On "success" in applied environmental research – What is it, how can it be achieved, and how do you know when you have achieved it?

In Prep for Environmental Reviews – Perspective Article

Steven J. Cooke[1,*], Trina Rytwinski[1], Jessica J. Taylor[1], Elizabeth Nyboer[1], Vivian M. Nguyen[1], Joseph R. Bennett[1], Nathan Young[2], Susan Aitken[3], Graeme Auld[4], John-Francis Lane[1], Kent Prior[5], Karen E. Smokorowski[6], Paul A. Smith[7], Aerin Jacob[8], David Browne[9], Jules M. Blais[10], Jeremy T. Kerr[10], Banu Ormeci[11], Steven M. Alexander[12], Christopher R. Burn[13], Rachel T. Buxton[1], Diane M. Orihel[14], Jesse Vermaire[3,13], Dennis L. Murray[15], Patrice Simon[7], Kate Edwards[16], John Clarke[16], Marguerite A. Xenopoulos[15], Irene Gregory-Eaves[17], Elena M. Bennett[18] and John P. Smol[19].

[1] Canadian Centre for Evidence-Based Conservation, Department of Biology and Institute of Environmental and Interdisciplinary Science, Carleton University, 1125 Colonel By Dr., Ottawa, ON, K1S 5B6, Canada

[2] School of Sociological and Anthropological Studies, University of Ottawa, 120 University Private, Ottawa, ON, K1N 6N5, Canada

[3] Institute of Environmental and Interdisciplinary Science, Carleton University, 1125 Colonel By Dr., Ottawa, ON, K1S 5B6, Canada

[4] School of Public Policy and Administration, Carleton University, 1125 Colonel By Dr., Ottawa, ON, K1S 5B6, Canada

[5] Parks Canada, 30 Victoria (PC-03-C), 3-84, Gatineau, QC, J8X 0B3, Canada

[6] Great Lakes Laboratory for Fisheries and Aquatic Sciences. Fisheries and Oceans Canada. 1219 Queen St. E., Sault Ste. Marie, ON, P6A 2E5, Canada

[7] Wildlife Research Division, Environment and Climate Change Canada, National Wildlife Research Centre, 1125 Colonel By Dr., Ottawa, ON, K1S 5B6, Canada

[8] Yellowstone to Yukon, 200-1350 Railway Ave, Canmore, AB, T1W 1P6, Canada

[9] Canadian Wildlife Federation, 350 Michael Cowpland Drive, Kanata, ON, K2M 2W1, Canada

[10] Department of Biology, University of Ottawa, 30 Marie Curie Pte, Ottawa ON, K1N 6N5, Canada

[11] Department of Civil and Environmental Engineering, Carleton University, 1125 Colonel By Drive, Ottawa ON K1S 5B6

[12] Environment and Biodiversity Science, Fisheries and Oceans Canada. 200 Kent Street, Ottawa, ON, K1A 0E6, Canada

[13] Department of Geography and Environmental Studies, Carleton University, 1125 Colonel By Dr., Ottawa, ON, K1S 5B6, Canada

[14] School of Environmental Studies and Department of Biology, Queen's University, 116 Barrie Street, Kingston, ON, K7L 3N6, Canada

[15] Department of Biology, Trent University, 1600 West Bank Dr., Peterborough, ON, K9L 0G2, Canada

[16] Natural Resources Canada, 580 Booth St, Ottawa, ON K1A 0E4, Canada

[17] Department of Biology, McGill University, 1205 Dr. Penfield, Montreal, QC, H3A 1B1, Canada

[18] McGill School of Environment, 3534 University St., Montreal, QC, H3A 2A7, Canada

[19] Paleoenvironmental Assessment and Research Lab (PEARL), School of Environmental Studies and Department of Biology, Queen's University, 116 Barrie Street, Kingston, ON, K7L 3N6, Canada

*Author for correspondence: steven.cooke@carleton.ca

Abstract

Environmental policy-makers and practitioners need and deserve high quality, applicable environmental evidence. Here we collate and share a suite of best practices for applied environmental researchers 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 that end, we assembled a diverse team of knowledge generators and knowledge users in Canada who routinely engage in or use applied environmental research so that those who have already had some success in this realm might share insights that could help guide others. We first reflected on what "success" (and failure) means in the context of applied environmental research from our collective perspective. We define "success" in applied environmental science as respectfully conducted, partner-relevant research that is accessible, understandable and shared, with the potential to create an opportunity for change. Next, we generated a list of best practices for delivering applied environmental research that is more likely to be "successful". We identified practical guidance for applied researchers and emphasize 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 the being transparent about uncertainties and limitations. Other important considerations include rewarding partners for their involvement and training early career researchers in applied partnership research. Finally, we generated a list of specific measurable indicators for evaluating "success" that broadly span the quality and quantity of scientific outputs, the relationship with the partner(s), the relevance and connectedness of the research, the accessibility and availability of outputs to users, the provision of outputs that are digestible and usable by different audiences, training and capacity building, and ultimate outcomes (e.g., including social, environmental, and economic outcomes, as well as partner satisfaction).

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, policy-makers and environmental practitioners often struggle to make the most appropriate 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. 2004). To that end, researchers in academia, government, industry, and the NGO community conduct studies that aim to generate new knowledge and deepen our understanding of environmental issues and problems.

Given that resources for conducting research are limited, applied research must generate information that is truly relevant and useful to policy makers and practitioners (Milner-Gulland et al. 2012). Moreover, because many current environmental issues are characterized as "crises" (e.g., climate change, biodiversity loss, plastic pollution – see Ripple et al. 2017), there is urgency to deliver this actionable science. Although fundamental science plays a crucial role in tackling environmental issues, problems, and solutions (Lederman 1994; see Littlewood et al. 2012 for an example of fundamental science contributing to improved management of grasslands), actionable findings generally arise from research with the explicit goal of informing policy and practice. As such, applied environmental research that aims to inform policy or practice but fails to do so are a waste of resources, and may put species, ecosystems and humans at risk. Quite simply, environmental policy-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, stakeholder 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.

Although most environmental researchers spend many years in university, formal efforts to train them in how to deliver research that can inform policy and practice are rare (Touval and Dietz 1994). Sometimes there are informal training opportunities usually associated with mentoring by those working in the policy sphere (see Chapman et al. 2015) or formal training programs such as the Leopold Leadership Program or the MITACS Canadian Science Policy Fellowship program. There are 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 to "practice" and learn from your mistakes (Cooke 2019). However, these approaches can be cumbersome, and delays compound the challenges of addressing already difficult environmental problems (Martin et al. 2012). Moreover, if a research project fails, it may jeopardize the ability to secure future funding, and impair other researchers' abilities to work with partners or stakeholders who may feel discouraged by a bad experience.

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. More recently, Fisher et al. (2019) identify four practical steps intended to enhance the impact of environmental science on decision making (i.e., (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). 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 – especially for early career researchers, those transitioning from fundamental to applied research, or those who have attempted to engage in applied research with limited success.

