Improving scientific impact: how to practice science that influences environmental policy and management

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Practice-focused Review

Short running title: How to improve scientific impact

Our audience is scientists (whether academic or applied) who want to increase the impact of their research; our paper has 5,943 words from the Abstract (167 words) through Acknowledgements and excluding the Literature Cited, and we have 86 references, 2 figures, and 1 table.

Abstract

Scientists devote substantial time and resources to research to help solve environmental problems. Environmental managers and policymakers must decide which actions to prioritize to achieve environmental outcomes, based on the best-available evidence. Yet there can be barriers to decision-makers using this evidence to decide how to act. They may be unaware of the evidence, lack access to it, not understand it, or view it as irrelevant. This means a valuable resource (evidence) is underused. To improve the impact of research on decision-making, we outline a set of practical steps for scientists: (1) Identify and understand the audience; (2) Clarify the need for evidence; (3) Gather "just enough" evidence; and (4) Share and discuss the evidence. These are guidelines, not a strict recipe for success. But we believe that developing a habit of following these recommendations should increase the chance of evidence being considered and used in environmental decision-making. Our goal is for this paper to be accessible to anyone, rather than a comprehensive review of the topic.

Keywords: research impact, evidence, applied science, decision-making, stakeholder engagement, science communication

Introduction

Decisions about environmental policy and management are often made in short time-frames (Rose et al. 2018) and with high uncertainty (Cook et al. 2010). Environmental managers and policymakers need to quickly decide what to do to achieve their goals (Esch et al. 2018). Environmental and conservation scientists seek to (and are regularly asked to) provide evidence to inform these decisions. Academic scientists are also increasingly motivated to conduct research that informs management and policy (Emerald Publishing 2019).

Yet often research does not shape action (Knight et al. 2008, Sutherland and Wordley 2017), and is designed without input from potential users. In our experience, environmental scientists face a double-edged sword. We are concerned about the slow pace of action and the lack of willingness by decision-makers to use evidence to shape policy and practice. But we also struggle to deliver evidence fast enough to affect decisions that are imminent. The result is that: 1) many environmental scientists—whether in non-profits, government, or universities—produce work that has little to no impact on the decisions they seek to influence; and 2) decisions are often made without the information needed to evaluate alternate actions. There is thus a need to better connect evidence with decision-making. But scientists cannot get their work used by themselves; many non-scientific skills are typically needed, including building relationships and communicating with decision makers and stakeholders. Scientists should work with colleagues who bring complementary skills, relationships, and experiences. An important step to increasing the impact of evidence has been progress in how to synthesize and communicate existing data to potential users. For example, there is growing focus on how to produce concise and actionable synopses (Walsh et al. 2015, Cairney and Kwiatkowski 2017), positive framing and highlighting "bright spots," (Tversky and Kahneman 1981, Cvitanovic and Hobday 2018), and how to respond to or create policy windows for evidence to be used (Rose et al. 2017). These advances focus on the process of synthesizing evidence; however, there is need for greater attention to what comes before and after the collection and analysis of data: how to decide what are the right data to collect and how to get that summary used. Academics have analyzed this gap and recommended the need to bridge it (Cook et al. 2013, Enquist et al. 2017, Hallett et al. 2017, Lawson et al. 2017). This literature often lacks step-by-step practical guidelines for scientists in a short and simple package that they can use to make their work more relevant and visible. It also often uses jargon or requires reading other papers for essential context. There are some exceptions with useful explicit suggestions (Jacobs et al. 2005, Cockburn et al. 2016, Beier et al. 2017, Pohl et al. 2017, Rose et al. 2017), but each omits some steps we have found to be important. For example, none of the guides we reviewed cover how much information to gather, most have minimal guidance on outreach for finished research (e.g. Beier et al. 2017 & Pohl et al. 2017), and some focus on how to build long-term collaboration rather than offering smaller and simpler opportunities (e.g. Cockburn et al. 2016).

Here, we provide practical recommendations to increase the likelihood that environmental science will lead to impact. These recommendations are broken down into four categories (Figure 1) with more detail in a flow chart (Figure 2). Most of our recommendations are well known by experts in research impact (Rose et al. 2019), but each of them has been novel to some of the potential users we spoke to when preparing this. Our intended audience is non-profit, government and interested academic environmental and conservation scientists of all career stages, though we believe our recommendations will be relevant to other applied scientists, like agronomists and public health researchers. We use the term “scientists” as shorthand for “environmental and conservation scientists.” Talking to our intended audience revealed that major barriers to reading scientific literature are paper length and the need to read several papers for essential context. So, we use simple language, favor brevity over completeness, and do not assume our readers are familiar with relevant literature or have time to read beyond this paper.

In writing this article we are motivated by our own challenges, failures, and successes to produce actionable evidence. We have struggled with wanting the evidence we create to have impact and seeking evidence to quickly incorporate into practice. Improving is hard: even in writing this, we struggled to follow our own advice at times, and we needed help from other experts. Most of our insights were gained from past successes and failures , which are critical for learning (Catalano et al. 2018).

