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

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Practice-focused Review

Short running title: How to improve the impact of your science

Our audience is scientists (whether academic or applied) who want to increase the impact of their research; our paper has 5,219 words from the Abstract (146 words) through Acknowledgements and excluding the Literature Cited, and we have 66 references, 2 figures, and 1 table.

Abstract

Scientists devote substantive time and resources to research to help solve environmental problems. Managers and policy makers must decide which actions will lead to desired environmental outcomes, based on the best-available research. Yet decision-makers frequently do not use much of this evidence. They may be unaware of it, lack access to it, not understand it, or view it as irrelevant. This means a valuable resource (research) is often wasted. To improve the impact of science on decision making, we outline a set of practical steps: (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. These are guidelines, not a strict recipe for success, and can be challenging to implement. But we believe that these recommendations should translate into science being used more often when informing environmental and conservation decisions.

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 and with high uncertainty. Environmental managers and policy makers need to quickly decide what to do to achieve their goals (Esch et al. 2018). Applied scientists seek to (and are regularly asked to) provide evidence to inform these decisions. And academic scientists are increasingly motivated to conduct research that informs management and policy (Emerald Publishing 2019), although less applied research also has value and scientists can have impact outside of research (e.g. via serving as advisors).

Yet often research does not shape action (Knight et al. 2008, Sutherland and Wordley 2017), and is designed without first talking to decision-makers. In our experience, scientists face a double-edged sword. We are concerned about the slow pace of action and the lack of willingness to use evidence to shape policy and practice. But we also struggle to deliver evidence fast enough to affect decisions that are imminent. In addition, many scientists conduct research that is disconnected from the decision making of managers and policy makers. The result is that: 1) many 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. This disconnect between the supply and demand for research represents wasted opportunity. Solving this requires more than science, including relationship building and communications.

There have been great advances in how to best synthesize and communicate evidence (Walsh et al. 2014, Alahdab et al. 2016). A key gap remains in what comes before and after evidence synthesis. Academics have analyzed this gap and recommend the need to bridge it (Cook et al. 2013, Enquist et al. 2017, Hallett et al. 2017, Lawson et al. 2017), but many practitioners are unaware of this body of literature. This literature is insightful but often lacks step-by-step practical guidelines for scientists that they can use to make their work more relevant and visible to decision-makers. There are some exceptions with useful explicit suggestions (Jacobs et al. 2005, Cockburn et al. 2016, Beier et al. 2017, Pohl et al. 2017), but they are not well known by practitioners and each omits some steps we have found to be important.

Here, we provide practical recommendations to increase the likelihood that science will lead to impact. Our intended audience is non-profit, government and interested academic scientists of all career stages. This includes both researchers and applied scientists who do not publish their work. We are motivated by our own difficulties in shaping action; difficulties that arise from not following some of the guidance we lay out here. Some of us have also been on the other side – quickly looking for highly relevant science and coming up short. Improving is hard: even in writing this, we struggled to follow our own advice at times. Most of our insights were gained from past failures in both academic and applied settings. Our recommendations focus on how to frame, conduct, and apply science.

In pursuit of clarity and brevity, we do not provide a comprehensive literature review. 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). We also recognize many papers have done an excellent job of describing the problem and making a case for the value of more impactful and inclusive science (Sutherland et al. 2004, McNie 2007, Knight et al. 2008, Enquist et al. 2017, Wall et al. 2017, Bednarek et al. 2018). Instead, we focus primarily 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). However, our guidelines should increase the likelihood of impact.

We group our recommendations into four areas: (1) Identify and understand your 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's important, how to do it, and what you should know when done with that step.

1. Identify and understand your audience

It is more likely that your research will be used if it answers a specific question for a specific group of decision-makers (your audience, "end users," or better yet, partners). Note that we use 'audience' here for simplicity, but we recommend a "translational" or "transdisciplinary" approach of partnering with decision-makers and other stakeholders throughout the research process (Enquist et al. 2017).

1.1 Why it's important

Knowledge informs action through people in a variety of roles who will have different objectives and information needs (Table 1). 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. Policy makers are frequently focused on the impact an action will have on desired objectives, as well as the costs, trade-offs and co-benefits. Research and scientific evidence need to influence several of these different kinds of decision-makers to lead to impact. These decision-makers often require different types of evidence – and research products – to address their needs and motivate them to change their planned actions. To that end, impactful science requires that you understand who will use the scientific information you provide and in what context. It also often requires collaborative work and sustained engagement with those decision-makers to ensure buy-in and relevance (Cockburn et al. 2016).