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 that end, we assembled a diverse 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 Approach 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 of fundamental research. In no way are we suggesting that applied research is better or more important than fundamental research. Indeed, much of the applied research of today is built upon the foundations provided by basic fundamental research. We also recognize that fundamental research can be applied in unexpected ways that were not envisioned when the work was conducted. However, when there is targeted funding dedicated towards solving environmental problems, research should deliver on that promise. We also wish to acknowledge that, because all of our authors are Canadian and have experience working in the Canadian funding system (mostly NSERC and SSHRC), our paper will have most relevance to Canada. Different governance structures, institutions, cultures, and values are likely to influence how the issues explored here can be summarized into "tips" that can be directly implemented. As such, although we consider this paper to be broadly relevant to the environmental research community, there will presumably be a need to tailor the recommendations to different contexts.

Our Approach

We assembled a multidisciplinary team of applied environmental researchers (spanning environmental studies and geography, ecology and biodiversity, environmental impact assessment, ecosystem services and sustainability science, environmental chemistry, environmental engineering, environmental policy and governance, and environmental social science) from academia and government. The researcher team spanned stages of career progress (from post docs to senior professors and research scientists) and had approximately equal gender balance. We also included several key figures from the environmental NGO sector (including the Canadian Wildlife Federation and Yellowstone to Yukon) 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 intersection of science and policy. Participants were recruited because they are active in environmental research, and they are recognized among peers 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 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 acknowledge and respect the important role of Indigenous knowledge and engagement with Indigenous Peoples when it comes to all environmental issues. However, how to do so requires specific expertise that is beyond our team or this project. For that reason, we refer readers to Bartlett et al. (2012), Johnson et al. (2016), and Chapman and Schott (2020) for more comprehensive frameworks and discussions on how to respectfully bridge western and Indigenous knowledge systems and engage in ethical and inclusive co-production. Given Indigenous peoples' central role in conservation and environmental management, it is important to better understand what "success" means to Indigenous partners and we urge further work in that space.

What does "success" mean in the context of 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 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 such that an environmental problem could be resolved, creating environmental, economic, or social benefits (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 equally, if not more, important (Nel et al. 2016). 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 Figure 1. In this conceptualization, the first component of "success" can be defined as the extent to which the planning and execution of research involves co-production, engages relevant stakeholders and partners, stimulates capacity building, and involves bi-directional communication (Chapman et al. 2014; 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/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/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 "rigorous" science has a strong likelihood of being ignored (Young et al. 2006). Relatedly, when success is viewed solely from the perspective of the knowledge generator, there can be a disconnect with socio-political 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 the science has been done and new knowledge is in hand (Figure 1). As such, our discussions elicited the idea that the minimum/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 (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 can not find the data or peer reviewed papers, the findings may be ignored (Cook et al. 2013). Conversely, if research is peer-reviewed but not communicated or delivered to appropriate stakeholders, then it will also likely be ignored (McKinley et al 2012). Another logical step is the creation of tools or other knowledge-based products that inform policy and practice (Possingham et al. 2001). If data generated or tools produced fail to meet the needs of partners (and co-creators), this would be a failure. Collectively these actions can establish the potential for outcome/change and result in project-specific proximate and/or ultimate outcomes. For some projects, impact may be viewed in broad terms, such as training the next generation of scientists, publishing papers, changing a policy, while in others impact is focused, such as recovering an at-risk species. It is also important to remember that success isn't always immediate – especially given that changing human behaviour is difficult (Schultz 2011; Nilsson et al. 2019). For example, in some cases, success is increased public awareness, which may take a long time to achieve and may never translate to changes in behaviour (de Lange et al. 2019; Selinske et al. 2018; Nilsson et al. 2019). In other cases, success may simply be providing advice to policy 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 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 policy maker may view success as a new tool or a completed decision. 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 create an opportunity for 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" or incomplete successes have immense value (see Box 2). It is for that reason that we focus on the idea of creating the "potential" to create an opportunity for change rather than change itself, not unlike how Palmer defines "actionable" science (Palmer 2012). We also recognize that it is possible to

conduct successful environmental research independent of partners, but doing so fails to recognize the importance of 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 be the one to use the research findings in the end, but that does not mean that there could not be broader impacts on 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).

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 (Figure 2). These strategies are intentionally short and punchy in the hopes that they resonate with and are retained by readers. We acknowledge that it was impossible to cite all relevant literature so encourage readers to use the cited references as a jumping-off point for finding other materials rather than assuming that they are the only or definitive reference for a given topic.

Know your networks 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 (Caviglia-Harris et al. In prep). 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 Gash 2008). A great place to start is building a 'network map' or visual image of all partners, stakeholders, researchers, and other potential members of the team. This is useful not only to see the connections among players, but also to identify any 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, stakeholders, partners, industry, government, and others. If you don't already know the key players in your study area or for your topic, you can ask those you already know for suggestions of who is missing from your network map and reach out to those people (after, of course, learning about the group so you can understand how they are likely to fit into your team). 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, an NGO with a long history of working with academics might both understand typical academic goals (publications, student training) and typical NGO goals (bring about change in the area).

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

Success in environmental research demands on-going 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, a relationship will never end but rather evolve through time to meet the needs of all 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 when a grant is due to seek a letter of support – and then the letter writer may not ever hear back from the researcher after such a letter is furnished. Similarly, some researchers have adopted a "parachute model" to research where they drop in to do research in a given region or community and then take off

and are never heard from again. Such habits are detrimental to the development of meaningful partnership and respect (Chapman et al. 2014). 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 uni-directional) has been shown to improve project outcomes (Evely et al. 2011).

Don't Rush Relationships

There is a growing momentum towards co-creating projects amongst academic and non-academic partners, which can increase the likelihood of "success" of applied environment research on a number of fronts: 1) ensures that the questions and experimental design of the project are relevant for the "real" world issues being faced; 2) provides fantastic learning opportunities for all members of the project to share knowledge and perspectives on a wide range of issues; and 3) has the potential to enhance the adoption of ideas. 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). In order to build trust effectively, engaging with all participants at the earliest possible moment is more likely to bring about a positive outcome. . For example, Levesque et al. (2017) highlighted that creating a more globally-distributed power structure across the membership and fostering a shared interest in understanding and joint solution development were other factors. Developing subgroups within a collaboration may help facilitate communication and foster engagement across larger networks, particularly when this is paired with opportunities for the entire network to hear from each of the subgroups. A core level of trust needs to be developed across the network of actors but some skepticism is also healthy for encouraging an active debate and the consideration of 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. Adopting a mindset where partners will be embedded as co-authors on the project can also lead to an effective means to truly co-create successful projects.