In pursuit of brevity, we do not provide a comprehensive review of the rich literature on science impact. In particular, our paper does not seek to replicate well-developed guidelines for evidence synthesis (Dicks et al. 2014, Game et al. 2015, Esch et al. 2018, Qiu et al. 2018, Schwartz et al. 2018, Salafsky et al. 2019, and many more). Instead, we offer an easy to read stand-alone document that can be used by scientists without knowledge of the broader literature. We also recognize many papers have made a case for the value of more impactful science (Sutherland et al. 2004, McNie 2007, Knight et al. 2008, Enquist et al. 2017, Wall et al. 2017, Bednarek et al. 2018). We build on this by focusing on *how* scientists can have more impact. This is not easy, and does not guarantee success; our guidelines are relatively simple and impact often depends on factors outside the control of scientists (Cairney and Oliver 2018, Rose et al. 2019). We believe that developing a habit of following these recommendations will increase the chance of one's science being considered and used in environmental decision-making.

We group our recommendations into four areas: (1) Identify and understand the audience; (2) Clarify the need for evidence; (3) Gather "just enough" evidence; and (4) Share and discuss the evidence (Figure 1). In each we explain why it is important and how to do it.

1. Identify and understand the audience

It is more likely that research will be used if it answers a specific question for a specific audience. We use the terms “audience” and “potential users” synonymously to avoid repetition. However, such umbrella categories (i.e. audience, potential users, stakeholders, decision-makers, etc.) are vague constructs and influencing action often requires influencing multiple actors (Table 1). We also recommend partnering with potential users throughout the research process, rather than a 1-way relationship focused on translation (Bednarek et al. 2018, Bertuol-Garcia et al. 2018). Scientists may begin with an “audience” in mind who develops into a close partner as opposed to just a recipient of evidence. Partnership enables co-production of solutions-oriented research (Enquist et al. 2017); (Lang et al. 2012).

1.1 Why it is important

For research to be used, it should answer a question that is relevant to at least one type of potential user, which requires understanding who will use the evidence and in what context. This will often require engaging with multiple audiences with different objectives and information needs (Table 1); decision-making is often the outcome of interactions between many types of “decision-makers.” For instance, the actions of land stewards are often influenced by immediate and practical management needs in a specific context. Program or organizational leaders require information on the broader impact or relevance of different strategies. Policymakers are frequently focused on the impact an action will have on multiple objectives, including costs and benefits, at a broad scale. Research and scientific evidence need to influence several types of people to lead to impact. People in these different roles often require different types of evidence – and research products – to address their needs and motivate them to change their planned actions. It also often requires collaborative work and sustained engagement with those potential users to ensure buy-in and relevance (Cockburn et al. 2016).

Understanding the audience and how they may use evidence allows tailoring the type and form of evidence to better meet their needs. Long-standing relationships between potential users and scientists can help with understanding one's audience, building trust and credibility, and creating opportunities for impact including co-developing applied research (Cvitanovic et al. 2016, Cairney and Oliver 2018). These relationships help scientists to understand and meet the needs of their partner.

Our guidance is focused on new scientific activities, but with the objective of developing long-standing partnerships. Such new scientific activities may come from a motivated scientist without established relationships who is seeking to apply their work. Similarly, scientists at nonprofit organizations may have a mission-driven strategy, without having clearly identified which audience is most important to influence. Scientists should be clear on their motivations and role – whether they are advocating for a particular action, or serving as an honest broker of options to meet an outcome without strong preferences of their own. Sharpening the focus of the research and end products on specific users (Table 1) will help improve the specificity of the evidence for the decision at hand and improve the likelihood the evidence will be used.

For example, given growing risks of severe forest fires in California there is a push to reintroduce prescribed fire. But there are competing value systems that will influence if and how this should be done. The conservation community already has solid evidence that reintroducing fire as a natural process is necessary for restoring the resilience of western forests (Hessburg et al. 2016). However, there are multiple barriers to increasing use of prescribed fire. Among these are the potential public health impacts of smoke exposure (Brown et al. 2009) and risk of property loss from escaped fires. To influence state agencies responsible for permitting prescribed fire, scientists may need to show how prescribed fire size and timing can minimize air quality and human health concerns (Prunicki et al. 2019). Alternatively, to get support from the Federal Emergency Management Agency (FEMA), it may be preferable to highlight the ability of prescribed fire to reduce damage caused by wildfires.

1.2 How to do it

Before gathering evidence, identify and engage the audience who can act to help solve a problem of mutual interest (Figure 2). Engage in the community working on this problem to deepen understanding of the problem and the relevant audience. Seek to understand which potential users influence the problem, their needs and objectives, how they see the problem, and whether they perceive a need for evidence. Alternatively, if the audience matters more than the research topic, determine how to collaborate with them and how they view the problem.