Understanding the audience and how they may use evidence allows you to tailor the type and form of evidence to better meet their needs. For research to be applied, it should answer a question that is relevant to at least one type of decision-maker. Further, long-standing relationships between practitioner and scientist build trust and credibility, and create opportunities for impact including co-developing applied research (Cvitanovic et al. 2016, Cairney and Oliver 2018). These relationships help scientists to understand the needs of their partner, and to tailor their science to meet those needs.

Our guidance is focused on early-stage work with the objective of developing such long-standing relationships and improving the efficacy of shorter ones. Such early-stage projects may come from a motivated scientist without established relationships who is seeking to apply their work to solve concrete problems. Similarly, applied scientists at nonprofit organizations may have a mission-driven strategy focused on influencing specific policies or land use change, without having clearly identified which decision-makers are 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 ultimately the end products – on specific users will help improve the specificity of the research for the decision at hand and improve the likelihood the research will be used.

As an 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), you may want 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 make things happen on the ground to help solve a problem of mutual interest.

1.2.1 Identify the specific, potential audience(s) you want to inform

There may be multiple audiences with different forms of influence and different science needs who could partner with you to achieve tangible impact (Marshall et al. 2017). Decide whether questions you address through research or evidence gathering are relevant to the decision making of each targeted audience (not always possible), or just the one that is likely to have the most influence on creating change.

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

Engage the key decision-makers and stakeholders 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). Ideally research is "co-produced" where stakeholders iteratively work together to design research (Dilling and Lemos 2011, Beier et al. 2017, Enquist et al. 2017).

1.2.3 Engage in the community of practice you are trying to influence

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

1.3 What you should know once you've done this step

You will have identified the stakeholders who influence the problem you want to help solve, their needs and objectives, how they see the problem, and whether they perceive a need for evidence. If they were not interested or need evidence outside of your expertise, you can recommend scientists or organizations better suited to meet their needs. Alternatively, if you began with specific stakeholders already in mind and you now understand their interests and needs, you will have developed a better idea of how to collaborate with them and how they view the problem.

2. Clarify the need for evidence

Evidence often does not lead to action, especially when the wrong evidence is collected. Build on your understanding of your audience and determine what evidence *would* motivate and empower them to do something new or different.

2.1 Why it’s important

After identifying your intended audience and their objectives, work with them to identify what type of evidence is most needed. 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. The role of applied science should be to contribute the most useful knowledge to help the actors reach a decision, although evidence alone rarely catalyzes action.

Decision-makers and scientists 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. 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

The following recommendations align with established guidelines for developing theories of change.

2.2.1 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. Understanding whether the audience thinks there is an evidence gap – and why – will help you determine whether to collect new evidence, or whether to re-synthesize or refine communication of existing information.

2.2.2 Identify actions the decision-maker is considering

Usually if a decision-maker is considering taking action, they have a set of potential actions in mind at specific spatial and temporal scales. Understanding actions being considered and how they will decide between them will help you hone your research to increase the likelihood of impacting those actions. Scientists sometimes overlook the policy context – how current policy and regulations influence the decision, and what may need to change. This will likely impact how they consider evidence and make decisions. Respect the legitimacy of their decision-making process and how they weigh science against other factors like public consensus.

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 your new research may help them overcome the barriers. For example, whether robust evidence for importance of the desired action would help them raise funds to make it possible.

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, planting winter cover crops on farms is often claimed to improve soil health. This claim could be evaluated by measuring how much carbon is built up when applying a specific cover-crop mixture. These questions are often more specific than the overall evidence need, so 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).

2.3 What you should know once you've done this step

You will know whether new evidence is likely to inform actions taken, and what type of evidence is most needed. You will also have specific research questions developed in partnership with end users that fill an evidence gap in a way that will help catalyze action.

3 Gather "just enough" evidence

Tailor your evidence collection to accommodate the realities of policy and practice (limited time and resources available), while advocating for the rigor needed for action to be credible.