Define questions and consider pathways <u>together</u>

By definition, applied research involves partnership. And these partnerships need to involve a collaborative approach to determining the questions a research project aims to answer. This is an opportunity to engage in a discussion about what partners are keen to understand and what questions flow from this. Indeed, once you have identified the members of your team and understand their general role in the network, it can be useful to spend time with each member or group, asking questions, and listening to their inputs, concerns, questions, and thoughts on the project. This serves a dual purpose: it gives you a better sense of everyone's role and stance, and it helps each person or group to feel valued as a member of the team. It can also help you understand the history of work, interactions, and progress on the topic at hand in your study area and among your team members. It is also a good idea to express your own interests and goals so that your position is also clear. It can also be useful at this point to try to get a feeling for whether there are strong opinions on different sides of the issue at hand, and if so, which people and groups fall on which side. Depending on your objectives, it may either be helpful to bring people together across this divide or start by keeping groups separate to minimize conflict. 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 trade-offs

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 understandings of the time commitments involved. Not all partners will want the same level of active involvement. Figuring this out at the outset can help ensure ongoing engagement is appropriate.

Be transparent with partners regarding uncertainty and limitations

No matter how good the science, there is always some level of uncertainty and other limitations that constrain the extent to which findings can be applied to a given problem. Scientists are well aware of these realities, yet partners may assume that science is absolute and findings are inherently certain. And, in some cases, it is the researcher who oversells their work – something that can be addressed through better training of scientists on how 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 fully transparent with partners about study uncertainty and limitations. Sutherland et al. (2013) provided a list of twenty 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 is 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 to application of findings. 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 be aiming 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. Boundary spanning demands environmental scientists to step back and appreciate the societal context of an environmental issue and consider the 'sphere of influence' of their research, especially during the planning phase of a project.

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) 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).

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 wildlife 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 that are crucial for success requires a unique skill set. "Successful" applied environmental researchers possess these skills, but they are not innate, and are not taught in university science programs. 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. Case studies in the literature describing challenges and best practices with respect to interdisciplinary partnership (e.g., Podesta et al. 2013; Parker et al. 2018), while useful resources, reinforce the challenges and serve to demonstrate the need for hands-on experience.

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 into partnerships has clear benefits for the students themselves. They are exposed to varied training environments and perspectives, which can make them better prepared for non-academic environmental careers (Cid and Brunson 2020) and broaden their experience and their professional network. In academic environments, they learn to value creativity and originality, while they pursue general understanding of natural phenomena. Stakeholder partners often give higher value to pragmatism and locally relevant information, and the tension between researcher 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, as this may create an unwelcome burden. Engagement early and often ensures that students are prepared with the skills and the 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 deadlines towards their degree, clear expectations and time commitments should be mutually discussed and revisited as needed. When this training is done successfully, the students also 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 conservation's 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 success can be mapped out at early stages of the project (see Define 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 HQP). While changing needs or priorities can sometimes cause tension, they can also lead to new opportunities and 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 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 didn't work (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 the partner in this exercise if at all possible).

Have a plan for outputs/knowledge mobilization/K* developed with partners

There is often a misalignment between research outputs and the demand of knowledge users. Research and discussions over the past couple of decades have illustrated that traditional scientific outputs (i.e. peer-review publications) are not optimal for mobilizing knowledge to the right audiences, particularly to practitioners and decision-makers who have limited time and resources for sifting through the literature (e.g., McNie 2007; Cvitanovic et al. 2016; Young et al. 2016a). Understanding the needs and constraints of knowledge users and partners are critical to developing effective knowledge mobilization (KMb) outputs and strategies. 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 in KMb strategies. Knowing this information is useful for fisheries researchers and managers to ensure evidence-based best practices are used among fishers (Nguyen et al. 2012). Researchers should thus consider making space and time for user needs assessments in their KMb plans.

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; Kalafatis et al. 2015; Young et al. 2016a, 2016b; Nguyen et al. 2019), leading researchers to re-envision 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. Such process can be considered K* (knowledge exchange, translation, brokering, mobilization, etc.), and involves building relationships, connections, and engaging with knowledge users in the design, implementation and dissemination of research. Doing so can both enhance the consideration of your research into practice

and enhance the quality of environmental decisions (reviewed by Reed et al. 2008). In particular, early career researchers may benefit from developing such connections as they may evolve into long-term partnerships where your work may directly feed into decisions and/or your expertise may be sought out directly to inform actions.

More and more granting agencies are requiring knowledge mobilization or K* plans. One cannot assume what the users need, want or what is most effective. Doing your background research, such as consulting with partners, reading annual reports, and familiarizing yourself with the user's context (organization, institution, community), will not only inform your research design but help you speak the same language. Applying what you learned from your background research will also increase the relevance and applicability of your research. Creating a knowledge mobilization or K* 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 or K* plan as well as time to understand user needs.

Reward and acknowledge partners

Token engagement abounds. We recommend wrapping up projects by 'closing the loop' with partners. This reminds us to consider the context of our research and to ask whether we have been effective research partners. It goes beyond the project's exit strategy, which outlines how it ends or is transitioned, and reminds us that the collaboration must meet the needs of our 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 supports and compensation for research activities that is the norm for academic researchers (Higginson 2018; Wallerstein 2019). An example of awareness of power relationships is recognizing rather than rewarding the contributions of research partners. This distinction is important because of the unspoken but inherent power imbalance in the idea of rewarding. Both academic and non-academic 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: advocate for non-academic partners to funding bodies with respect to valuing in-kind contributions of data and expertise; include funding to cover the time of non-academic partners, particularly NGOs, in grant applications; be aware of paywalls and provide access to library resources; find win-win opportunities to use university resources to showcase stories featuring the work and contributions of research partners (e.g. videos). In some instances, the level of acknowledgement may include considering co-authorship on research papers. The extent to which a given partner values such acknowledgement will depend on the interests, organizational culture and contributions of research partners. For example, NGO employees may not be compensated for publication work. Where individual authorship is not appropriate (e.g. community science), authorship that recognizes the contributions of a group provide an alternative (Ward-Fear 2019)

Change the narrative

Successful uptake of environmental research is about more than getting information to the desk of a policy-maker -- evidence must be framed in a user-friendly, persuasive, and politically salient way (Rose 2015; Rose et al. 2017). This means that successful applied research does not end at a peer reviewed publication or even a policy brief, which few busy policy-makers or practitioners have time to read and

which are unlikely to be successful instruments of change. Effectively communicating evidence from research findings is a process that involves understanding the audience that will use the evidence - where listening and connecting is 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). Although communication with partners can be written, emails and other text-based modes of communication are consistently less effective and persuasive than face-to-face meetings (Roghanizad and Bohns 2017). Moreover, do not assume that partners have web access or that an unanswered email is a lack of response. Do not be afraid to pick up the phone, which is also known to 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). Keep in mind that 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 are appealing to emotions and that focus on positive outcomes and solutions are known to effectively communicate scientific messages to wide audiences (Begon 2017; Balmford and Knowlton 2017). To build these clear messages, 'message box' approaches are available to distill research findings into a story tailored to your audience (https://www.compassscicomm.org/message-box-online). For more complex research messages, interactive data visualization tools that allow participation can be far more persuasive (Herring et al. 2017). Decision-makers, again like most people, have different perspectives and values (Sandbrooke et al. 2011); thus, understanding their needs and perspectives is paramount for effective communication (Bainbridge 2014). Finally, if researchers themselves 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

Good environmental management decisions need good information. One of the most powerful aspects of applied research, if done correctly and when possible includes experimentation, is that it can increase our understanding and lead to the generation of 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 harmful decisions (Sells et al. 2018). As noted by Hofself (2018) "If science isn't rigorous, it's reckless", and although this message was coming from the human health field, it is just as relevant to the environmental field. To provide practical and applied information that has relevance – ideally beyond the immediate question or problem – requires a genuine collaboration among researchers and partners (see Define questions and consider pathways together, above); however, scientific rigor 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 rigor. However, researchers must ensure that the integrity and credibility of research is not sacrificed. The underlying goal of researchers should be to produce rigorous, 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/when asked to do anything less.