1.2.1 Identify the specific, potential audience(s) the research should inform

There may be multiple audiences with different forms of influence and different science needs who could be partners to achieve tangible impact (Marshall et al. 2017). Decide whether questions addressed through research or evidence gathering are relevant to the decision-making of each targeted audience (not always possible), or just one audience. For example, the Pew Charitable Trusts is developing a tool aimed at helping policy-makers understand how potential changes to fishing subsidies would impact fish catch and economic activity. While doing so, it became clear that it would not work well for an intended secondary audience of the general public.

1.2.2 Engage in the relevant community of practice

This can include going to practitioner's conferences and joining science advisory committees that are collectively tackling the issue the research addresses. It could also include discussions on social media or online forums, and individual meetings with key potential users. Scientists can play an important role in bringing parties together around an issue and guiding collaborative development of research to solve a problem for a specific audience.

1.2.3 Work with the target audience(s) to identify and clarify the problem(s) they are trying to solve

Ideally research is "co-produced" where potential users iteratively work with scientists to design research (Dilling and Lemos 2011, Beier et al. 2017, Enquist et al. 2017), as opposed to knowledge only flowing from scientists to potential users (Bertuol-Garcia et al. 2018). Engage the target audience to discuss their perspective on the problem. If they are interested in a different problem, determine whether both can be solved together or identify a problem that is a shared priority. Discuss possible applications which can sharpen the research concept and lead to tangible collaborations. Understand their vision for the future as it relates to this issue, and what aspects of research they value (Dunn and Laing 2017). Co-production carries some risks (e.g., participating scientists may be perceived as less independent or credible by other scientists) and takes longer (Oliver et al. 2019). If initial assessments with potential users reveal that research will not be generalizable for broader application, consider whether co-production is still worth it (Sutherland et al. 2017).

2. Clarify the need for evidence

Evidence often does not lead to action, especially when the evidence does not meet the information needs of potential users. Determine what evidence *would* motivate and empower the audience to do something new or different.

2.1 Why it is important

As noted above, evidence alone rarely catalyzes action. The role of applied science should be to produce and share whatever knowledge would best help the potential users reach a good decision. It is important to understand how the target audience perceives evidence, and whether or not a lack of evidence is a barrier to change (Marshall et al. 2017, Kary et al. 2018). For example, more research on the causes of climate change has had a minimal effect on public beliefs about the underlying cause (Brulle et al. 2012). Further, when conflicting evidence exists, it can lead to camps becoming entrenched behind different paradigms.

Evidence users and evidence creators may have different ideas of the type of evidence needed (Game et al. 2018). Consider the example of mitigating climate change through soil management that sequesters carbon from the atmosphere into soils (Zomer et al. 2017). To include soil management in formulating national greenhouse gas emission targets for the United Nations Framework Convention on Climate Change (UNFCCC), evidence is needed to identify which practices most effectively build soil carbon. Why soil carbon stocks increase is less relevant than how to build them and how soil carbon compares to other mitigation options like reforestation. Although there is intense academic debate about the why (Amundson and Biardeau 2018), resolving this debate may not inform action.

2.2 How to do it

Scientists should identify what actions their audience is considering, ask them if a lack of evidence is a barrier to deciding, and if so what type of evidence is most needed (Figure 2). If new evidence should catalyze action, they can develop research questions in partnership with end users.

2.2.1 Identify actions the audience is considering

Usually if someone is considering acting, they have a set of potential actions in mind at specific spatial and temporal scales. Understanding the actions being considered and how they will decide between them will help scientists hone research to increase the likelihood of impacting those actions. Scientists sometimes overlook the political and economic context – how current policies and supply chains influence a decision, and what may need to change. This will likely impact how potential users consider evidence and make decisions. Respect the legitimacy of your audience's decision-making process and how they weigh scientific evidence against other factors like public consensus.

2.2.2 Identify if the audience thinks there is an evidence gap (and why)

A perceived evidence gap can come from a lack of evidence, or because available evidence is seen as inadequate to select the right action. Understanding whether the audience thinks there is an evidence gap – and why – will help determine whether to collect new evidence, or whether to re-synthesize or refine communication of existing information.

2.2.3 Determine if new evidence will be enough to drive action

In some cases, an audience may want to act but lacks the capacity to do so. For example, they may lack financing or staff capacity, in which case even highly relevant new evidence may have no impact. There also may be high organizational resistance to new actions. If these barriers block action more than lack of evidence, explore whether the new research being designed could help them overcome the barriers. Robust evidence for the importance of the desired action may help potential users raise funds or change policy to enable the desired action(s). For example, a partnership between The Nature Conservancy and the Dow corporation showed that reforestation could meet Dow's requirements for ozone mitigation at competitive cost (Kroeger et al. 2014). While the EPA has not agreed to allow reforestation to meet Dow's legal obligation, Dow is still planning to proceed in hopes that it will help provide more evidence for the policy change (personal communication).

2.2.4 Translate actions being considered into research questions

The need for evidence is often too broad to be actionable until it is translated into key research questions. For instance, wildlife crossings like bridges and underpasses are often claimed to reduce wildlife-vehicle collisions. This claim could be evaluated by looking at the efficacy of bridges vs. underpasses for a species of interest. These questions are often more specific than the overall evidence need, for example which types of crossings offer the most risk reduction across species. It is important that generating questions be done collaboratively with the end users to ensure data will be enough to advance action (once collected, synthesized, and communicated).