3.1 Why it's 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 raise program costs. 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). 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). Policy makers working at different spatial and temporal scales may then vary in how they weigh different types of uncertainty.

3.2 How to do it

Gather the amount and type of evidence needed to inform a decision in a timely manner.

3.2.1 Understand the type of data your 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 increases soil carbon, but won't for some geographies because of soil type and climate (Govaerts et al. 2009).

3.2.2 Tailor the type of evidence to the value of information

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). If the value of new information is low and/or time constraints are high, consider expert assessment or other rapid methods. If the value of information is high and time allows, consider more time-intensive approaches.

3.2.3 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 for monitoring than on generating extensive evidence up front.

3.2.4 Make and execute a work plan that meets the hard deadline for a decision to be made

Working with decision-makers, identify methods appropriate for the research question and type of data needed. Given resource and other constraints, ensure that data collection or synthesis can be completed in time to influence the decision.

3.3 What you should know once you've done this step

You understand the appropriate time, rigor, and approach for collecting and synthesizing "just enough" evidence to best inform an action or policy given the audience's known tolerance for risk.

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 how the evidence is communicated.

4.1 Why it's 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 policy makers. Peer-reviewed papers are still tremendously 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 potential users, the highly technical language of peer-reviewed work can limit full understanding and, thus, potential 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

Building on the three steps outlined in previous sections, scientists should invest in communicating their findings (Figure 2). This may require an investment in your own professional development as a scientist (such as communications training), and enlisting help from communications experts.

4.2.1 Develop a clear, compelling message

You should have a consistent message summarizing your research that will motivate your audience. It should include key results, why they matter, and clear recommendations or options for decision-makers (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 your audience will be key in both developing and testing your message. Examples include COMPASS’ Message Box training and Alan Alda’s Center for Communicating Science. There are also written resources like “Don’t be such a scientist” (Olson 2009) and "Do I make myself clear?" (Evans 2017).

4.2.2 Document relevance and caveats associated with the evidence

Explore your 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.

4.2.3 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 your audience will read (e.g. blogs, video, news, webinars, etc.); 2) identifying the most effective venues (e.g. electronic, by mail, 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 your 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(s) (Fisher et al. 2018).

4.2.4 Meet with your 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 you communicate, which is why communications training is so valuable. These personal interactions are part of a long process of building relationships with decision-makers that is essential to see your work make an impact in the world.

4.2.5 Improve your writing

You need to produce good written products, through improving your writing skills and/or enlisting 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. Always seek feedback on your writing from multiple people outside of your technical area, including from a potential user, communications expert, or friend. This can help you find jargon and knowledge assumptions that impede full understanding. Even peer-reviewed journal articles should have a compelling narrative with engaging language, while also being technical and precise (Schimel 2012).

4.2.6 Remove barriers to access

Lack of access to protected articles is a barrier for a decision-makers, so commit to making research papers and products publicly available. If open access is not an option, posting the accepted version on a personal website is typically permitted. Follow copyright laws and journal guidelines; sharing via institutional web pages, or repositories like ResearchGate, is increasingly not allowed. Before acceptance, you can post a copy of your submission in a pre-print archive, which allows you to share your product with your audience earlier.

4.2.7 Publish accessible summaries of your work

Write and share non-technical summaries of your 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 US Inc. 2019). Ensure your 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 may be more memorable than citing the mean reduction in soil erosion under cover crops. Then, promote your own work through social media with an engaging tweet (or a coordinated series of tweets) that link to the summaries and the paper.

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

Following best practices in data availability means your work is more available to both academics and non-target decision-makers. A bias towards significant findings in peer-reviewed literature can mask what does not work. We recommend making all results available and visible, even if they are not the center-point of your 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 on GitHub.

4.3 What you should know once you've done this step

You have a communications plan developed with your research team, and ideally with your intended audience. After you have results, you have met with users and discussed your work. You published your work in a technical journal, and/or you have non-technical products. Your target audience can accurately describe the core findings of the work and how that evidence is important to their potential actions. Finally, you shared all data and code (within legal and ethical limits) on a stable repository, ideally with a DOI for data.

Conclusion

Scientists need to work deliberately on shaping their science to have impact. This applies both to applied scientists whose job requires influencing decision-makers, 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 doesn't 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.