Protect your integrity

Partnership and co-production can create dynamics and tensions that may be unfamiliar to researchers trained in traditional scientific norms and methods. Partners often have particular outcomes or applications in mind, including political aims which 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. 2016a), 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 explicit agreements with partners about access to raw data, analysis of findings, and communication of results. 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. 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 but also the challenges that they will face in the future as a result of climate change and human population growth, for example.

What are specific indicators of success?

Every project is somewhat unique. For that reason, using the same criteria to assess success for every project will be ineffective. To that end, any efforts that allow project applicants to work with their partners to co-develop relevant metrics/indicators that span the suite of themes identified here is an important strategy for gauging success. Importantly, if this is done from the beginning (i.e., during application phase) it means that efforts to track success will presumably be incorporated into the project and not simply be 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. Accordingly, researchers and partners should be encouraged to be reflective and comment on what worked and what did not. Ideally these reflections would be shared with the broader scientific community if they enabled others to avoid the same pitfalls. Research that reveals "no change" or "status quo" might be a very valid outcome of a project if it is determined that the current tactics used by the partner are effective. In other words, confirmatory research is as relevant as research that leads to change.

Some of the ideas proposed here require significant investment to be done well. For example, detailed debriefing interviews and their analysis require technical capacity. 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 often the informal feedback is more useful and valued than formal teaching evaluations. 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 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. Altmetrics are an example of such an innovation that allows one to assess influence in social media, but it also has its challenges (Erdt et al. 2016). Yet, how to assess societal impact (broadly) in a quantitative manner remains difficult (Bornmann 2012, 2013). Here, we provided some examples of metrics/indicators for environmental impact but note that these will require tailoring for a given study/project/partnership (Table 1).

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 are literally drowning in the knowledge they need to make good evidence-based environmental decisions. Yet, despite being called for more than a decade ago (i.e., Sutherland et al. 2004), evidence-based management still faces many challenges. The reasons why this idea has not been fully embraced or realized 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 rooted in the peer reviewed literature, yet includes proven methods or strategies that are also used by our team members 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 not a 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 and to be simultaneously self-reflective and adaptive to adjust efforts and move towards success. If failure occurs, we strongly encourage researchers to take time to learn from such experiences and share lessons when and where possible. 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 always predict what the future will hold nor how fundamental research will inform policy and practice. If governments and other funding bodies are going to fund applied research with the intent of informing policy and

practice, then such research should have the potential to do so. The strategies that we outline here should facilitate successful outcomes and help researchers, partners and funders gauge when success has been achieved.

Acknowledgements

We thank Jennifer Bean from NSERC for participating in the workshop. Funding was provided by NSERC via an NSE Grant to SJC. Additional support was provided by Carleton University via the Multidisciplinary Research Catalyst Fund.

References

Ansell C., and Alison G. 2008. Collaborative Governance in Theory and Practice. Journal of Public Administration Research and Theory, 18 (4): 543–71. DOI: 10.1093/jopart/mum032.

Bainbridge I. 2014. How can ecologists make conservation policy more evidence based? Ideas and examples from a devolved perspective. Journal of Applied Ecology, 51(5): 1153–1158. DOI: 10.1111/1365-2664.12294

Balmford A., and Knowlton N. 2017. Why earth optimism? Science, 356(6335): 225 LP – 225. DOI: 10.1126/science.aan4082

Baron N. 2010. Escape from the Ivory Tower: A Guide to Making Your Science Matter. Island Press, Washington D.C., USA.

Bartlett C, Marshall M, and Marshall A 2012 Two-eyed seeing and other lessons learned within a co-learning journey of bringing together Indigenous and mainstream knowledges and ways of knowing. J Environ Stud Sci, 2(4):331–340. DOI: 10.1007/s13412-012-0086-8

Begon M. 2017. Winning public arguments as ecologists: time for a new doctrine? Trends in Ecology & Evolution, 32(6): 394–396. DOI: 10.1016/j.tree.2017.03.009

Beier P, Hansen LJ, Helbrecht L, and Behar D. 2017. A how-to guide for coproduction of actionable science. Conservation Letters, 10(3): 288-296.

Beier P, Hansen L J, Helbrecht L, and Behar D. 2017. A how-to guide for coproduction of actionable science. Conservation Letters, 10(3): 288-296.

Bornmann L. 2012. Measuring the societal impact of research. EMBO reports, 13(8): 673-676.

Bornmann L. 2013. What is societal impact of research and how can it be assessed? A literature survey. Journal of the American Society for information science and technology, 64(2): 217-233.

Brown V, Gutknect J, Harden L, et al. 2010. Understanding and engaging values in policy relevant science. Bull. Brit. Ecol. Soc, 41: 48– 56.

Chapman JM, Algera D, Dick M, Hawkins EE, Lawrence MJ, Lennox RJ, and Vu M. 2015. Being relevant: practical guidance for early career researchers interested in solving conservation problems. Global Ecology and Conservation, 4: 334-348.

Chapman JM and Schott S. 2020. Knowledge coevolution: generating new understanding through bridging and strengthening distinct knowledge systems and empowering local knowledge holders. Sustain Sci, DOI: 10.1007/s11625-020-00781-2

Charles A, Loucks L, Berkes F, and Armitage D. 2020. Community science: A typology and its implications for governance of social-ecological systems. Environmental Science & Policy, 106: 77-86.

Cid CC and Brunson MW. 2020. Engaging faculty in preparing students for non-academic environmental careers. Frontiers in Ecology and the Environment, 18: 52-53 DOI: 10.1002/fee.2158

Cook CN, Hockings M, and Carter RW. 2010. Conservation in the dark? The information used to support management decisions. Frontiers in Ecology and the Environment, 8(4): 181-186.

Cook CN, Mascia MB, Schwartz MW, Possingham HP, and Fuller RA. 2013. Achieving conservation science that bridges the knowledge–action boundary. Conservation Biology, 27(4): 669-678.

Cook CN, Nichols SJ, Webb JA, Fuller RA, and Richards RM. 2017. Simplifying the selection of evidence synthesis methods to inform environmental decisions: A guide for decision makers and scientists. Biological conservation, 213: 135-145.