3 Gather "just enough" evidence

Tailor evidence collection given the limited time and resources available, while advocating for the rigor needed for action to be credible (Figure 2).

3.1 Why it is important

Gathering evidence takes time and money that could be spent on implementation (Salzer and Salafsky 2008). Further, the ability of new evidence to influence decisions often has a limited timeframe (e.g. new legislation or incentive programs are being considered on a certain date). The effort dedicated to gathering or synthesizing evidence should reflect the timeframe for making a decision (Dunn and Laing 2017) and the expected value of having new information. The "Value of Information" (VOI) is influenced by factors such as risk associated with making a poor decision, stakeholder comfort with uncertainty, and cost of gathering more information (McDonald-Madden et al. 2010, Polasky et al. 2011, Runge et al. 2011, Canessa et al. 2015, Maxwell et al. 2015, Minelli and Baio 2015, Bennett et al. 2018).

For example, Fisher et al. (2018) evaluated an end user's decision to invest in conservation to improve water quality rather than building a new water pipeline. Comparing models using high-resolution (1-m) spatial data to models using lower resolution data (30-m) they found the finer-scale data would not have changed the decision made to invest in conservation. In this case, higher accuracy did not drive better decisions, but did significantly raise both program costs and perceived credibility of the science beyond the minimum needed (Hamel et al. 2020). By failing to spend enough time understanding the user's needs up front, we missed a chance to reduce research costs and spend more on implementation.

Beyond accuracy and spatial resolution, "just enough" can relate to many facets of evidence synthesis and creation, including depth and breadth of literature review, complexity of modeling, the extent of new data collection, and the precision of estimated effects. Additional effort for evidence collection should be carefully weighed against the probability of it influencing the decision (Canessa et al. 2015). Research may be used for future decisions in unexpected ways, but this is hard to predict.

Risk tolerance and uncertainty influence how much effort should be invested in evidence gathering. When uncertainty is high, but known or perceived risks of the wrong decision are low, then acting immediately, without new evidence, may be the appropriate strategy. Actions can then be improved through adaptive management. However, if the risk is high or tolerance for risk is low, then the value of new information increases (Howard, 1966).

Yet risk and uncertainty come in various guises, which can influence the impact new evidence will have on a decision.

For example, when crafting policies to incentivize reducing greenhouse gas emissions, many forms of uncertainty exist, and their importance varies with context and the kind of decision made (Hawkins and Sutton 2009). Policymakers working at different spatial and temporal scales may differ in how they weigh uncertainty and variation (Lehmann and Rillig 2014). When quantitative greenhouse gas reductions are tied to regulatory or funding incentives, improved precision of the impact of management interventions can be high. There is usually high uncertainty in modeled estimates of the impact of different interventions, and high value in research to improve those estimates. But when setting broader climate policy (e.g. to guide global targets and investment), precise estimates are less important than identifying which major drivers of climate change to target (Knutti and Sedláček 2013, Bradford et al. 2016).

3.2 How to do it

Research design should reflect the appropriate time, rigor, and approach for collecting and synthesizing “just enough” evidence to best inform an action or policy given the audience’s timeline and tolerance for risk. This requires understanding what kind of data the audience considers actionable, their tolerance for risk, and whether adaptive management is an option before choosing a research approach.

3.2.1 Understand the type of data the audience needs

Establish whether specific quantitative evidence is needed to ensure an outcome (e.g. X tons of CO_2e reduced by a certain practice at a certain location and timeline) or if qualitative directional evidence will suffice (e.g. intervention X will increase CO_2e captured, or will increase it more than intervention Y). Explore whether site-specific information is needed, or if general information will do. For example, conservation agriculture on average decreases net greenhouse gas emissions, but will not for some geographies because of soil type and climate (Govaerts et al. 2009).

3.2.2 Evaluate the potential for adaptive management

Adaptive management is a continual learning process. It emphasizes trying different practices, measuring their success, and changing management accordingly (Walters 1986). If adaptive management is viable (especially if the initial value of new information is low), invest more effort in planning ongoing monitoring than on generating extensive evidence up front.

3.2.3 Tailor the type of evidence to the value of information and timeline

Working with potential users, identify a research approach to provide actionable evidence given constraints in time and resources. Different approaches vary in their strengths and weaknesses, ranging from time-consuming, quantitative meta-analyses usually focused on a narrow body of literature to rapid expert assessments that provide a qualitative projection of outcomes but may be more inclusive of available evidence (Grant and Booth 2009). Consider expert assessment or other rapid methods when the value of new information is low, time constraints are high, and the audience understand and accept the limits of the approach. If the value of information is high and time allows, or when the risk of making a non-ideal decision is high, consider more time-intensive approaches. As noted in the conservation for water quality example above, early communication with the audience is key to avoid making assumptions about what approach is needed.

4. Share and discuss the evidence

Most scientific articles are not read by targeted or potential audiences. To achieve the desired impact of their research, scientists should invest time in developing a clear, compelling message, and communicating it (Figure 2).