When engaging on a project where decisions have already been made (e.g. defining an audience and the need for evidence), reviewing all steps can help you catch up and improve the chance that the work going forward will have impact. How you engage will likely be influenced by the context, as well as the resources available to both you and the decision-makers. For example, many decision-makers are embedded within organizations that have effective communications, so your role could be limited to ensuring the veracity of evidence presented. However, even in this context, the scientist should remain involved in development of communications materials to ensure important details from the evidence are not lost. Focusing your involvement in areas that best fit your expertise and those that the decision-makers lack, will help you efficiently inform the decision process. Engaging in this process should lead to a stronger relationship between scientist and users (ideally long-term). In many organizations, scientists often serve multiple roles as applied scientists 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 you work with decision-makers.

We deeply appreciate that people spend a great deal of time developing and synthesizing much-needed science to help address problems in conservation and the environment. Our hope is that the recommendations we make will translate to that science being used more to inform decisions about the issues you care about.

Acknowledgements

We benefited greatly from input from many people who reviewed or contributed to earlier drafts. This included both colleagues doing exemplary applied science in academia and conservation, and an outside perspective from several others. Thanks especially to: Paul

Armsworth, William Bardel, Dick Cameron, Chelsea Carey, Joe Fargione, Eddie Game, Tom Gardali, Ryan Haugo, Sarah Husband, Aaron Iverson, Liz Kalies, Dan Kane, Lizzy King, Bob Lalasz, Johannes Lehmann, Kerry Metlen, Brynn Pewtherer, Hugh Possingham, Dan Salzer, Nat Seavey, and Paul West. This work was part of the “Managing Soil Carbon” working group for the Science for Nature and People Partnership (SNAPP), whose members also provided valuable feedback on earlier drafts.

Authorship contributions

All authors contributed to this work equally.

References

Alahdab F, Alsawas M, Murad MH. 2016. Where should preappraised evidence summaries and guidelines place in a pyramid? Evidence-Based Medicine 21: 240.

Amundson R, Biardeau L. 2018. Opinion: Soil carbon sequestration is an elusive climate mitigation tool. Proceedings of the National Academy of Sciences 115: 11652–11656.

Bednarek AT, Wyborn C, Cvitanovic C, Meyer R, Colvin RM, Addison PFE, Close SL, Curran K, Farooque M, Goldman E, Hart D, Mannix H, McGreavy B, Parris A, Posner S, Robinson C, Ryan M, Leith P. 2018. Boundary spanning at the science–policy interface: the practitioners’ perspectives. Sustainability Science 13: 1175–1183.

Beier P, Hansen LJ, Helbrecht L, Behar D. 2017. A How-to Guide for Coproduction of Actionable Science. Conservation Letters 10: 288–296.

Bennett JR, Maxwell SL, Martin AE, Chadès I, Fahrig L, Gilbert B. 2018. When to monitor and when to act: Value of information theory for multiple management units and limited budgets. Journal of Applied Ecology 55: 2102–2113.

Bradford MA, Wieder WR, Bonan GB, Fierer, N. Raymond PA, Crowther TW. 2016. Managing uncertainty in soil carbon feedbacks to climate change. Nature Climate Change 6: 751–758.

Brown TJ, Esperanza A, Bytnerowicz A, Tarnay L, Zhong S (Sharon), Preisler HK. 2009. Estimating contribution of wildland fires to ambient ozone levels in national parks in the Sierra Nevada, California. Environmental Pollution 158: 778–787.

Brulle RJ, Carmichael J, Jenkins JC. 2012. Shifting public opinion on climate change: An empirical assessment of factors influencing concern over climate change in the U.S., 2002-2010. Climatic Change 114: 169–188.

Cairney P, Oliver K. 2018. How Should Academics Engage in Policymaking to Achieve Impact? Political Studies Review .

Canessa S, Guillera-Arroita G, Lahoz-Monfort JJ, Southwell DM, Armstrong DP, Chadès I, Lacy RC, Converse SJ. 2015. When do we need more data? A primer on calculating the value of information for applied ecologists. Methods in Ecology and Evolution 6: 1219–1228.

