master this skill is simply to practice and learn from trial and error (Cooke 2019). Such practices can be cumbersome, and delays caused by this more complex way of working compound the challenges of addressing already difficult environmental problems (Martin et al. 2012). Moreover, a research project that fails to deliver useful information (note: failure can arise from issues with the research itself or that the knowledge generated was not used or a combination of the two) can jeopardize future funding, negatively affect environmental outcomes for policy, and cause stakeholders to limit future, partnered research.

There are some resources for applied environmental researchers that share perspectives on how to be successful in applied environmental research, but rarely have they been collated in a peer reviewed paper. Laurance et al. (2012) highlight some strategies for scientists to design and undertake research that should help conservation practitioners. Specifically, they identify the importance of producing time-critical research, attacking "wicked" problems, using multidisciplinary approaches, and better communicating their findings. Moore et al. (2018) brought together environmental scientists and environmental lawyers to understand gaps, barriers, and opportunities to collaboration in the science–law interface and to develop a conceptual model of how different scientific activities can lead to more informed legislative, regulatory, and policy decisions. More recently, Fisher et al. (2019) identified four practical steps intended to enhance the impact of environmental science on decision-making: (1) identify and understand your audience (or partners); (2) clarify the need for evidence; (3) gather "just enough" evidence; and (4) share and discuss the evidence.

There is also extensive literature on how to bridge the knowledge–action divide more broadly. Cash et al. (2003) and Cook et al. (2013) suggest that for evidence to be actionable it needs to be salient (relevant and timely), credible (authoritative, believable, and trusted), and legitimate (developed via a process that considers the values and perspectives of all relevant actors). It is also intuitive that the evidence needs to be "correct", reproducible, and repeatable (Baker 2016). Others argue that evidence syntheses and not individual studies can be powerful tools for moving science into policy and practice (e.g., Dicks et al. 2014; Walsh et al. 2015). How this translates into the process by which research ideas are developed and executed is somewhat less clear, such as for early career researchers and those whose primary experience is in fundamental research. Topical research work on applied problems can involve polarizing debates that are difficult to navigate, regardless of background or experience.

Because of the aforementioned reasons, there have been calls for rethinking how we do applied environmental research (e.g., Keeler et al. 2017). To that end we aim to collate and share a suite of best practices for those embarking on applied environmental research to improve their likelihood of achieving "success". Of course, this raises a number of important questions: What does success look like? What is meant by application? How does one know if they have been successful? And what is the recipe for success? To address these questions, we assembled a team of knowledge generators and knowledge users in Canada who routinely engage in or use applied environmental research with the idea that those who have already had some success in this realm have insights that could help guide others (see "Our approach" section below for more details on the team). We first reflect on what success (and failure) means in the context of applied environmental research from our collective perspective of knowledge users and generators. Next, we generate a list of best practices for delivering applied environmental research that is successful. Finally, we present a list of specific measurable indicators for evaluating success. For the purpose of the paper, it is necessary to define key terms (e.g., stakeholder, partner, team, etc.), which we do in a glossary (Box 1).

We preface this discussion by explicitly acknowledging the value and vitality of fundamental research. Applied research often depends wholly, and always partly, on curiosity-driven, fundamental research. Divisions between different research motivations — basic research, use-inspired basic research, and applied research — necessarily oversimplifies the continuous interplay and lack of real boundaries between any such research category (Baum et al. 2017). This work reflects the experiences of its authors, which draw most heavily on experiences within the Canadian research ecosystem (especially the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council). Suggestions for improving applied research outcomes might differ if applied elsewhere, but are likely to be fundamentally similar.

## Our approach

We assembled a multidisciplinary team of applied environmental researchers (spanning environmental studies and geography, ecology and conservation, impact assessment, ecosystem services and sustainability science, environmental chemistry, environmental engineering, environmental policy and governance, and environmental social science) from academia and government. The research team spanned stages of career progress (from postdocs to senior professors and research scientists) and had approximately equal gender balance. We also included several key figures from the environmental nonprofit sector (including the Canadian Wildlife Federation and Yellowstone to Yukon Conservation Initiative), as well as individuals from science-based government departments (including Fisheries and Oceans Canada; Environment and Climate Change Canada; Parks Canada; Natural Resources Canada) working at the intersections of science, management, and policy. Participants were recruited because they are active in environmental research, and they are recognized among peers (admittedly this was somewhat subjective) as being adept in both obtaining funding for applied environmental research and generating science that has impact. Participants were mostly from the provinces of Ontario and Quebec; however, all participants work in various regions across Canada from coast to coast to coast, including the Arctic. We acknowledge the lack of representation from the Francophone community notwithstanding the fact that we did have team members from Quebec. We held a face-to-face workshop (although several team members participated remotely) where we used breakout sessions and modified Delphi methods to obtain consensus around topics. We present alternative views where appropriate.

We recognize and respect the essential role of Indigenous knowledge and the importance of engagement with Indigenous Peoples. However, this engagement requires specific expertise that is beyond our team or this project. For that reason, as a starting point we refer readers to Ermine (2007), Bartlett et al. (2012), Johnson et al. (2016), and Chapman and Schott (2020) for more comprehensive frameworks and discussions on how to respectfully bridge scientific and Indigenous knowledge systems and engage in ethical and inclusive co-production. Given Indigenous Peoples' central roles and legal rights in environment-related management, it is important to better understand what success means to Indigenous partners. We urge further work in that space and suggest that is a logical next step to further refine the messages we share here. Doing so would require engagement not only with Indigenous scholars but with community members and relevant Indigenous governments and organizations.

## Defining success in applied environmental research

Success in applied environmental science can take many forms. An easy definition is elusive (Wells et al. 1992) given that there are multiple pathways to success (Phillis et al. 2013) and that societal values dictate environmental behaviours and receptivity to new

**Box 1.** Glossary of key terms.

These operational definitions reflect what we perceive as norms in the realm of environment-related research and practice in Canada.

Co-production — An approach to research in which researchers and relevant partners and (or) rights- or stakeholders, some of whom are presumably end users, work together, sharing power and responsibility from the start to the end of the project, including the generation of knowledge. Synonymous with co-creation.

Community science — The practice of public participation (to various extents) and collaboration in scientific research (Charles et al. 2020). Synonymous with citizen science but being increasingly recognized as a more appropriate and inclusive term.

End user — An individual, organization, or body that has the potential to use a given knowledge product or tool to inform environmental policy, practice, investments, activities, management, decisions, etc.

Partner — Two or more individuals (i.e., at least one of whom is a researcher and one of whom is end user) or parties engaged together in the same activity either informally or formally. Formal partnerships may involve legal agreements and often include co-funding or providing other forms of in-kind support. For environment-related research, there are often a number of partners involved in a given project, although the specifics tend to be dictated by the terms of granting programs.

Rights holder — A person or organization that owns the legal rights to something. In Canada, Indigenous Peoples have constitutionally and treaty-protected rights; in this context, they are not "stakeholders". This can also be "rights and title holder".