4.1 Why it is important

If evidence is not seen and understood by the relevant audience, it will have little to no impact on action (Dunn and Laing 2017). Many excellent peer-reviewed papers are not read beyond researchers. Even applied journals in conservation and ecology are not regularly read by environmental managers and policymakers. Peer-reviewed papers are still important outlets for reporting science, but are insufficient to ensure adoption of information (van Kerkhoff and Lebel 2006). Even where work is co-developed (and potentially co-implemented) with the audience, the highly technical language of peer-reviewed work can limit full understanding and, thus, its application. Impact can be improved by communicating results to the broadest suite of relevant audiences in ways that capture attention and meet their needs.

4.2 How to do it

The research team and intended audience should have agreed on a rough communications plan before beginning research (Figure 2). Once the audience understands the results, work with them to develop the key message of the research, along with important context to convey. Scientists can enlist help to improve their communication, publish accessible summaries of the research, and have effective in-person meetings with the audience. Once results are published (along with data and code), scientists should seek to remove barriers to access.

4.2.1 Create a communications plan as part of the research design

Science communications are often planned around the release of a paper. Beginning planning for communications much earlier allows for: 1) selecting a product format(s) and outlet the audience will read (e.g. blogs, video, news, webinars, etc.); 2) identifying the most effective venues (e.g. electronic or in-person) to share the communications product(s); and 3) creation of additional tools to facilitate uptake of the evidence (e.g. a web page to visualize results). Communications plans are ideally developed with both communications experts and members of the target audience and updated as research is completed. Communication products should be shared repeatedly over time to increase the likelihood of them being received by the intended audience (Fisher et al. 2018).

4.2.2 Develop a clear, compelling message

The research team should have a consistent message summarizing the evidence that will motivate the audience. It should include key results, why they matter, and clear recommendations or options for the target audience (Ruhl et al. 2019). A good message is short but memorable, avoids denigrating the audience's beliefs, and is positive (Cook and Lewandowsky 2011). People want to see solutions that show how they can have positive impact, rather than avoiding what they have been doing wrong (Tversky and Kahneman 1981). There are several trainings (online and in-person) publicly available to help scientists craft and deliver clear messages, and the audience will be key in both developing and testing the message. Examples include COMPASS' Message Box training and resources (COMPASS 2020) and Alan Alda's Center for Communicating Science (Alan Alda Center for Communicating Science 2020). There are also written resources like "Don't be such a scientist" (Olson 2009) and "Do I make myself clear?" (Evans 2017).

4.2.3 Document relevance and caveats associated with the evidence

Explore the audience's confidence in the underlying science, and flag key concerns or questions. Explain how appropriate the data sources and methods are for addressing the questions being asked (e.g. Silver 2012, Ionides et al. 2017). For example, document the credibility of the data sources and methods, the applicability of the evidence to their particular context, and explain the (in)consistency of results among approaches (Game et al. 2018). If relevant comparative case studies exist, use them to highlight key factors that could impact the results.

4.2.4 Improve communication skills

Good written products are important for evidence to be used. Scientists can improve their writing skills and/or enlist help from experts. "Good" products provide information that is efficiently understood and used by the intended audience. This is a challenge for even experienced writers. Scientists should seek feedback on their writing from multiple people outside of their technical area, including from a potential user, communications expert, or friend. This can help to flag jargon and assumptions that impede understanding. Even peer-reviewed journal articles should have a compelling narrative with engaging language, while also being technical and precise (Schimel 2012). In some cases, oral communication skills are more important than writing, and the mode of communication should be driven by the audience's preference. A short presentation may be more impactful than a written document; for example, presentations based on this manuscript have led to more follow-up with users than the manuscript itself. But preparation is key; we have had in-person meetings that the audience did not find compelling, which led them to be unwilling to read or hear more about the research.

4.2.5 Publish accessible summaries of the research

Write and share non-technical summaries of research results on social media, for a blog, or other online outlets (e.g. for The Conversation, a research news site dedicated to sharing scientific research in a journalistic style; The Conversation 2019). Ensure the summaries are accessible and engaging. Ideally use a variety of approaches, as different people learn better through diagrams, by reading, or by listening. Communicate key technical terms and concepts with a good narrative — use engaging language without obscuring nuance (Dubé and Lapane 2014) and connect to tangible examples (Dahlstrom 2014). For example, a story about a farmer who planted cover crops and how it impacted her farm and stream may be more memorable than citing general statistics about how cover crops can reduce sediment loads. Then, promote the work through social media with an engaging tweet (or a coordinated series of tweets) that link to the summaries and the paper.

4.2.6 Meet with the audience(s) face-to-face

Face-to-face interaction between scientists and users is one of the most important ways to increase use of evidence (Seavy and Howell 2010). This can include meetings, field visits, workshops, conferences, and high-quality videoconferencing. Not all face-to-face interactions are equal; the quality of interaction depends, in part, on how well scientists and their partners communicate, which is why communications training is so valuable. These personal interactions are part of a long process of building evidence-practice relationships that is essential for research to make an impact.