Cook CN, Wintle BC, Aldrich SC, and Wintle BA. 2014. Using strategic foresight to assess conservation opportunity. Conservation Biology, 28(6): 1474-1483.

Cooke SJ. 2019. From frustration to fruition in applied conservation research and practice: ten revelations. Socio-Ecological Practice Research, 1:15-23.

Costanza R, and Jorgensen SE. (Eds.). 2002. Understanding and solving environmental problems in the 21st century: toward a new, integrated hard problem science. Elsevier, Amsterdam.

Crutzen PJ. 2006. The “anthropocene”. In Earth system science in the anthropocene (pp. 13-18). Springer, Berlin, Heidelberg.

Jones MD, and Anderson Crow D. 2017. How can we use the ‘science of stories’ to produce persuasive scientific stories? Palgrave Communications, 3(1): 53. DOI: 10.1057/s41599-017-0047-7

Rose DC, Mukherjee N, Simmons BI, Tew ER, Robertson RJ, Vadrot ABM, Doubleday R, and Sutherland WJ. Policy windows for the environment: Tips for improving the uptake of scientific knowledge. Environmental Science and Policy, In Press. DOI: 10.1016/j.envsci.2017.07.013.

De Lange E, Milner-Gulland EJ, and Keane A. 2019. Improving environmental interventions by understanding information flows. Trends in ecology & evolution, 34(11): 1034-1047.

De Wit A. 1988. Measurement of project success. International journal of project management, 6(3): 164-170.

Deventer H, and Reyers B. 2016. Knowledge co-production and boundary work to promote implementation of conservation plans. Conservation Biology, 30:176-188.

Dicks LV, Walsh JC, and Sutherland WJ. 2014. Organising evidence for environmental management decisions: a ‘4S’hierarchy. Trends in ecology & evolution, 29(11): 607-613.

Donaldson MR, and Cooke SJ. 2014. Scientific publications: Moving beyond quality and quantity toward influence. BioScience, 64(1): 12-13.

Donner SD. 2017. Risk and responsibility in public engagement by climate scientists: Reconsidering advocacy during the Trump era. Environmental Communication, 11(3): 430-433.

Dubois NS, Gomez A, Carlson S, and Russell D. 2020. Bridging the research-implementation gap requires engagement from practitioners. Conservation Science and Practice, 2(1): e134.

Ellison AM. 2010. Repeatability and transparency in ecological research. Ecology, 91(9): 2536-2539.

Erdt M, Nagarajan A, Sin SCJ, and Theng YL. 2016. Altmetrics: an analysis of the state-of-the-art in measuring research impact on social media. Scientometrics, 109(2): 1117-1166.

Evely AC, Pinard M, Reed MS, and Fazey I. 2011. High levels of participation in conservation projects enhance learning. Conservation Letters, 4(2): 116-126.

Filstrup CT. 2019. How to be a better scientist. Limnology and Oceanography Bulletin, 28: 148-149.

Fisher JRB, Wood S, Bradford MA, and Kelsey TR. 2019. Improving your impact: how to practice science that influences environmental policy and management. DOI: 10.32942/osf.io/u34b2

Herring J, VanDyke MS, Cummins RG, and Melton F. 2017. Communicating Local Climate Risks Online Through an Interactive Data Visualization. Environmental Communication, 11(1): 90–105. DOI: 10.1080/17524032.2016.1176946

Higginson K. 2018. Start the CCE relationship right – opportunities for community and academic partners to think about power. Community First: Impacts of Community Engagement blog, 12 October, 2018. Available at: https://carleton.ca/communityfirst/2018/start-the-cce-relationship-right-opportunities-for-community-and-academic-partners-to-think-about-power/

Hilborn R. 1987. Living with uncertainty in resource management. North American Journal of Fisheries Management, 7(1): 1-5.

Hofseth LJ. 2018. Getting rigorous with scientific rigor. Carcingoenesis, 39(1): 21-25.

Johnson JT, Howitt R, Cajete G, Berkes F, Pualani Louis R, Kliskey A. 2016. Weaving Indigenous and sustainability sciences to diversity our methods. Sustain Sci, 11:1–11. DOI: 10.1007/s11625-015-0349-x

Kingdon JW. 2003. Agendas, alternatives, and public policies. 2nd edition. Little Brown and Company, Boston.

Kuebbing SE, Reimer AP, Rosenthal SA, Feinberg G, Leiserowitz A, Lau JA, and Bradford MA. 2018. Long-term research in ecology and evolution: A survey of challenges and opportunities. Ecological Monographs, 88(2): 245-258.

Kyvik S, Smeby J. 1994. Teaching and research. The relationship between the supervision of graduate students and faculty research performance. High Educ, 28: 227–239 DOI: 10.1007/BF01383730

Lackey RT. 2016. Keep science and scientists credible: avoid stealth policy advocacy. Bulletin of the Ecological Society of Australia, 46(3): 14-15.

Laurance WF, Koster H, Grooten M, Anderson AB, Zuidema PA, Zwick S, ... and Anten NP. 2012. Making conservation research more relevant for conservation practitioners. Biological Conservation, 153: 164-168.

Lederman LM. 1984. The value of fundamental science. Scientific American, 251(5): 40-47.

Leung W, Noble B, Gunn J, and Jaeger JA. 2015. A review of uncertainty research in impact assessment. Environmental Impact Assessment Review, 50: 116-123.

Littlewood NA, Stewart AJ, and Woodcock BA. 2012. Science into practice–how can fundamental science contribute to better management of grasslands for invertebrates? Insect Conservation and Diversity, 5(1): 1-8.

Lovallo D, and Kahneman D. 2003. Delusions of success. Harvard business review, 81(7): 56-63.

Martin TG, et al. 2012. Acting fast helps avoid extinction. Conserv Lett, 5:274–280.

Matson P, Clark WC, and Andersson K. 2016. Pursuing sustainability: a guide to the science and practice. Princeton University Press, New Jersey.

Maxwell K, Hubbell B, Eisenhauer E. 2019. Institutional insights on integrating social and environmental science for solutions-driven research. Environ. Sci. Policy, 101:97–105.

McKinley DC, Briggs RD, and Bartuska AM. 2012. When peer-reviewed publications are not enough! Delivering science for natural resource management. Forest Policy and Economics, 21, 1–11. DOI: 10.1016/j.forpol.2012.03.007Nel

Milner-Gulland EJ, Barlow J, Cadotte MW, Hulme PE, Kerby G, and Whittingham MJ. 2012. Ensuring applied ecology has impact. Journal of Applied Ecology, 49(1): 1-5.

Moon K, Adams VM, Januchowski-Hartley SR, Polyakov M, Mills M, Biggs D, ... and Raymond CM. 2014. A multidisciplinary conceptualization of conservation opportunity. Conservation Biology, 28(6): 1484-1496.

Nel JL, Roux DJ, Driver A, Hill L, Maherry AC, Snaddon K, ... and Reyers B. 2016. Knowledge co-production and boundary work to promote implementation of conservation plans. Conservation Biology, 30(1): 176-188.