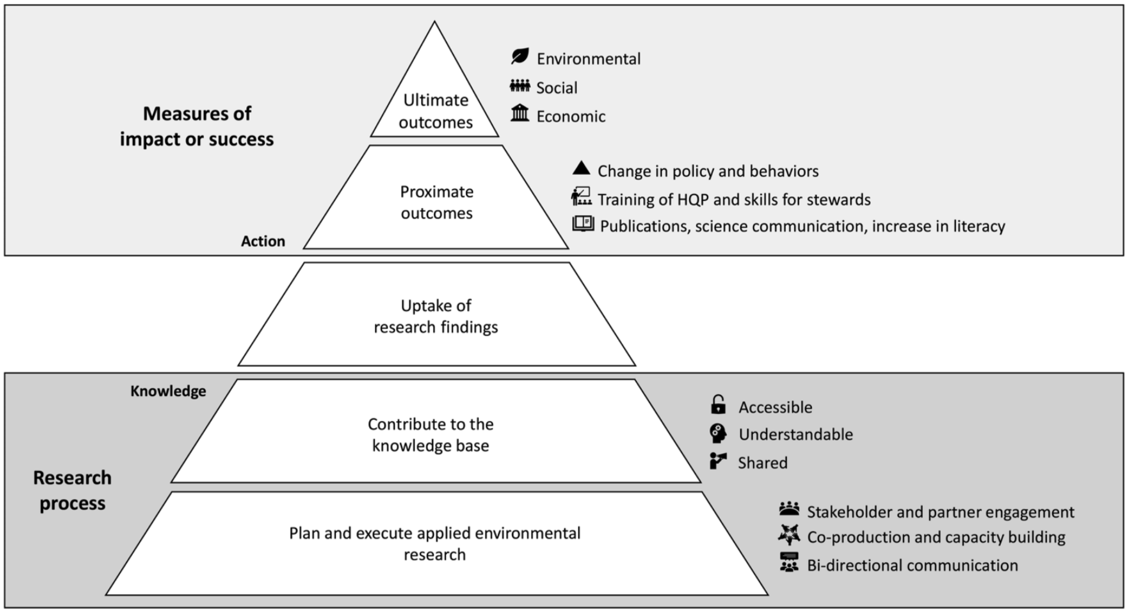
Stakeholder — A person or group of people with interest in a given topic or issue. Some stakeholders or stakeholder groups may also end up being engaged as research partners (see below), and some may have capacity to be end users (extending beyond simply having an interest in a given topic or issue).

Team members — The "team" members would typically refer to the research team — the knowledge generators working on a given study. However, it is not uncommon for the word "team" to also be extended to include the broader suite of partners, rights holders, and stakeholders.

knowledge (Brown et al. 2010). It may seem intuitive that success is measured in terms of the ultimate outcomes. That is, did the research address key science needed to inform action to resolve or ameliorate an environmental problem so as to reduce its negative environmental, cultural, health, economic, and (or) social impacts (Wall et al. 2017) (including tangential benefits such as raising public awareness)? Yet, it is also clear that regardless of whether the ultimate outcome is achieved, the process by which the science is conducted and how it is shared is also important (Nel et al. 2016). Certainly, the research needs to be rigourous and deemed to be of high quality, but that alone is insufficient for success. When one thinks of success in terms of the broader research ecosystem, it can be achieved (or not) in various components that are visualized in Fig. 1. In this conceptualization, the first component of success can be defined as the extent to which the planning and execution of research involves creating ethical space, co-production, engages relevant stakeholders and partners, stimulates capacity building, and involves bidirectional communication (Ermine 2007; Chapman et al. 2015; Beier et al. 2017; Schwartz et al. 2018). The process by which research occurs will be further influenced by other considerations, such as the scale of the issue or problem and associated research efforts, the timing (relative to needs of end users), the relevance of the work, and the broader context. Successful applied research is well-designed and connected or relevant to an applied issue, resulting from the co-creation of research agendas and new knowledge (Nel et al 2016). Failure to recognize the importance of engagement in the research process will mean that even the most rigourous science has a strong likelihood of being ignored (Young et al. 2016*b*). Relatedly, when success is viewed solely from the perspective of the knowledge generator, there can be a disconnect with sociopolitical issues.

Between the research processes and the proximate and ultimate measures of impact is the so-called knowledge–action gap (Cook et al. 2013), where there exist many barriers to uptake even when new knowledge is in the hands of decision-makers and practitioners (Fig. 1). As such, our discussions elicited the idea that the minimum or lowest threshold for success is that the research findings contribute to the knowledge base by being accessible, understandable, and shared, thus creating the potential for change. Assuming that the science was done in a way that is respectful

**Fig. 1.** Components of success in an applied environmental research ecosystem. Tier 1 (starting from the base of the pyramid): conduct well-designed and connected and relevant applied research, with consideration for the scale, timing, and relevance of the work to the broader context. Tier 2: contribute to the knowledge base by sharing research findings in an accessible and understandable way and create the potential for change. Tier 3: the so-called knowledge–action gap, where barriers to uptake of research findings by end users exist. Tier 4: proximate outcomes, while not always immediate, include those that are a direct result of the research project (HQP, highly qualified personnel). Tier 5 (top of the pyramid): ultimate outcomes result from providing the science needed to resolve an environmental problem and creating environmental, economic, or social benefits.






(Shackeroff and Campbell 2007), it must then be clearly communicated such that findings are delivered to relevant parties in ways that can be useful and understandable. Accessibility is important. If findings are communicated, but end users cannot find the data or peer reviewed papers, findings may be ignored (Cook et al. 2013). Conversely, peer reviewed research that is not communicated or delivered to appropriate stakeholders contributes little to resolving environmental problems (McKinley et al 2012).

The creation of knowledge-based products can inform policy and practice (Possingham et al. 2001). Collectively these actions can establish the potential for outcome or change and result in project-specific proximate and (or) ultimate outcomes. For some projects, impact may be viewed in broad, almost vague terms, such as training the next generation of scientists, publishing papers, or changing policy (e.g., stronger science in impact assessment). In others, impact may be highly focused, often site-, organism-, or sector-specific, such as recovering an at-risk species in Banff National Park or identifying regulatory thresholds for a novel substance arising from the electroplating industry. To the extent that improving environmental outcomes depends on changing human behaviours, success is likely to take far longer (Schultz 2011; Nilsson et al. 2020). For example, success can depend on increased public awareness about a given issue intended to alter human behaviour, which may take a long time to achieve (de Lange et al. 2019; Selinske et al. 2018; Nilsson et al. 2020). In other cases, success may simply be providing advice to decision-makers, even if this advice is ignored. Although applied research can provide the evidence, it may be overridden by values as it is translated into policy (or ignored altogether; e.g., "evidence complacency" as described by Sutherland and Wordley 2017).

A clear theme throughout our discussions was that success is defined differently according to scale (temporal, spatial, institutional) and context. As such, success is presumably viewed and prioritized differently (or even conflictingly) by various actors. For example, an academic may define success as graduating students or publishing papers in high-impact journals, while a decision-maker may view success as a new tool, a completed decision, or reduced conflict. Nonetheless, as noted above, the focus is often on the degree to which an ultimate goal (or goals) is addressed, while in reality, there are more proximate successes that may collectively contribute to ultimate successes over longer time scales. For those reasons, a singular definition of success is challenging to identify, but for the purpose of this paper we suggest that success in applied environmental science is "respectfully conducted, partner-relevant research that is accessible, understandable, and shared, with the potential to contribute to change". Change could be in the context of improved decision-making or changes in behaviour or attitudes but could also reinforce the status quo (i.e., continuation of good practices). We acknowledge that others have attempted to define success. For example, Lubchenco (1998) considered success to be when knowledge generators provided the "best possible science that is useful". In providing such a definition, we also recognize that failure and incomplete successes both have immense value (see Box 2). Creating the potential to contribute to change rather than change itself, not unlike how Palmer defines "actionable" science (Palmer 2012), is a necessary distinction between scientists' knowledge creation and dissemination for policy purposes and policy-makers' work on policy creation and evolution. Indeed, there are many sociopolitical and economic reasons why change may not occur that are entirely beyond the sphere of influence of a researcher. We also recognize that it is possible to conduct successful environmental research independent of partners, but doing so omits co-production in knowledge creation and uptake (e.g., Matson et al. 2016). It is also possible that the partner on a given project may not use research findings directly, but that research may still have broader impacts within the environmental community. It goes without saying that the research also needs to be unbiased and high-quality such that it contributes meaningfully to the evidence base (Roche et al. 2019).