4.2.7 Share all data and code, not just statistically significant findings

Following best practices in data availability means the evidence will be more available to all potential users. A bias towards significant findings in peer-reviewed literature can mask what does not work. We recommend making all results available and visible (within legal and ethical limits), even if they are not the center-point of a communications strategy (Sutherland et al. 2004). Key findings should be summarized in an evidence library (e.g. Conservation Evidence; ConservationEvidence.com, 2019). Data should be archived in a repository (e.g. Knowledge Network for Biocomplexity or others depending on norms for a given field) that generates digital object identifiers (DOIs) and cites these in publications. We recommend sharing code and analysis summaries (through R Markdown or Jupyter Notbeooks) on GitHub.

4.2.8 Remove barriers to access

Lack of access to articles behind a paywall is a barrier for many potential users, so research papers and products should be publicly available. Open access articles are often cited much more frequently even within a given journal (Kurtz and Brody 2006, Piwowar et al. 2018), although this could be due to confounding variables like citations of previous work and number of authors (Calver and Bradley 2009). If full (“gold”) open access is not practical, posting the accepted version on a personal website (“green” open access or “self-archived”) is typically permitted (see Fisher 2018 for a guide on how to do so). Only 10-20% of eligible articles have been shared in this way (Harnad et al. 2008), which is an opportunity to improve. Follow copyright laws and journal guidelines; public sharing via institutional web pages, or repositories like ResearchGate, is often not allowed. Before acceptance, post a copy of the manuscript in a pre-print archive, which allows sharing it with the audience earlier. For example, a pre-print of this paper was downloaded 440 times prior to publication; we received invaluable suggestions from some early readers and heard from others that it was already useful to them.

Conclusion

Scientists need to work deliberately on shaping their science to have impact. This applies both to applied scientists whose job requires influencing action, and to academic researchers interested in having their work be applied. The practical steps outlined here are critical elements to having a tangible influence on decision making. Ideally scientists can follow them from start to finish when involved in a project from the beginning, working with colleagues with complementary expertise (in policy, communications, boundary-spanning, etc.). See Figure 2 for a potential decision tree for this process.

However, they are guidelines rather than a recipe. Following them does not guarantee success (especially when seeking to influence major policy change, Cairney and Oliver 2018) and may not always be possible. Luck and persistence are also often needed to achieve impact. These guidelines also do not address systemic challenges like incentive structures for academics that do not reward impact. Unplanned impact is also possible; in the example about research on reforestation to reduce ozone, that research led The Nature Conservancy's urban program to begin other work using trees to improve human health (personal communication).

When engaging on a project where decisions have already been made (e.g. defining an audience and the need for evidence), reviewing all our recommended steps can help to improve the chance that the work going forward will have impact. The role of scientists depends on context; in organizations with effective communications teams, scientists may focus primarily on ensuring the veracity of evidence presented. However, even in this context, scientists should remain involved in development of communications materials to ensure important details from the evidence are not lost.

Engaging in this process should lead to a stronger relationship between scientists and the audience (ideally long-term). In many organizations, scientists often serve multiple roles as applied researchers and facilitators of partnerships with management agencies or individual managers. We believe that strong applied science relies on forming trusting relationships between scientists and their partners. Following this guidance should help those relationships develop. Ideally much of our guidance will eventually feel normal and become part of how scientists work with potential users.

We deeply appreciate that people spend a great deal of time developing and synthesizing much-needed evidence to help address problems in conservation and the environment. Our hope is that better awareness and use of our recommendations will translate to evidence being used more to inform environmental decisions.

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Authorship contributions

All authors contributed to this work equally.

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Tables

Table 1. Typology of potential users of scientific information. Scientists often use generic words like practitioner and policymaker to refer to a diverse set of potential users with different objectives. Understanding these diverse objectives is important for targeting science to have impact.

Type of user	**Nature of objective**	**Type of information they need**
Land/property managers (e.g. reserve manager)	Needs to know the best management practices to achieve their desired objectives for a specific geographic place.	Practical, context-specific, and precise
Corporate sustainability director	Needs simple questions they can ask suppliers about whether they're using key sustainable practices. Often needs very general guidelines very quickly.	Practical, simple, and urgent
Leader of a team focused on a specific issue, community, or region	In addition to understanding what the best management practices are, they need to understand contributing factors to success or failure. This includes how these factors interact with each other to influence the outcomes for the target issues.	Practical and context-specific, as well as broader awareness of enabling conditions
Leader of a government agency or large	Needs to know multiple benefits,	Practical-Conceptual

department, or an executive leader for non-profit organization	trade-offs, and costs (time, effort, and money) among varying actions and priorities at a broader scale (e.g. across contexts) to balance outcomes and to communicate effectively about issues. They also will want to see constituent support for acting.	
Environmental scientists	Wants to know both how new science can inform their own research, as well as practical implications for putting it into practice.	Practical-Conceptual
A major donor or public figure who can dedicate resources, catalyze support, and/or influence public opinion	Wants to know the latest and most impactful science and practice to promote promising work.	Conceptual
Stakeholders without formal decision-making power	Wants to know how actions being considered will impact them and their interests.	Conceptual

Figures

Figure 1. Categories of steps to increase the likelihood that research will have an impact on decision making, while recognizing that 'impact' relies on other factors beyond research. This may not be a linear process, but generally will begin at the top and move down. This figure is highly simplified, see Figure 2 for a more complete representation of the relevant steps.