Cockburn J, Rouget M, Slotow R, Roberts D, Boon R, Douwes E, O'donoghue S, Downs CT, Mukherjee S, Musakwa W, Mutanga O, Mwabvu T, Odindi J, Odindo A, Procheş Ş, Ramdhani S, Ray-Mukherjee J, Sershen, Schoeman MC, Smit AJ, Wale E, Willows-Munro S. 2016. How to build science-action partnerships for local land-use planning and management: Lessons from Durban, South Africa. Ecology and Society 21: 28.

ConservationEvidence.com. 2019. [Internet]. Available from: https://www.conservationevidence.com/

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

Cook J, Lewandowsky S. 2011. The debunking handbook. Queensland, Australia: Global Change Institute, University of Queensland.

Cvitanovic C, McDonald J, Hobday AJ. 2016. From science to action: Principles for undertaking environmental research that enables knowledge exchange and evidence-based decision-making. Journal of Environmental Management 183: 864–874.

Dahlstrom MF. 2014. Using narratives and storytelling to communicate science with nonexpert audiences. Proceedings of the National Academy of Sciences 111: 13614–13620.

Dicks L V., Walsh JC, Sutherland WJ. 2014. Organising evidence for environmental management decisions: A “4S” hierarchy. Trends in Ecology and Evolution 29: 607–613.

Dilling L, Lemos MC. 2011. Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. Global Environmental Change 21: 680–689.

Dubé CE, Lapane KL. 2014. Lay abstracts and summaries: writing advice for scientists. Journal of Cancer Education 29: 577–579.

Dunn G, Laing M. 2017. Policy-makers perspectives on credibility, relevance and legitimacy

(CRELE). Environmental Science and Policy 76: 146–152.

Emerald Publishing. 2019. Change ready report 2019. .

Enquist CA, Jackson ST, Garfin GM, Davis FW, Gerber LR, Littell JA, Tank JL, Terando AJ, Wall TU, Halpern B, Hiers JK, Morelli TL, McNie E, Stephenson NL, Williamson MA, Woodhouse CA, Yung L, Brunson MW, Hall KR, Hallett LM, Lawson DM, Moritz MA, Nydick K, Pairis A, Ray AJ, Regan C, Safford HD, Schwartz MW, Shaw MR. 2017. Foundations of translational ecology. Frontiers in Ecology and the Environment 15: 541–550.

Esch BE, Waltz AEM, Wasserman TN, Kalies EL. 2018. Using best available science information: determining best and available. Journal of Forestry 116: 473–480.

Evans H. 2017. Do I Make Myself Clear?: Why Writing Well Matters. Little, Brown.

Fisher JRB, Montambault J, Burford KP, Gopalakrishna T, Masuda YJ, Reddy SMW, Torphy K, Salcedo AI. 2018. Knowledge diffusion within a large conservation organization and beyond. PLoS ONE 13: 1–24.

Game ET, Schwartz MW, Knight AT. 2015. Policy Relevant Conservation Science. Conservation Letters 8: 309–311.

Game ET, Tallis H, Olander L, Alexander SM, Busch J, Cartwright N, Kalies EL, Masuda YJ, Mupepele A-C, Qiu J, Rooney A, Sills E, Sutherland WJ. 2018. Cross-discipline evidence principles for sustainability policy. Nature Sustainability 1: 452–454.

Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre KD, Dixon J, Dendooven L. 2009. Conservation agriculture and soil carbon sequestration: Between myth and farmer reality.

Critical Reviews in Plant Sciences 28: 97–122.

Grant MJ, Booth A. 2009. A typology of reviews: An analysis of 14 review types and associated methodologies. Health Information and Libraries Journal 26: 91–108.

Hallett LM, Morelli TL, Gerber LR, Moritz MA, Schwartz MW, Stephenson NL, Tank JL, Williamson MA, Woodhouse CA. 2017. Navigating translational ecology: creating opportunities for scientist participation. Frontiers in Ecology and the Environment 15: 578–586.

Hawkins E, Sutton R. 2009. The Potential to Narrow Uncertainty in Regional Climate Predictions. Bulletin of the American Meteorological Society 90: 1095–1108.

Hessburg PF, Spies TA, Perry DA, Skinner CN, Taylor AH, Brown PM, Stephens SL, Larson AJ, Churchill DJ, Povak NA, Singleton PH, McComb B, Zielinski WJ, Collins BM, Salter RB, Keane JJ, Franklin JF, Riegel G. 2016. Tamm review: management of mixed-severity fire regime forests in Oregon, Washington, and Northern California. Forest Ecology and Management 366: 221–250.