**Box 2.** Failure.

An important outcome of our discussions regarding what we mean by success is that failure is not an indictment that the science is "bad" or "wrong". In fact, even environmental science that is co-produced and follows "best practices" (outlined below) may not be used, at least within a reasonable time scale (e.g., within say 5 years — it could be after retirement or even after someone is deceased). For example, it is entirely possible that the receptor community is not primed for the findings, and thus the research is acknowledged but not immediately "used". Even when opportunity exists (i.e., an advantageous combination of circumstances that allows goals to be achieved), it is possible that such opportunities cannot be effectively leveraged (Moon et al. 2014). The phenomenon of "policy windows" is increasingly recognized as providing opportunities for research to be inserted into timely discussions (see Kingdon 2003; Rose et al. 2017). However, policy windows are moving targets that may be subject to elections, fiscal year, and shifting priorities. There could even be instances in which research is initiated to respond to a policy window; yet given the time needed to conduct the science and constantly changing policy needs, the window is "closed" by the time the science is available (Rose et al. 2017). On the other hand, sometimes external pressures can shift the priorities of decision-makers to create a policy window where none existed before (e.g., sustained advocacy). Much of this may be outside a researcher's control (Cook et al. 2014), which makes it imperative that any judgements of success are done through the lens that despite best intentions and adopting best practices, broader forces are at play even when strategic foresight is embraced. Efforts to understand such dynamic aspects of policy influence related to would be profitable.



## What are the ingredients for success (best practices) in applied environmental research?

Here we provide a series of strategies that collectively create a recipe for designing and delivering applied environmental research that is more likely to be successful. At the core of this recipe are actions that foster a strong and respectful partnership throughout the entire research process, supported by actions that can be embraced at one or more stages in the process (Fig. 2). These strategies are intentionally short and punchy in the hopes that they resonate with and are retained by readers. To facilitate uptake of these strategies, we also created a video summary, which can be viewed at https://youtu.be/JdMVueunJfo. We acknowledge that it was impossible to cite all relevant literature; we encourage readers to use the cited references as a starting point to find other materials rather than assuming that these are the only or definitive references for a given topic.

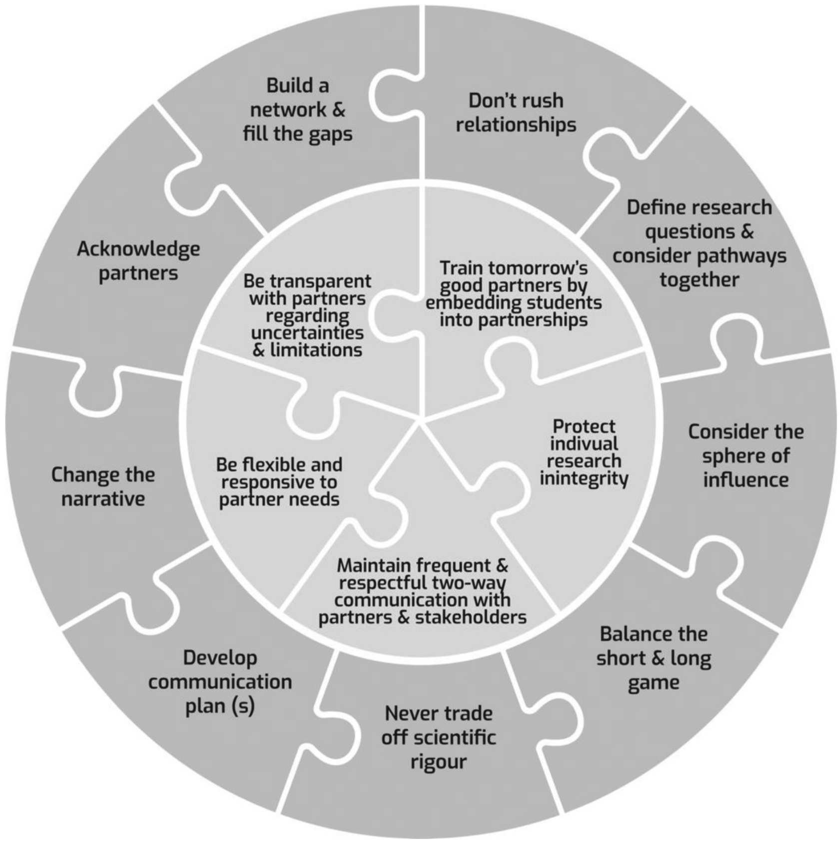
### *Build a network and fill the gaps*

A collegial team with mutually defined goals that are agreed upon in advance is key to research that is relevant to all (partners and researchers) and has the potential to create change. It follows that researchers who want to engage in co-designed work must invest time and effort into networking and building and maintaining this team (Ansell and Alison 2008). A great place to start is building a "network map" or visual image of all known or potentially interested or affected parties, including rights- and stakeholders, researchers, and decision-makers. This is useful not only to see the connections among players, but also to identify important gaps that should be filled. It is also useful to understand the variety of roles played by people and groups in the network, including the roles of science and scientists, rights- and stakeholders, partners, industry, and different levels of government. Researchers may want to rely on those more established in their study area to help identify gaps in the network and make introductions when necessary. Here, boundary organizations can be especially helpful (Safford et al. 2017). Boundary organizations are those groups that can effectively help bridge divides between groups with different norms and goals; for example, a nonprofit with a long history of working with academics might understand both typical academic goals (e.g., publications, student training) and typical nonprofit goals (e.g., mission-driven change). It is worth noting that there are broader networks and social spheres in which applied environmental research is embedded increasingly fueled by connectivity of humans around the globe. Although this can be a force for good, it can also lead to misinformation and disinformation activities (e.g., climate change denial; Dunlap and McCright 2010) and the notion of living in a post-truth world (Gross 2017). The scientific community will have to become more savvy in using various networks to spread evidence-based knowledge and stand up for environmental science by demonstrating its value and relevance (see Lubchenco 2017).

### *Maintain frequent and respectful two-way communication with partners and stakeholders*

Success in environmental research demands ongoing communication with partners and stakeholders from before the project is designed through to after it is completed, which is inherent in co-production (Beier et al. 2017; Dubois et al. 2020). If done well, such relationships might continue over long periods of time, evolving to meet changing circumstances and needs of different parties. Nguyen et al. (2019) reported that ongoing engagement and co-production yielded more actionable science than science done independent of partners or with more limited communication. Related to the need for frequent communication is the need for such communication to be respectful. It is not uncommon for researchers to reach out within days of a grant deadline to seek a letter of support, and then the letter writer may not ever hear back from the researcher after such a letter is supplied. Similarly, some researchers have adopted a "parachute model" where they drop in to do research in a given region or community for a short

**Fig. 2.** Best practices that collectively create a recipe for achieving success in applied environmental research. At the core are five strategies that, when used together, form the basis for a strong and respectful partnership. Nine strategies that can be used during one or more stages of the project surround and support this partnership by working together to promote a successful and impactful applied environmental research project.






period of time and then take off and are never heard from again. Such practices are detrimental to the development of meaningful partnerships and respect (Chapman et al. 2015). Respect also means understanding cultural differences among individuals, organizations, and regions. Active listening is regarded as an effective strategy to understand the needs of partners and end users to ultimately achieve success in collaborative environmental research (Toomey et al. 2017). Moreover, early and frequent communication that is participatory (rather than unidirectional) has been shown to improve project outcomes (Evely et al. 2011).