Nguyen VM, Rudd MA, Hinch SG, and Cooke SJ. 2013. Recreational anglers' attitudes, beliefs, and behaviors related to catch-and-release practices of Pacific salmon in British Columbia. Journal of Environmental Management, 128: 852-65.

Nguyen VM, Young N, and Cooke SJ. 2017. A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. Conservation Biology, 31(4): 789–798

Nguyen VM, Young N, Brownscombe JW, Cooke SJ. 2019. Collaboration and engagement produce more actionable science: quantitatively analyzing uptake of fish tracking studies. Ecological Applications, 29(6):e01943.

Nilsson D, Fielding K, and Dean A. 2019. Achieving conservation impact by shifting focus from human attitudes to behaviors. Conservation Biology, 34(1): 93-102.

Palmer MA. 2012. Socioenvironmental sustainability and actionable science. BioScience, 62(1): 5-6.

Parker PG, Miller RE, Goodman SJ. 2018. Collaboration and the Politics of Conservation. In: Parker P. (eds) Disease Ecology. Social and Ecological Interactions in the Galapagos Islands. Springer, Cham.

Parr TW, Sier AR, Battarbee RW, Mackay A, and Burgess J. 2003. Detecting environmental change: science and society—perspectives on long-term research and monitoring in the 21st century. Science of the total environment, 310(1-3): 1-8.

Penfield T, Baker MJ, Scoble R, and Wykes MC. 2014. Assessment, evaluations, and definitions of research impact: A review. Research evaluation, 23(1): 21-32.

Phillis CC, O'Regan SM, Green SJ, Bruce JE, Anderson SC, Linton JN, ... and Favaro B. 2013. Multiple pathways to conservation success. Conservation Letters, 6(2): 98-106.

Podesta et al. 2013. Interdisciplinary production of knowledge with participation of stakeholders: A case study of a collaborative project on climate variability, human decisions and agricultural ecosystems in the Argentine Pampas. Environmental Science & Policy 26: 40-48.

Polasky S, Carpenter SR, Folke C, and Keeler B. 2011. Decision-making under great uncertainty: environmental management in an era of global change. Trends in ecology & evolution, 26(8): 398-404.

Posner SM, Cvitanovic C. 2019. Evaluating the impacts of boundary-spanning activities at the interface of environmental science and policy: A review of progress and future research needs. Environ. Sci. Policy, 92:141–151.

Possingham HP, Andelman SJ, Noon BR, Trombulak S, and Pulliam HR. 2001. Making smart conservation decisions. Conservation biology: research priorities for the next decade, 23: 225-244.

Ripple WJ, Wolf C, Newsome TM, Galetti M, Alamgir M, Crist E, ... and 15,364 scientist signatories from 184 countries. 2017. World scientists' warning to humanity: a second notice. BioScience, 67(12): 1026-1028.

Roche DG, Bennett JR, Provencher J, Rytwinski T, Haddaway NR, Cooke SJ. 2019. Environmental sciences benefit from robust evidence irrespective of speed. Science of the Total Environment 696: e134000 DOI: 10.1016/j.scitotenv.2019.134000

Roghanizad, M. M., & Bohns, V. K. (2017). Ask in person: You're less persuasive than you think over email. Journal of Experimental Social Psychology, 69, 223–226. DOI: 10.1016/j.jesp.2016.10.002

Kuehne L, Twardochleb L, Fritschie K, Mims M, Lawrence D, GIBSON P, … and Olden J. 2014. Practical Science Communication Strategies for Graduate Students: Graduate Student Science Communication. Conservation Biology, 28. DOI: 10.1111/cobi.12305

Rose DC, Amano T, González-Varo JP, Mukherjee N, Robertson RJ, Simmons BI, ... and Sutherland WJ. 2019. Calling for a new agenda for conservation science to create evidence-informed policy. Biological Conservation, 238: 108222.

Rose DC, Mukherjee N, Simmons BI, Tew ER, Robertson RJ, Vadrot AB, ... and Sutherland WJ. 2017. Policy windows for the environment: Tips for improving the uptake of scientific knowledge. Environmental Science & Policy.

Safford HD, Sawyer SC, Kocher SD, Hiers JK, and Cross M. 2017. Linking Knowledge to Action: The Role of Boundary Spanners in Translating Ecology. Frontiers in Ecology and the Environment, 15(10): 560–68. DOI: 10.1002/fee.1731.

Sandbrook C, Scales IR, Vira B, and Adams WM. 2011. Value Plurality among Conservation Professionals. Conservation Biology, 25(2): 285–294. DOI: 10.1111/j.1523-1739.2010.01592.x

Schultz PW. 2011. Conservation means behavior. Conservation Biology, 25(6): 1080-1083.

Schwartz MW, Cook CN, Pressey RL, Pullin AS, Runge MC, Salafsky N, ... and Williamson MA. 2018. Decision support frameworks and tools for conservation. Conservation Letters, 11(2): e12385.

Selinske M, Garrard G, Bekessy S, Gordon A, Kusmanoff A, and Fidler F. 2018. Revisiting the promise of conservation psychology. Conservation Biology, 32(6): 1464-1468.

Sells SN, Bassing SB, Barker KJ, Forshee SC, Keever AC, Goerz JW, and Mitchell MS. 2018. Increased scientific rigor will improve reliability of research and effectiveness of management. The Journal of Wildlife Management, 82(3): 485-494.

Shackeroff JM, and Campbell LM. 2007. Traditional ecological knowledge in conservation research: problems and prospects for their constructive engagement. Conservation and Society, 5(3): 343-360.

Smith B, Baron N, English C, Galindo H, Goldman E, McLeod K, … Neeley E. 2013. COMPASS: Navigating the rules of scientific engagement. PLOS Biology, 11(4): e1001552. DOI: 10.1371/journal.pbio.1001552

Sutherland WJ, and Woodroof HJ. 2009. The need for environmental horizon scanning. Trends in ecology & evolution, 24(10): 523-527.

Sutherland WJ, Spiegelhalter D, and Burgman M. 2013. Policy: Twenty tips for interpreting scientific claims. Nature News, 503(7476): 335.

Rose DC. 2014. The case for policy relevant conservation science. Conservation Biology, 29(3): 748-754.

Toomey AH, Knight AT, and Barlow J. 2017. Navigating the space between research and implementation in conservation. Conservation Letters, 10(5): 619-625.

Touval JL, and Dietz JM. 1994. The problem of teaching conservation problem solving. Conservation Biology, 8(3): 902-904.

Turner BL, Esler KJ, Bridgewater P, Tewksbury J, Sitas JN, Abrahams B, Chapin FS, Chowdhury RR, Christie P, Diaz S, Firth P, Knapp CN, Kramer J, Leemans R, Palmer M, Pietri D, Pittman J, Sarukhán J, Shackleton R, Seidler R, van Wilgen B, Mooney H. 2016. Socio-Environmental Systems (SES) Research: What have we learned and how can we use this information in future research programs. Curr. Opin. Environ. Sustain, 19:160–168.