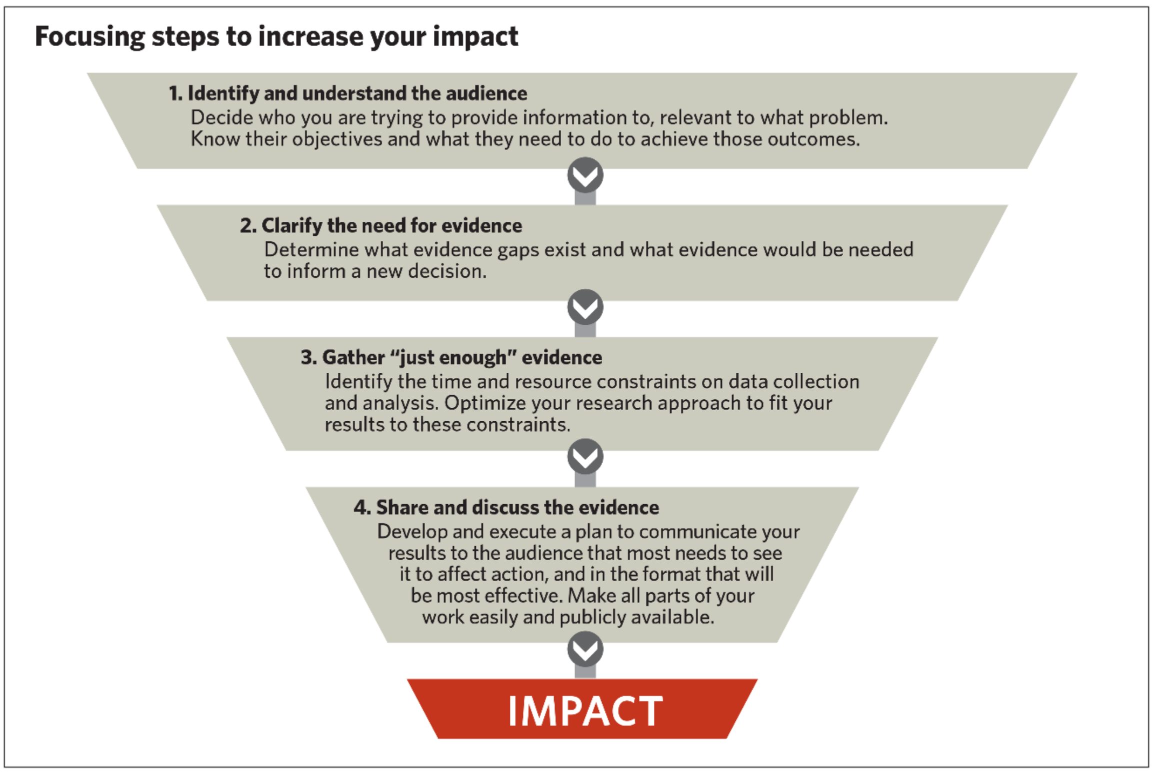
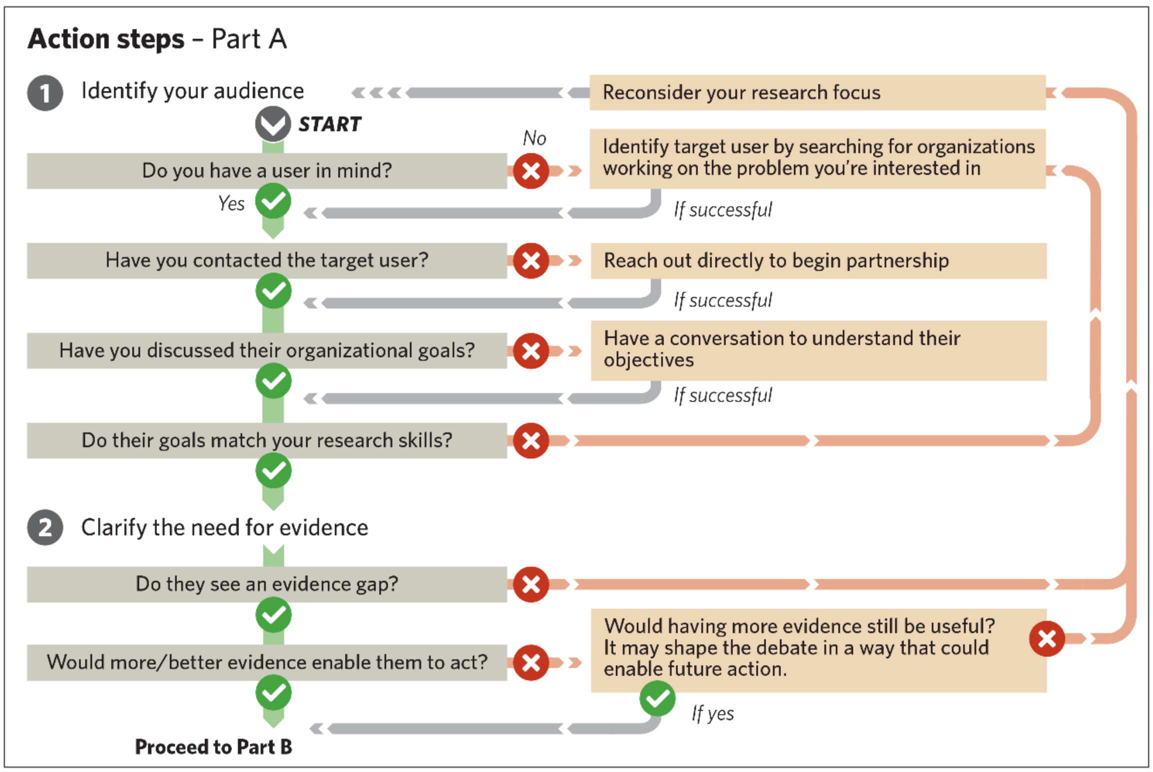
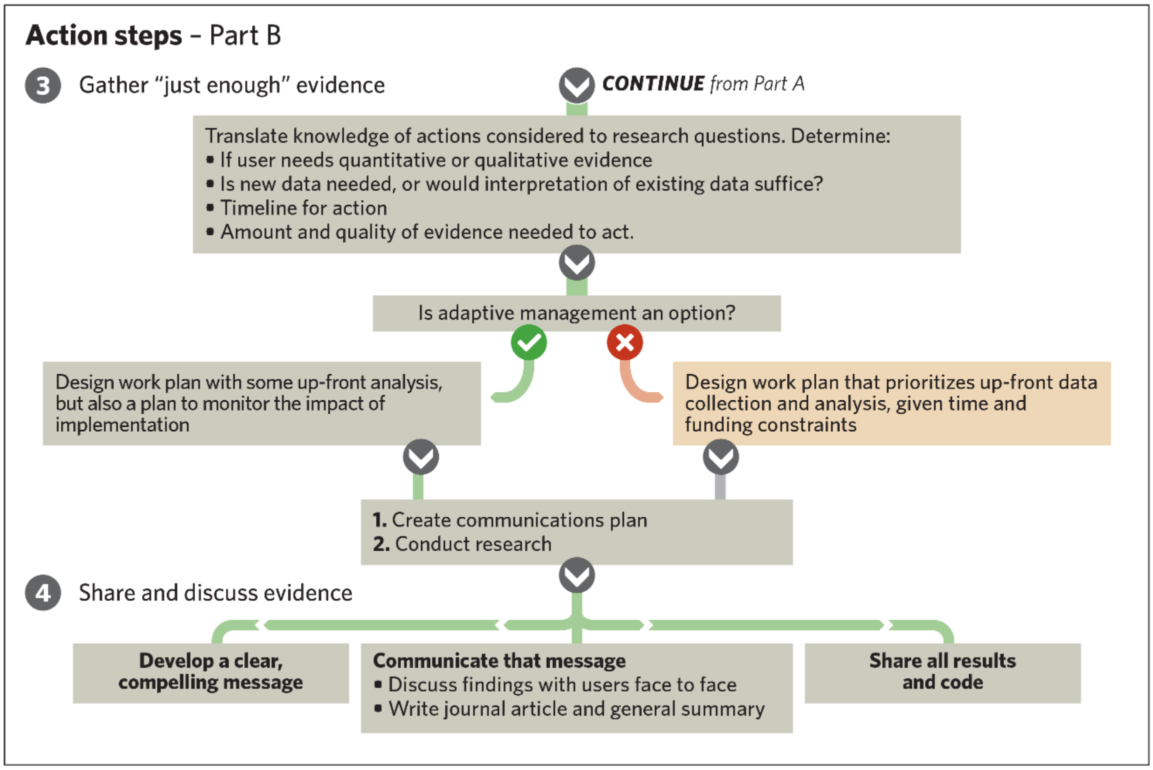


Figure 2. A potential decision tree for following the guidelines in this paper.





Action steps – Part B
3 Gather "just enough" evidence
CONTINUE from Part A
Translate knowledge of actions considered to research questions. Determine:
• If user needs quantitative or qualitative evidence
• Is new data needed, or would interpretation of existing data suffice?
• Timeline for action
• Amount and quality of evidence needed to act.
Is adaptive management an option?
Design work plan with some up-front analysis, but also a plan to monitor the impact of implementation
Design work plan that prioritizes up-front data collection and analysis, given time and funding constraints
1. Create communications plan
2. Conduct research
4 Share and discuss evidence
Develop a clear, compelling message
Communicate that message
• Discuss findings with users face to face
• Write journal article and general summary
Share all results and code