***Do not rush relationships***

There is a growing momentum to co-create projects amongst academic and nonacademic partners. This can increase the likelihood of success for applied environment research by (1) ensuring that the questions and experimental design of the project are relevant for the real world; (2) providing opportunities for all members of the project to share knowledge and perspectives on a wide range of issues; and (3) potentially enhancing the chance that recommendations based on project outcomes are adopted.

Interpersonal trust is essential for effective collaboration across diverse groups. Trust can be defined in numerous ways, but in all cases it involves the acceptance of vulnerability, with parties placing a level of confidence in the motives and actions of others despite inherent uncertainties (Stern and Coleman 2015). To build trust effectively, engaging with participants as early and as transparently as possible is more likely to bring about a positive outcome. Trust is also affected by key decisions about the structure of relationships. For example, Levesque et al. (2017) argue that groups committing to a more globally distributed power structure engender more trust among participants. Additionally, creating subgroups within a project to tackle specific tasks may help facilitate communication and foster engagement across larger networks, particularly when paired with opportunities for the network to hear from each subgroup. A core level of trust needs to be developed across the network of actors, but some skepticism is also healthy for encouraging active debate and considering new ideas (Stern and Baird 2015). As with anything worth doing as part of a joint project, it is critical to dedicate time and resources to ensure there are opportunities for sharing at all steps of the project.

***Define research questions and consider pathways together***

Applied research very commonly involves some degree of partnership, which implies a collaborative approach to identifying the motivating questions for a research project — something that takes both time and effort. This is an opportunity to engage in a discussion about what partners are keen to understand, relevant time frames, and what questions flow from this. Indeed, once team members have been identified and their general role in the network has been established (note: this should be self-identified or discussed, not assigned), it can be useful for a coordinator to work with each member or group, asking questions and listening to their concerns, questions, and thoughts on the project. This serves a dual purpose; it provides a clearer sense of each participant's role and stance, and (if communicated among the group as a whole) it can help each person or group to feel valued as a member of the team. It can improve common understanding of the history of work, interactions, and progress on the topic at hand in the study area and among team members. Expressing personal interests, priorities, and goals helps ensure participants' positions are clear. Given that meetings feature prominently in such interactions, it can be instructive to adopt structures (e.g., the Six Thinking Hats approach; see de Bono 2017) that enable parallel thinking that helps arrive at consensus in a cohesive way. Early on, it is important to understand power relationships and ensure that the partners do not feel that their involvement is tokenism. It is also an opportunity to discuss success for the project, as this can inform how questions are asked and how the research seeks to answer them, as well as consideration of tradeoffs in terms of the optimal design of research and its associated costs. Doing this will help to truly understand what the partner needs and wants out of the relationship. For example, consider what the pathway looks like if it is expected to be a standalone project, a long-term relationship, or an opportunity to build capacity. Projects, moreover, are rarely static. Situations change. New information is acquired. And building in time and resources to ensure discussions are ongoing can be essential, particularly if early insights from the research leads partners to rethink or pose new questions. But doing this also requires establishing clear understanding of time commitments. Not all partners will want the same level of involvement, so it is useful to determine that at the outset. When dealing with environmental issues, it is not uncommon for there to be strong opinions on different sides of the core issues. Having early and frequent discussions about how to respectfully engage in debate to achieve understanding is critical. Depending on project objectives, it may either be helpful to bring people together across this divide (potentially with help of a mediator) or keep groups separate to minimize conflict.

***Be transparent with partners regarding uncertainties and limitations***

No matter how good the science, uncertainties and other limitations always constrain the extent to which findings can be applied to a given problem. While scientists are aware of these realities, non-scientists might assume that research findings are inherently certain. And, in some cases, a researcher oversells their work. In both cases, this can be addressed through better training scientists to communicate uncertainty (Leung et al. 2015; Rose et al. 2019). That said, environmental management and policy is inherently embedded within an uncertain world, which creates challenges for all involved (Hilborn 1987; Polasky et al. 2011). An important aspect of achieving successful environmental research is being transparent with partners about the strengths, uncertainty, and limitations of the project. Sutherland et al. (2013) provided a list of 20 concepts that they suggest need to be understood by decision-makers to help them interpret scientific claims (e.g., bias is rife; no measurement is exact; extrapolating beyond the data are risky). We suggest that this list should be mandatory reading for scientists; anything that can be done to minimize those issues in the research process or communication of scientific evidence will contribute to project success. Uncertainty and limitations should be considered from project inception through to application of findings. Similarly, it is important to recognize that there are often disconnects between perceived risk and actual risk, which can lead to poor policy choices (Gilbert 2011). Transparency is a key concept that can be incorporated during all phases of environmental research as a mechanism for clarifying and overcoming aspects of uncertainty — both with current research but also in contextualizing that work relative to existing and future evidence (Ellison 2010).

***Consider the sphere of influence***

The overall goal that applied environmental scientists should aim for is to answer research questions that are not only interesting and important to science, but also have the potential to help solve environmental problems. Boundary spanning, defined as "work to enable exchange between the production and use of knowledge to support evidence-informed decision-making in a specific context" (Posner and Cvitanovic 2019), is essential to the success of solutions-oriented environmental research. Intrinsic to boundary spanning is assessment of the societal context of the environmental issue being addressed and consideration of its "sphere of influence", particularly during project planning stages.

Before initiating a research project, we recommend environmental scientists first identify a timely environmental issue of interest and begin to understand it through multiple lenses (e.g., economic, social, political) and at different scales (e.g., time, space) to appreciate the most pressing and timely science needs. This is best achieved through conversations with people who care about the environmental issue, often outside of academia — such as landowners, elders, government scientists, resource managers, and stewardship groups — and by collaborations between social and biophysical scientists. Integrating social science into research planning helps put the environmental problem in a societal context and better understand stakeholder perspectives (Maxwell et al. 2019). It is vital to consider the political jurisdiction relevant to the environmental issue(s) at hand — specifically, whether it falls within the purview of municipal, regional, federal, or Indigenous authorities — and the applicable statutes, laws, and regulations.

We also recommend creating a conceptual diagram of the "sphere of influence" of a proposed project, including likely "influencers". The sphere of influence of a project describes, hypothetically, the various pathways that research outcomes could lead to valued impacts (e.g., change in environmental policy, creation of a protected area, or enhanced protection of a threatened species). Influencers (including "boundary spanners"; Posner and Cvitanovic 2019) are actors who help catalyze pathways in the sphere of influence. Influencers can help frame and shape research questions and are also important for catalyzing co-learning during the project (Turner et al. 2016). The exercise of creating a sphere-of-influence diagram is not only helpful at the front end of a project to assess which research questions are the most likely to lead to successful outcomes, but can also be used as a road map to guide actions throughout the life of the research project.