Howard R. 1966. Information Value Theory. IEEE Transactions on Systems Science and Cybernetics 2: 22–26.

Ionides EL, Giessing A, Ritov Y, Page SE. 2017. Response to the ASA's statement on p-Values: context, process, and purpose. American Statistician 71: 88–89.

Jacobs K, Garfin G, Lenart M. 2005. More than Just Talk: Connecting Science and Decisionmaking. Environment: Science and Policy for Sustainable Development 47: 6–21.

Kary A, Newell BR, Hayes BK. 2018. What makes for compelling science? Evidential diversity in the evaluation of scientific arguments. Global Environmental Change 49: 186–196.

van Kerkhoff L, Lebel L. 2006. Linking knowledge and action for sustainable development. Annual Review of Environment and Resources 31: 445–477.

Knight AT, Cowling RM, Rouget M, Balmford A, Lombard AT, Campbell BM. 2008. Knowing but not doing: Selecting priority conservation areas and the research-implementation gap. Conservation Biology 22: 610–617.

Knutti R, Sedláček J. 2013. Robustness and uncertainties in the new CMIP5 climate model projections. Nature Climate Change 3: 369–373.

Lawson DM, Hall KR, Yung L, Enquist CAF. 2017. Building translational ecology communities of practice: insights from the field. Frontiers in Ecology and the Environment 15: 569–577.

Marshall N, Adger N, Attwood S, Brown K, Crissman C, Cvitanovic C, De Young C, Gooch M, James C, Jessen S, Johnson D, Marshall P, Park S, Wachenfeld D, Wrigley D. 2017. Empirically derived guidance for social scientists to influence environmental policy. PLoS One 12: e0171950.

Maxwell SL, Rhodes JR, Runge MC, Possingham HP, Ng CF, Mcdonald-Madden E. 2015. How much is new information worth? Evaluating the financial benefit of resolving management uncertainty. Journal of Applied Ecology 52: 12–20.

McDonald-Madden E, Baxter PWJ, Fuller RA, Martin TG, Game ET, Montambault J, Possingham HP. 2010. Monitoring does not always count. Trends in Ecology and Evolution 25: 547–550.

McNie EC. 2007. Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. Environmental Science and Policy 10: 17–38.

Minelli C, Baio G. 2015. Value of information: a tool to improve research prioritization and reduce waste. PLoS Medicine 12: e1001882.

Olson R. 2009. Don’t be such a scientist. Washington, Covelo, London: Island Press.

Pohl C, Krütli P, Stauffacher M. 2017. Ten reflective steps for rendering research societally relevant. GAIA 26: 43–51.

Polasky S, Carpenter SR, Folke C, Keeler B. 2011. Decision-making under great uncertainty: Environmental management in an era of global change. Trends in Ecology and Evolution 26: 398–404.

Prunicki M, Kelsey R, Lee J, Zhou X, Smith E, Haddad F, Wu J, Nadeau K. 2019. The impact of prescribed fire versus wildfire on the immune and cardiovascular systems of children. Allergy: European Journal of Allergy and Clinical Immunology .

Qiu J, Game ET, Tallis H, Olander LP, Glew L, Kagan JS, Kalies EL, Michanowicz D, Phelan J, Polasky S, Reed J, Sills EO, Urban D, Weaver SK. 2018. Evidence-Based Causal Chains for Linking Health, Development, and Conservation Actions. BioScience 68: 182–193.

Ruhl JB, Posner SM, Ricketts TH. 2019. Engaging policy in science writing: Patterns and strategies. PLOS ONE 14: e0220497.

Runge MC, Converse SJ, Lyons JE. 2011. Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biological Conservation 144:

1214–1223.

Salafsky N, Boshoven J, Burivalova Z, Dubois NS, Gomez A, Johnson A, Lee A, Margoluis R, Morrison J, Muir M, Pratt SC, Pullin AS, Salzer D, Stewart A, Sutherland WJ, Wordley CFR. 2019. Defining and using evidence in conservation practice. Conservation Science and Practice 1: e27.