Wall TU, McNie E, and Garfin GM. 2017. Use-inspired science: making science usable by and useful to decision makers. Frontiers in Ecology and the Environment, 15(10): 551-559.

Wallerstein N, Muhammad M, Sanchez-Youngman S, Epinosa PR, Avila M, Baker EA, Barnet S, Belone L, Golub M, Lucero J, Mahdi I, Noyes E, Nguyen T, Roubideaux Y, Sigo R, and Duran B. 2019. Power

dynamics in community-based participatory action research: A multiple-case study analysis of partnering contexts, histories, and practices. Health Education & Behavior. 46(1S): 19S-32S.

Walsh JC, Dicks LV, and Sutherland WJ. 2015. The effect of scientific evidence on conservation practitioners' management decisions. Conservation Biology, 29(1): 88-98.

Ward-Fear G, Pauly GB, Vendetti JE and Shine R. 2020 Trends in Ecology & Evolution, 35(3): 187-189.

Wells RP, Hochman MN, Hochman SD, and O'Connell PA. 1992. Measuring environmental success. Environmental Quality Management, 1(4): 315-327.

Young N, Corriveau M, Nguyen VM, Cooke SJ, and Hinch SG. 2016. How do potential knowledge users evaluate new claims about a contested resource? Problems of power and politics in knowledge exchange and mobilization. Journal of Environmental Management, 184(2): 380–388.

Box 1. Glossary of Key Terms – These operational definitions reflect what we perceive as norms in the realm of environmental research and practice in Canada.

Co-Production – An approach to research in which researchers and relevant partners and/or stakeholders, some of which 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 which is a researcher and one of which 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 form of in-kind support. For environmental 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.

Stakeholder – A person or group of people with interest in a given topic/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/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 and stakeholders.

Box 2. On 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". In fact, even environmental science that is co-produced and follows "best practices" (outlined below) does not mean that it will be used, at least within a reasonable time-scale (e.g., within say 5 years – it could be after ones career has ended 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 and there could even be instances in which the research is initiated in an attempt to exploit a policy window yet given the time needed to conduct the science and constantly evolving policy needs, the window is "closed" by the time the science is available (Rose et al. 2017). There is much outside the control of the researcher (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.

Table 1. Indicators of Success. Here we list indicators of success organized by themes. For each indicator we also comment on (1) timeline for which the indicator can be reliably assessed including prior to starting the project (Prior), during project (During), immediately at project conclusion (Conclusion), one year after conclusion (1yr) or five or more years after project conclusion (5yr+) or a combination of time periods; (2) responsible party for evaluating impact (e.g., researchers, partners, trainee, broader scientific community [including referees, granting bodies, peers], etc.), and the (3) 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 or stakeholders).

Indicator	**Timeline**	**Responsible Party**	**Relative Ease**
Quality and Quantity of Scientific Outputs			
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 humans in research)?	During, Conclusion	Researchers, Broader scientific community	Easy
How many outputs have been produced (e.g., peer reviewed publications, conference presentations)?	During, Conclusion, 1yr	Researchers	Easy
Were outputs shared in reputable outlets with rigorous peer review processes (e.g., that align with the Committee on Publication Ethics guidelines)?	During, Conclusion, 1yr	Researchers, Broader scientific community	Easy
Have outputs been cited by other peer reviewed outlets?	Conclusion, 1yr, 5yr+	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	During, Conclusion	Researchers, Partners	Moderate

outputs or group authorships where appropriate)?			
To what extent does the partner trust the research team (e.g., measured by nature of letters in application)?	Prior, During	Researchers, Partners, Broader scientific community	Moderate
To what extent has the partner interacted directly with trainees?	During, Conclusion	Trainees, Researchers, Partners	Moderate
Are the partner workshops well-attended with increasing attendance?	During, Conclusion	Researchers	Easy
Has previous research with partner led to additional questions/research ideas?	During, Conclusion, 1yr	Researchers, Partner	Moderate
To what extent has the partner provided tangible financial or in-kind contributions (scaled to the size of the organization)?	During, Conclusion	Researchers, Partner	Easy
To what extent has the funders/partners sought continued partnership?	Conclusion, 1yr, 5yr+	Researchers	Easy
Relevance and Connectedness of Research			
Is there an articulated conceptual model which describes how research will (or could) inform the activities of the partner?	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, 1yr, 5yr+	Researchers, Partners	Easy
To what extent have the findings from the research been incorporated into evidence syntheses?	1yr, 5yr+	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/expertise are made by the partner?	During	Researchers, Partners	Easy
To what extent are outputs (especially publications) “audience-reviewed” (not just academic/peer-reviewed)?	During	Researchers, Partners	Easy
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/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 the public (based on website hits and downloads)?	During, Conclusion, 1yr	Researchers, Partners, Broader scientific community	Easy
Are the data FAIR – findable, accessible, interoperable and reusable (i.e., do they follow FAIR guidelines)?	Conclusion, 1yr	Researchers, Broader scientific community	Easy
How many FAIR data sources have been made available online?	Conclusion, 1yr	Researchers, Broader scientific community	Easy
Is relevant statistical code available online?	Conclusion, 1yr	Researchers, Broader scientific community	Easy
How many times have end users and others downloaded or requested information?	Conclusion, 1yr, 5yr+	Researchers, Broader scientific community	Easy
Who has downloaded or requested information (e.g., which types of organizations)?	Conclusion, 1yr, 5yr+	Researchers, Broader scientific community	Moderate
How many open access publications were generated?	Conclusion, 1yr	Researchers	Easy
What are the Altmetric scores for outputs?	Conclusion, 1yr	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, 1yr	Researchers, Partners, Broader scientific community	Easy
Are relevant components of the project outcomes translated to key audiences (e.g., French, Indigenous languages)?	Conclusion	Researchers	Easy
Were plain language summaries appropriate for policy makers (e.g., policy brief) or the general public produced?	Conclusion, 1yr	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, 1yr, 5yr+	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 non-scientific audiences (and number of attendees)?	Conclusion	Researchers	Easy