***Train tomorrow's good partners by embedding students into partnerships***

Developing and maintaining partnerships requires particular skills. Successful applied environmental researchers possess these skills, but they are not innate and are typically not taught in university science programs at either the graduate or undergraduate level. Partnerships are inherently interdisciplinary, both across scientific fields and within and outside of academia. Navigating these different perspectives requires an understanding of each, an ability to build consensus, or an ability to make progress in its absence. Relatedly, navigating the things necessary to achieve success is itself an important opportunity for learning. Case studies and perspective articles in the literature describing challenges and best practices with respect to interdisciplinary research and partnership (e.g., Podesta et al. 2013; Parker et al. 2018; Cooke et al. 2020), while being useful resources, reinforce the challenges and serve to demonstrate the need for hands-on experience (see Kelly et al. 2019 for resources specific to early career scholars and learners).

As in other scientific endeavours, students often play a crucial role in applied environmental research. Training students so that they are equipped with the skills required to build and maintain partnerships can yield current and future benefits for all involved. Embedding students in partnerships has clear benefits for the students themselves. They are exposed to varied training environments and perspectives, which can make them better prepared for nonacademic environmental careers (Cid and Brunson 2020) and broaden their experience and professional networks. In academic environments, they learn to value creativity and originality while also pursuing general understanding of natural phenomena. Since partners may ascribe higher value to pragmatism and locally relevant information, the tension between researchers' pursuit of the general and stakeholders' desire of the specific is a frequently cited conflict in applied environmental research partnerships (e.g., Podesta et al. 2013). Navigating these and other conflicts to see a project through to application is an incredibly valuable experience for young scientists.

The onus should be on the supervisor to be the role model (Filstrup 2019) so that students learn to be good citizens in partnerships, with skills that include collaboration, critical thought, creativity, patience, respect, and effective communication. Yet, academics should avoid sharing their responsibility for students with partners without having discussions about it. For some it may create an unwelcome burden, but other partners may want to embrace such responsibility as long as it is not an abdication of responsibility by the academic mentor. Engagement early and often ensures that students are prepared with the skills and habits needed to work with the partner organization. It further strengthens student access to supportive relationships and resources, and it helps identify shared skills for capacity building. Because students often need to meet certain institutional deadlines towards their degree, clear expectations and time commitments should be mutually discussed and revisited as needed. When this training is done successfully, the student can bring demonstrable benefits to the partnership. Students can bring a level of focused dedication to a project that is difficult for later-stage professionals to sustain, and their inclusion elevates scientific productivity (e.g., Kyvik and Smeby 1994). The potential for co-learning increases as students and partners participate in joint field and (or) lab experiences. Moreover, these students will become the leaders of tomorrow's partnerships, having learned the challenges and rewards and applying these skills to solve so-called "wicked problems" through collaborative and interdisciplinary approaches.

### *Be flexible and responsive to partner needs*

To foster successful partnerships, we recommend that applied environmental research have a degree of adaptive capacity embedded in all stages. There is no single path or process that works for every partnership, and pathways to mutually defined success can be mapped out at early stages of the project (see section above on "Define research questions and consider pathways together"). That said, all parties will need to remain nimble and responsive over the course of the project as situations change. It is important for researchers to recognize that there may be areas where partners can be flexible (e.g., academic partners may be able to take on new tasks, government partners may be able to make resources available for emerging problems) and areas where there is little to no flexibility (e.g., government partners with fiscal deadlines, academic deadlines for students (highly qualified personnel), nonprofit organizational mission). While changing needs or priorities can sometimes cause tension, they can also lead to new opportunities — this benefit should not be overlooked. Remaining flexible with partners and building the research plan in stages and at a reasonable pace (see above regarding not rushing relationships) can allow researchers to be responsive (e.g., targeting a newly introduced invasive species) and integrating research questions that were not identified at the onset of the project. There is much to learn from the different paths that partnerships in applied environmental research can take, and they should be documented. At the end of a project, take time to think critically about what worked and what did not (with the partners), what was unexpected and how it was handled, and how being flexible and responsive benefitted the project and long-term relationship with the partner (and involve partners in this exercise if possible).

### *Develop communication plan(s)*

There is often misalignment between the demands of knowledge users and research outputs. Research over the past couple of decades has shown that traditional scientific outputs (i.e., peer-reviewed journal articles) can have limited value in knowledge mobilization (KMb), particularly for practitioners and decision-makers who have limited time and capacity to sift through the primary literature (e.g., McNie 2007; Cvitanovic et al. 2016; Young et al. 2016*a*), which may also be behind a paywall (Matheson and Edwards 2016). Instead, understanding the needs and constraints of knowledge users and partners is critical to developing effective strategies to communicate and mobilize knowledge. For example, interviews with recreational salmon anglers in British Columbia revealed three typologies of communication preferences among the participants, demonstrating that there is no one-size-fits-all KMb strategy to ensure that fishers use evidence-based, best practices (Nguyen et al. 2013). Researchers should consider allocating space, time, and resources for user needs assessments in their KMb plans and work with communications specialists to develop effective strategies. Similarly, funding bodies need to allow for a portion of research funds to be devoted to KMb activities (e.g., like NSERC Alliance Grants).

A growing body of research points to the importance of engaging and building connections with knowledge users for promoting evidence-informed decision-making (Jacobs et al. 2005; Young et al. 2016*a*, 2016*b*; Nguyen et al. 2019). One of the outcomes of this work is that some researchers are re-envisioning more collaborative and social scientific outputs. As a result, the process by which research outputs are developed can be argued to be equally or more important than the deliverable itself. Activities such as knowledge exchange, translation, brokering, and mobilization involve building relationships, connections, and engaging with knowledge users in the design, implementation, and dissemination of research. Doing so can both enhance the consideration of research into practice and enhance the quality of environmental decisions (reviewed by Reed 2008). In particular, early career researchers may benefit from developing such connections, as they may evolve into long-term partnerships for their work or expertise to directly feed into decisions and inform actions.

More and more granting bodies are starting to require KMb plans. One cannot assume what the users need or want and in which forms. Doing background research, such as consulting with partners, reading annual reports, and reviewing the user's context (e.g., organizational mission; past, present, and future projects; community), will not only inform research design but help both parties to find common language and may increase the relevance and applicability of the research itself. Creating a KMb plan that includes participation of knowledge users is essential but needs to be underpinned by the philosophy that emphasizes empowerment, equity, trust, and learning. The iterative exchanges should be considered in the KMb plan as well as time to understand user needs.

### *Acknowledge partners*

Token partner engagement abounds. We recommend wrapping up projects by "closing the loop" with partners (for long-term projects, occasional reviews during the research process may also be useful). Such reflection is a reminder to consider the context of the research and to ask for feedback about whether partners have been effective. It goes beyond the project's exit strategy, which outlines how it ends or is transitioned (e.g., to a future project) and reminds us that the collaboration must meet the needs of research partners. This challenges us to think outside of what is valued in the academic context, to ask what would benefit our partners, and then not only to build that into the project plan but into what we do to maintain the relationship. Closing the loop also means thinking about power and recognizing the privilege inherent in the access to funding, research support, and compensation for research activities that is the norm for academic researchers (Higginson 2018; Wallerstein et al. 2019).