Salzer D, Salafsky N. 2008. Allocating Resources Between Taking Action, Assessing Status, and Measuring Effectiveness of Conservation Actions. Natural Areas Journal 26: 310–316.

Schimel J. 2012. Writing science: how to write papers that get cited and proposals that get funded. Oxford University Press.

Schwartz MW, Cook CN, Pressey RL, Pullin AS, Runge MC, Salafsky N, Sutherland WJ, Williamson MA. 2018. Decision support frameworks and tools for conservation. Conservation Letters 11: 1–12.

Seavy NE, Howell CA. 2010. How can we improve information delivery to support conservation and restoration decisions? Biodiversity and Conservation 19: 1261–1267.

Silver N. 2012. The Signal and the Noise - Why so many predictions fail. Pengiun Press.

Sutherland WJ, Pullin AS, Dolman PM, Knight TM. 2004. The need for evidence-based conservation. Trends in Ecology and Evolution 19: 305–308.

Sutherland WJ, Wordley CFR. 2017. Evidence complacency hampers conservation. Nature Ecology and Evolution 1: 1215–1216.

The Conversation US Inc. 2019. [Internet]. Available from: https://theconversation.com/us

Tversky A, Kahneman D. 1981. The framing of decisions and the psychology of choice. Science 211: 453–458.

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

Walsh JC, Dicks L V., Sutherland WJ. 2014. The effect of scientific evidence on conservation practitioners' management decisions. Conservation Biology 29: 88–98.

Walters C. 1986. Adaptive Management of Renewable Resources. New York: Macmillan Publishers Ltd.

Zomer RJ, Bossio DA, Sommer R, Verchot L V. 2017. Global Sequestration Potential of Increased Organic Carbon in Cropland Soils. Scientific Reports 7: 15554.

Tables

Table 1. Typology of potential users of scientific information. Scientists often use catch all words like practitioner and policy maker 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	Description	Nature of objective	Most useful knowledge
Land steward	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
Project/Program Manager	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	Practical and context-specific, as well as broader awareness of enabling conditions

		includes how these factors interact with each other to influence the outcomes for the target issues.	
Department or Agency Leader, Executive Director, Policy Maker	Leader of a government agency or large department, or an executive leader for non-profit organization	Needs to know multiple benefits, 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.	Practical-Conceptual
Philanthropist or Influencer	A major donor or public figure who can dedicate resources, catalyze	Wants to know the latest and most impactful science and	Conceptual

	support, and/or influence public opinion	practice to promote promising work.	

Figures

Figure 1. Steps to increase the likelihood that research will have an impact on decision making. This may not be a linear process, but generally will begin at the top and move down. Consider monitoring the influence of the work to improve in the future.