Were any alternative forms of engagement delivered to non-scientific audiences (e.g., story boards, training to conduct ongoing monitoring)?	Conclusion	Researchers	Easy
Were there changes in literacy or human behaviour?	1yr, 5yr+	Researchers	Difficult
Were there changes in readiness for adoption of new technologies?	1yr, 5yr+	Researchers	Difficult
Training and Capacity Building			
How many of the trainees have been hired by the partner or other allied organizations?	During, Conclusion, 1yr	Trainees, Researchers, Partners	Moderate
Have trainees obtained relevant employment (recognizing the breadth of employment opportunities that are potentially relevant)?			
Did the trainees have an enriched experience as a result of working with the partner (captured via stories/narratives from trainees)?	During, Conclusion, 1yr	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
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, Economical			
Was the problem/issue of the partner solved/addressed?	Conclusion, 1yr, 5yr+	Researchers, Partners	Moderate
By solving/addressing the problem/issue were there benefits that extended to other partners and society more broadly?	Conclusion, 1yr, 5yr+	Researchers, Partners, Publics	Difficult
Were pre-defined targets achieved? Note – these can be tailored to a given project. For example, some may include: Increased area of land/water/air-scape protected from development; Stricter regulation on use/disposal of toxic chemicals; Reduction in	Conclusion, 1yr, 5yr+	Researchers, Partners, Publics	Moderate

number of at-risk species in defined area; Trends in consumer and/or investor behaviour; Implementation of action plans based on evidence)			
To what extent does the research address issues identified in broader horizon scans or gap analyses?	Conclusion, 1yr	Researchers, Broader scientific community	Moderate
To what extent has knowledge arising from the project influenced political will and platforms?	1yr, 5yr+	Researchers, Broader Scientific community, Publics	Difficult
Is the work cited in impact assessment or other regulatory decision documents?	1yr, 5yr+	Researchers, Broader Scientific community	Moderate
Were qualitative honest narratives summarizing successes and failures/challenges produced?	Conclusion, 1yr	Researchers	Moderate
Has there been an increase in public engagement related to the topic (e.g., increase in stewardship, donations, volunteer time)?	Conclusion, 1yr, 5yr+	Researchers, Broader Scientific community, Publics	Difficult

FIGURES

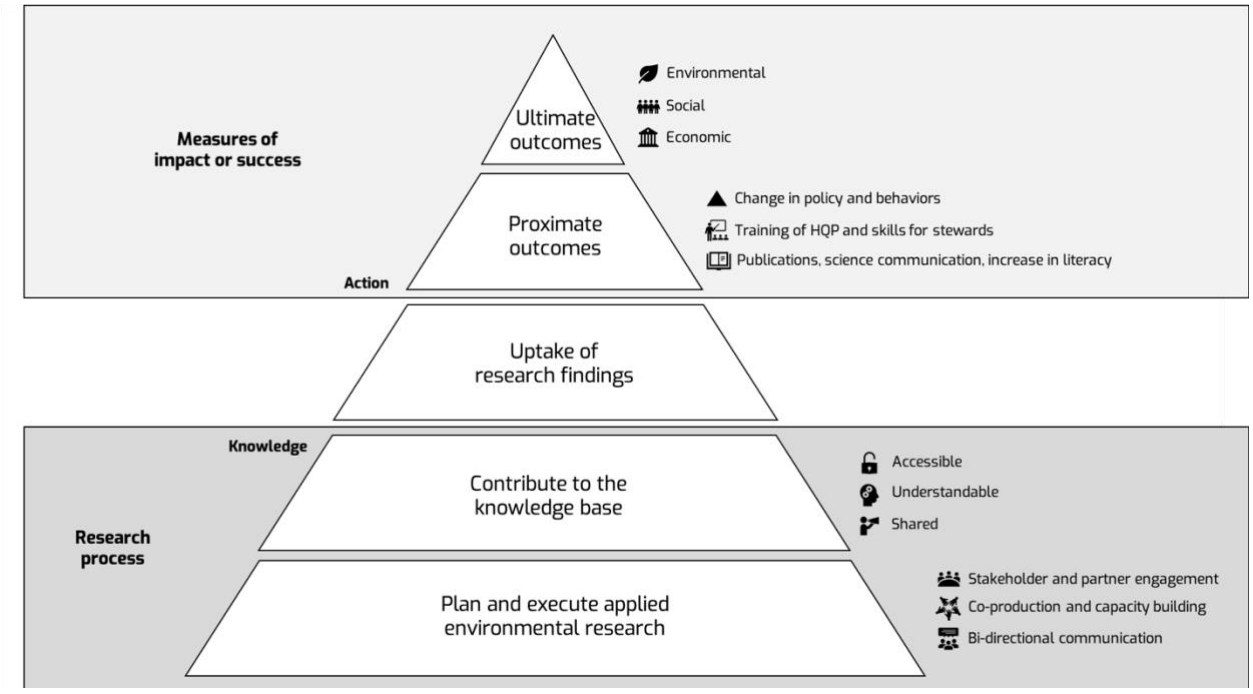

Figure 1.

Components of "success" in an applied environmental research ecosystem. Tier 1 – Conduct well-designed and connected/relevant applied research, with consideration for the scale, timing, and the 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. Tier 5 – Ultimate outcomes result from providing the science needed to resolve an environmental problem and creating environmental, economic, or social benefits.

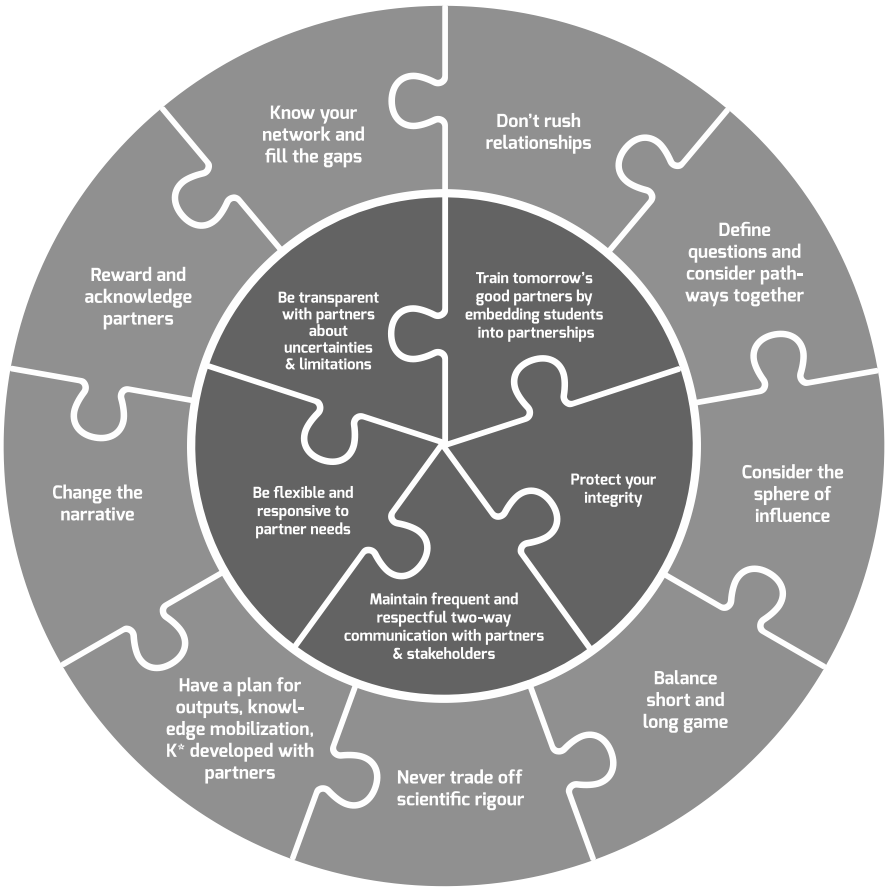

Figure 2.

Best practices that collectively create a recipe for achieving success in applied environmental research. At the core, 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.