Awareness of power relationships may lead to recognition rather than reward for the contributions of research partners. Rewarding carries with it an implicit imbalance of power between the partners receiving and distributing rewards. Both academic and nonacademic partners reap the rewards of a well-designed collaboration, but this does not necessarily mean the rewards flow from one to the other. The nature of the recognition and of the support that academic partners can provide is specific to the research partner and project. Examples include the following: advocate for nonacademic partners to funding bodies with respect to valuing in-kind contributions of data and expertise; include funding in grant applications to cover the time contributed to the project by nonacademic partners, especially not-for-profit and community groups; be aware of paywalls and provide access to library resources; find opportunities to use university resources to showcase stories featuring the work and contributions of research partners (e.g., quotes and contact information in university press releases about research partnership, feature partners alongside researchers in university-created videos about the project; invite partners to give solo or joint seminars about the research and its applications). The importance of returning to a community to share results (in person or by video conference) and to hear feedback cannot be understated; it can help to interpret and validate results, adapt analysis or communication as necessary, and increase uptake and implementation.

In some instances, acknowledging involvement in the research may include considering co-authorship on peer-reviewed journal articles. This ought to be discussed early in the research process, particularly for partners who are unfamiliar with academic publishing or for interdisciplinary work where publishing norms may differ (Cooke et al. 2020). The extent to which a given partner values — and is able to engage in — co-authoring publications will depend on the interests, resources, organizational culture, and contributions of research partners. For example, partners may not be compensated for time spent to publish or have publications factor into career advancement; some groups might have limited internet access, familiarity with or access to specialized computer programs, or seasonal activities that make it difficult to turn around manuscripts. Where individual authorship is not appropriate (e.g., community science, degree of involvement), authorship that recognizes the contributions of a group can provide an alternative (Ward-Fear et al. 2020).

***Change the narrative***

Successful uptake of environmental research is about more than getting information to the desk or email inbox of a decision-maker — evidence must be framed in clear, persuasive, and, in some instances, politically salient ways (Rose 2015; Rose et al. 2017). This means that successful applied research does not end at peer reviewed publications or even policy briefs, which few busy decision-makers or practitioners have time to read and may not be successful instruments of change. Effectively communicating the weight of evidence and implications of research findings is a process that involves understanding the audience that will use the evidence — where listening and connecting are just as important as talking (Smith et al. 2013). Successful communication that engages with decision-makers is one of the most potent catalysts for action (Baron 2010; see above section "Consider the sphere of influence").

Written communications have been shown consistently to be less effective or persuasive than face-to-face meetings (Roghanizad and Bohns 2017), and in many cases, telephone conversations may be more productive than email communication. Moreover, do not assume that partners have reliable internet access or that an unanswered email is a lack of interest. Do not be afraid to pick up the phone, which can often be more effective in forging meaningful connections than email.

There are several helpful tools and training programs to help researchers craft the content of their message for effective communication to decision-makers (see Kuehne et al. 2014 for a summary). Decision-makers, like most people, are more likely to be influenced by relevant, human-based stories rather than stark presentation of facts (Jones and Crow 2017). Using evidence to create simple messages that appeal to emotions and focus on positive outcomes and solutions is known to effectively communicate scientific messages to wide audiences (Begon 2017; Balmford and Knowlton 2017). To build these clear messages, distill research findings into the elements most relevant to the audience(s) (e.g., https://www.compassscicomm.org/leadership-development/the-message-box/). Learning and using basic narrative structure can make communication more memorable (e.g., identifying setting, characters, plot, and moral in a narrative policy framework; Jones and Crow 2017). For more complex research messages, interactive data visualization tools that allow participation can be persuasive (Herring et al. 2017). Decision-makers, like most people, have different perspectives and values (Sandbrooke et al. 2011; Baron 2010); thus, understanding their needs and perspectives is paramount for effective communication (Bainbridge 2014). Finally, if researchers are unable to communicate messages effectively with decision-makers, knowledge brokers and intermediaries are available that speak the language of science and policy (Nguyen et al. 2017).

***Never trade off scientific rigour***

Sound environment-related decisions need sound environment-related information. One of the most powerful aspects of applied research is that it can increase our understanding and lead to new, reliable knowledge. Poorly designed and (or) executed applied research runs the risk of providing incomplete or incorrect information that could lead to ineffective or even harmful decisions (Sells et al. 2018). As noted by Hofseth (2018), "If science isn't rigorous, it's reckless"; although this message was coming from the field of human health, it is just as relevant to environment-related management. Providing practical and applied information that has relevance — ideally beyond the immediate question or problem — requires a genuine collaboration among researchers and partners (see section above on "Define research questions and consider pathways together"); however, scientific rigour should never be compromised in the process. For some collaborative environmental projects, there can be a sense of urgency to deliver actionable science to end users, and in this process, there may be temptation or pressure to disregard proper scientific rigour. Indeed, some decisions, or the implications of those decisions, may require less detail or specificity than others. However, researchers must ensure that the integrity and credibility of research findings and interpretations are not sacrificed. The underlying goal of researchers should be to produce rigourous, unbiased, and reproducible science that is conducted in a way that is ethically minded, regardless of speed (Roche et al. 2019) and (or) pressure from partners, and to be willing to maintain scientific independence (i.e., walk away from the partnership) if (or) when asked to do anything less. The researcher will need to navigate the need to get the science done while working diligently to ensure that stakeholder and partner engagement occurs throughout the process.

***Protect individual research integrity***

Partnership and co-production can create dynamics and tensions that may be unfamiliar to researchers trained in traditional scientific norms and methods. Partners may have particular outcomes or applications in mind, including sociopolitical aims that may or may not be shared by researchers. Partners may also have ideas about what types of data and findings are most useful to them (Young et al. 2016*a*) and may exert pressure on researchers (intentionally or not) to focus their efforts on research questions and data collection of potential high utility. Some researchers are comfortable accommodating such interests, while others are concerned with maintaining distance from policy or political considerations (e.g., Lackey 2016; Donner 2017). In all cases, however, it is important for researchers to reflect on such possibilities prior to engaging in partnerships and co-production and to take measures to anticipate and clarify how research will be conducted and results communicated. For instance, it is advisable to develop

**Table 1.** Indicators of success.

| Indicator | Timeline | Responsible party | Relative ease |
|---|---|---|---|
| **Quality and quantity of scientific output** | | | |
| Is the science of sufficient rigour that it could be defended in legal proceedings or used in evidence synthesis (e.g., meta-analysis and (or) systematic review)? | During, conclusion | Researchers, broader scientific community | Easy |
| Does the work ascribe to best scientific practices (e.g., disciplinary norms, such as use of blinding) with respect to methodological rigour and reporting (e.g., sufficient detail that it could be replicated)? | Prior, during, conclusion | Researchers, broader scientific community | Easy |
| Was there an a priori published protocol or other form of research registration prior to conducting the research? | During, conclusion | Researchers, broader scientific community | Easy |
| To what extent were research ethics observed (e.g., appropriate permitting, following appropriate ethical guidelines related to animal care or use of human subjects)? | During, conclusion | Researchers, broader scientific community | Easy |
| How many outputs have been produced (e.g., peer reviewed publications, conference presentations)? | During, conclusion, 1 year | Researchers | Easy |
| Were outputs shared in reputable outlets with rigourous peer review processes (e.g., that align with the Committee on Publication Ethics guidelines)? | During, conclusion, 1 year | Researchers, broader scientific community | Easy |
| Have outputs been cited by other peer reviewed outlets? | Conclusion, 1 year, 5+ years | Researchers, broader scientific community | Easy |
| **Relationship with partner** | | | |
| To what extent was a co-production model embraced (e.g., involvement in co-development of research agenda and grant; involvement in collection–analysis of data; co-authorship on outputs or group authorships where appropriate)? | Prior, during, conclusion | Researchers, partners | Moderate |
| To what extent does the partner trust the research team (e.g., evaluated by asking partners — often during grant evaluation)? | Prior, during, conclusion | Researchers, partners, broader scientific community | Moderate |
| To what extent has the partner interacted directly with trainees, and vice versa (or attempted to)? | During, conclusion | Trainees, researchers, partners | Moderate |
| Are the partner workshops well-attended, with agendas and outputs co-developed? | During, conclusion | Researchers | Easy |
| Has previous research with partner led to additional questions or research ideas? | During, conclusion, 1 year | Researchers, partner | Moderate |
| To what extent has the partner provided tangible financial or in-kind contributions (scaled to the size and ability of the organization)? | During, conclusion | Researchers, partner | Easy |
| To what extent has the funders or partners sought continued partnership? | Conclusion, 1 year, 5+ years | Researchers | Easy |
| **Relevance and connectedness of research** | | | |
| Is there an articulated conceptual model that describes how research will (or could) inform partner activities? | Prior, during | Researchers, broader scientific community | Easy |
| Did the research lead to any formal processes to incorporate new knowledge into partner organization (e.g., structured decision-making exercises; formal science advisory processes)? | During, 1 year, 5+ years | Researchers, partners | Easy |
| To what extent have the findings from the research been incorporated into evidence syntheses? | 1 year, 5+ years | Researchers, broader scientific community | Moderate |
| To what extent does the partnership include multiple partners that extend across sectors and organizations? | Prior, during | Researchers | Easy |
| Was the research proposal co-created with the partner? | Prior | Researchers, broader scientific community, partners | Moderate |
| How many requests for advice or expertise are made by the partner? | During | Researchers, partners | Easy |
| To what extent are outputs (especially publications) "audience-reviewed" (not just academic or peer reviewed)? | During | Researchers, partners | Easy |

**Table 1** (*continued*).

| Indicator | Timeline | Responsible party | Relative ease |
|---|---|---|---|
| **Accessibility and availability of project outputs to users** | | | |
| Was there a communication and knowledge mobilization (KMb) plan with clear identification of target audiences with reporting and access given to these audiences? | Prior, during, conclusion | Researchers, partners, broader scientific community | Easy |
| Is there an up-to-date website that shares information with relevant audiences (based on meaningful metrics of website traffic)? | During, conclusion, 1 year | Researchers, partners, broader scientific community | Easy |
| Are the data FAIR — findable, accessible, interoperable, and reusable (i.e., do they follow FAIR guidelines; see Wilkinson et al. 2016)? | Conclusion, 1 year | Researchers, broader scientific community | Easy |
| How many FAIR data sources have been made available online? | Conclusion, 1 year | Researchers, broader scientific community | Easy |
| Is relevant statistical code available online? | Conclusion, 1 year | Researchers, broader scientific community | Easy |
| How many times have end users and others downloaded or requested information? | Conclusion, 1 year, 5+ years | Researchers, broader scientific community | Easy |
| Who has downloaded or requested information (e.g., which types of organizations)? | Conclusion, 1 year, 5+ years | Researchers, broader scientific community | Moderate |
| How many open access publications were generated? | Conclusion, 1 year | Researchers | Easy |
| What are the altmetric scores for outputs? | Conclusion, 1 year | Researchers | Easy |
| **Outputs in forms that are digestible and usable by different audiences** | | | |
| Are there clearly identified products–tools–platforms linked to specific audiences or end users during project planning? | Prior, during | Broader scientific community | Moderate |
| Were there any tools or products created that can be used by the partner and other relevant users? | During, conclusion, 1 year | Researchers, partners, broader scientific community | Easy |
| Are relevant components of the project outcomes translated to key audiences (e.g., the country's other official language, frequently spoken languages among target audiences or partners)? | Conclusion | Researchers | Easy |
| Were plain language summaries appropriate for decision-makers (e.g., policy brief) or other target audiences (e.g., key constituencies, influencers) produced? | Conclusion, 1 year | Researchers, partners, broader scientific community | Easy |
| How many technology transfer activities were produced and how much uptake has there been (e.g., workshops, videos, apps, internships)? | Conclusion, 1 year, 5+ years | Researchers, partners, broader scientific community | Moderate |
| How many non-peer-reviewed publications (e.g. popular articles, blogs) were produced? | Conclusion | Researchers | Easy |
| How much media coverage occurred (e.g., readership of outlets, reads of specific articles)? | Conclusion | Researchers | Moderate |
| How many presentations were made to nonscientific audiences (and number of attendees)? | Conclusion | Researchers | Easy |
| Were any alternative forms of engagement delivered to nonscientific audiences (e.g., story boards, training to conduct ongoing monitoring)? | Conclusion | Researchers | Easy |
| Were there changes in literacy, numeracy, or human behaviour? | 1 year, 5+ years | Researchers | Difficult |
| Were there changes in readiness for adoption of new technologies? | 1 year, 5+ years | Researchers | Difficult |
| **Training and capacity building** | | | |
| How many of the project trainees have been hired by the partner or other allied organizations? | During, conclusion, 1 year | Trainees, researchers, partners | Moderate |
| Have trainees obtained relevant employment (recognizing the breadth of employment opportunities that are potentially relevant)? | 1 year, 5+ years | Trainees, researchers | Moderate |
| Did the trainees have an enriched experience as a result of working with the partner (captured via stories–narratives from trainees)? | During, conclusion, 1 year | Trainees, researchers, partners | Moderate |
| To what extent were trainees co-supervised or otherwise mentored by individuals from partner organizations? | During, conclusion | Trainees, researchers, partners | Easy |

**Table 1** (*concluded*).

| Indicator | Timeline | Responsible party | Relative ease |
|---|---|---|---|
| Did trainees develop skills that extend beyond just "doing science"? | During, conclusion | Trainees, researchers, partners | Moderate |
| Were trainees engaged with the dissemination and knowledge translation with the partner(s)? | During, conclusion | Trainees, researchers, partners | Easy |
| Were trainees exposed to the partners' appraisal of research? | During, conclusion | Trainees, researchers, partners | Easy |
| Was there capacity building within partner organizations relevant to the project topic? | During, conclusion | Researchers, partners | Moderate |
| Was there broader stakeholder community (e.g., community science) relevant to the project topic? | During, conclusion | Researchers | Easy |
| **Ultimate outcomes: environmental, social, economic** | | | |
| Was the problem or issue of the partner solved or addressed? | Conclusion, 1 year, 5+ years | Researchers, partners | Moderate |
| By solving or addressing the problem or issue, were there benefits that extended to other partners and society more broadly? | Conclusion, 1 year, 5+ years | Researchers, partners, public | Difficult |
| Were predefined targets achieved? Note: these can be tailored to a given project. For example, some may include increased area of land-, water-, or air-scape protected from development; stricter regulation on use or disposal of toxic chemicals; reduction in number of at-risk species in defined area; trends in consumer and (or) investor behaviour; implementation of action plans based on evidence) | Conclusion, 1 year, 5+ years | Researchers, partners, publics | Moderate |
| To what extent does the research address issues identified in broader horizon scans or gap analyses? | Conclusion, 1 year | Researchers, broader scientific community | Moderate |
| To what extent has knowledge arising from the project influenced political will and platforms? | 1 year, 5+ years | Researchers, broader scientific community, public | Difficult |
| Is the work cited in impact assessments or other regulatory decision documents? | 1 year, 5+ years | Researchers, broader scientific community | Moderate |
| Were qualitative narratives summarizing successes and failures–challenges produced? | Conclusion, 1 year | Researchers | Moderate |
| Has there been an increase in public engagement related to the topic (e.g., increase in stewardship, donations, volunteer time)? | Conclusion, 1 year, 5+ years | Researchers, broader scientific community, public | Difficult |

**Note:** Here we list indicators of success organized by themes. For each indicator we also comment on (*i*) timeline for which the indicator can be reliably assessed including prior to starting the project (prior), during project (during), immediately at project conclusion (conclusion), 1 year after conclusion (1 year), or 5 or more years after project conclusion (5+ years), or a combination of time periods; (*ii*) responsible party for evaluating impact (e.g., researchers, partners, trainees, broader scientific community (including referees, granting bodies, peers), etc.); and (*iii*) the relative ease of applying a given indicator (i.e., the indicator is easy, moderate, or difficult — easy would be things that can be done without specialized training with perhaps several hours of effort, while more difficult activities would include having to recruit or hire individuals with specific skills, such as an economist; moderate is intermediate and is the minimum level of difficulty if information needs to be harvested from partners). We acknowledge that the classifications for "relative ease" are somewhat subjective and may vary by context.



explicit agreements with partners about access to raw data and metadata, analysis of findings, and communication of results (noting, however, the imbalance in familiarity with what these things mean and the implications). Such agreements may include commitments to publicize information that is useful to the broader scientific community, even if they run contrary to partner priorities or expectations. Information about methods, study limitations, and null findings (if applicable) are important for our global understanding of phenomena and should be communicated transparently. More generally, these issues relate to questions of research integrity and credibility. Partnership and co-production imply that all parties contribute to the research process for mutual gain. Prior reflection and agreement on questions of integrity can help structure these collaborations to ensure that research is both useful to partners and credible in the eyes of the broader scientific community.

### *Balance the short and long game*

Most environmental problems are sufficiently complex that they are best approached by tackling focused questions that can be addressed in a short time frame (months to a few years) while simultaneously collecting data that will feed into larger, often longer-term studies (decades or more). This means having outcomes that are project-specific and achievable, yet contain the vision and forethought for the long term, recognizing that sustained funding for long-term research is challenging to secure (Parr et al. 2003; Kuebbing et al. 2018). Short-term research can also be used to identify new questions that can be addressed in the future through identifying profitable research areas and excluding others. For example, taking time to engage in strategic visioning and horizon scanning (see Sutherland and Woodroof 2009) with partners and stakeholders can be valuable to ensure that the research activities and outputs are relevant to both immediate needs and future challenges, such as global environmental change and human population growth and consumption.

## What are specific indicators of success?

Every project is unique, so each project requires unique criteria to assess success. To that end, scientists should work with their partners at the very start of a project to co-develop relevant metrics or indicators to gauge success. Importantly, if this is done from the beginning (i.e., during application phase), then efforts to track success can be incorporated all along the project and not be relegated to a disconnected post hoc activity. Such an approach is intuitively more effective than simply providing researchers (and partners) with a generic survey after the fact into which they have to try and fit their successes. Moreover, although we focus here on the idea of success, learning from failure is also a form of success; when strategic and timely, sharing hard-won lessons can be an act of generosity to both the research and nonresearch communities. Accordingly, researchers and partners should be encouraged to reflect and comment on what worked, what did not, and why. Ideally these reflections would be shared with the broader communities if they enabled others to avoid the same pitfalls. We stress that funders tend to see these exercises as part of the learning process; put another way, the willingness to "fail forward" should not be used to overtly or inadvertently punish people who take time to reflect on and to share lessons learned. Research that reveals no change or status quo might be a valid project outcome if current tactics used by the partner are effective. In other words, confirmatory research can be as relevant as research that leads to change.

Some of the ideas proposed here require substantial investment to be done well. For example, detailed debriefing interviews and their analysis require technical capacity and additional time. However, there is also room for creativity. For example, how often are trainees asked to provide candid assessments of success from their perspective? Students could conduct informal interviews with partners. Or perhaps time should be set aside at project wrap-up meetings to identify "five things that worked well and five things that didn't work as well as they could have". Academics are familiar with this concept from student teaching evaluations, where informal, constructive feedback can be more useful than formal teaching evaluations for improvement. Having open discussions would presumably create more learning and sharing opportunities than simply having the researchers and partners reflect on this in a written final report. We also note that the topic of research evaluation (whether specific to applied research or more broadly) remains an area where there is much ongoing discussion (Penfield et al. 2014). Moving beyond counting papers and using peer reviewed journal "impact factor" to assess paper quality to better gauge influence of research remains a fundamental challenge (Donaldson and Cooke 2014). To that end, some of the ideas raised here are inherently subjective. In the future, it is hoped that more robust and reliable indicators will be available to gauge success in applied environmental research. Although altmetrics can assess reach across media platforms (Erdt et al. 2016), it is a limited reflection of whether and how research results had meaningful impact and is subject to manipulation (Bornmann 2014). How to assess societal impact (broadly) in a quantitative manner remains difficult (Bornmann 2012, 2013). Here, we provided some examples of metrics and indicators for impact in environment-related management, policy, and decisions (Table 1), with the caveat that these will require tailoring for a given study–project–partnership.

## Conclusion

Given the number of researchers that self-identify as environmental scientists, applied ecologists, conservation scientists, sustainability scientists, and so on, one would expect that policy-makers and decision-makers would be drowning in the knowledge needed to make good evidence-based environmental decisions. Yet, despite being called for more than a decade ago (i.e., Sutherland et al. 2013), evidence-based management still faces many challenges. The reasons why this idea has not been fully realized into action are many and complex (Cook et al. 2010), yet what is apparent is that there is much that the scientist or researcher can do to increase the likelihood that their work will be used and create the potential for change (i.e., a core aspect of our first objective of identifying what we mean by success). The recipe for success that we share here is driven both by peer reviewed literature and the methods or strategies that our team members, or their partners, use to achieve success. A number of key themes emerged, notably acknowledging limitations, the need for extensive partner engagement (ideally in a co-production framework), sharing outputs via diverse channels, and ensuring that there are opportunities to train early career researchers in applied partnership science. What is clear from our discussions and writing is that there is no single path to success nor a singular action that will ensure success.

The best advice we can provide to those embarking on applied environmental research is to embrace the strategies that we outline here, to continuously reflect on progress toward shared research goals, and to remain open to adjusting course where necessary. Failures happen and present researchers with opportunities to learn and share lessons. We emphasize the importance of fundamental science and the need to balance it with applied, mission-oriented research. Although this paper is focused on how to deliver applied research with impact, we cannot predict what the future will hold nor how fundamental research will inform policy and practice. Governments and other funding bodies fund applied environmental research to inform policy and practice, so we suggest that it is incumbent on researchers to adopt strategies that make such outcomes as effective as possible. The strategies we outline here (also see companion video; https://www.youtube.com/watch?v=JdMVueunJfo&t=0s) are intended to support that effort and to improve transparency so that partners and funders are better able to assess the success of the work and where new efforts might then be needed.

## Acknowledgements

We thank Jennifer Bean from NSERC for participating in the workshop. Funding was provided by NSERC via a Natural Sciences and Engineering (NSE) Grant to SJC. Additional support was provided by Carleton University via the Multi-disciplinary Research Catalyst Fund. Two referees provided thoughtful reviews of this perspective article.

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