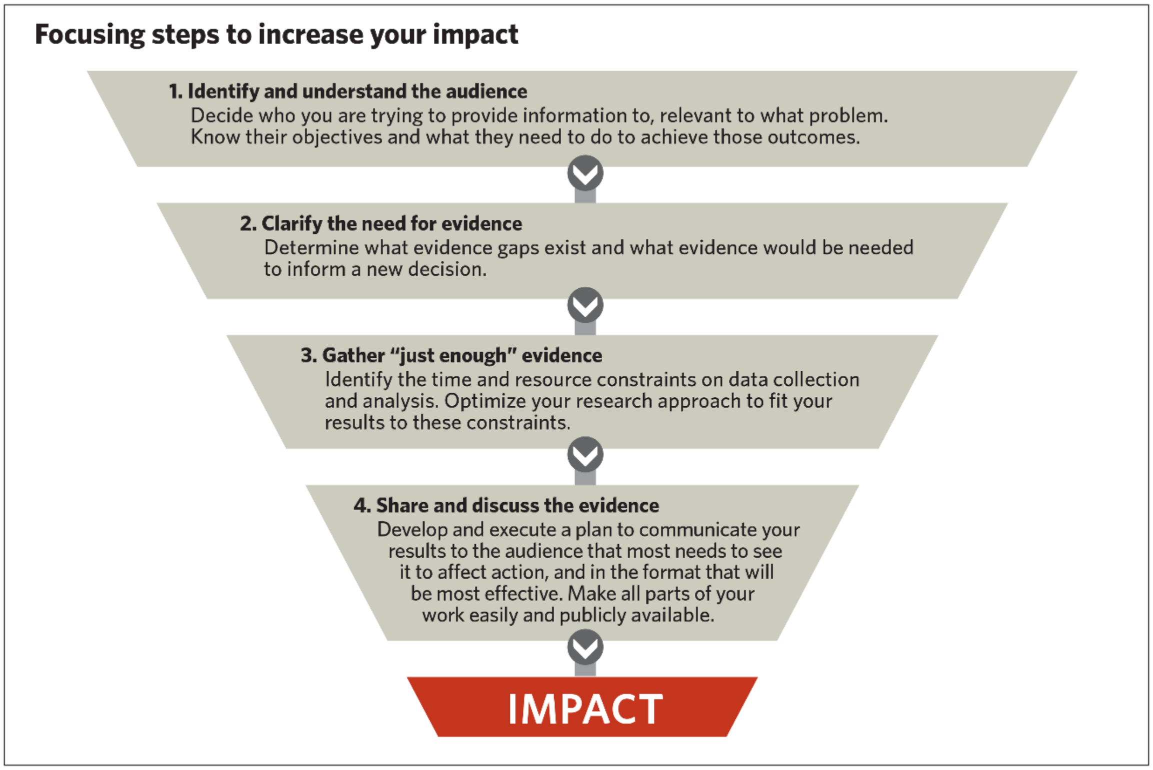
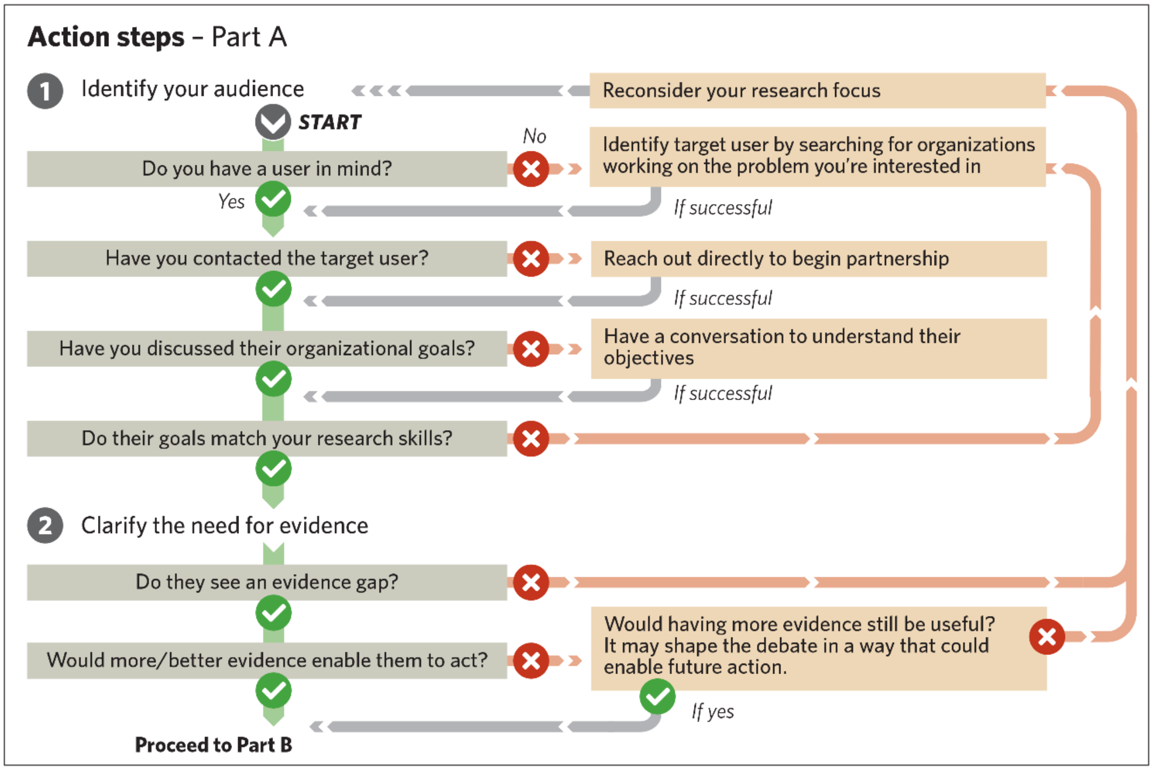
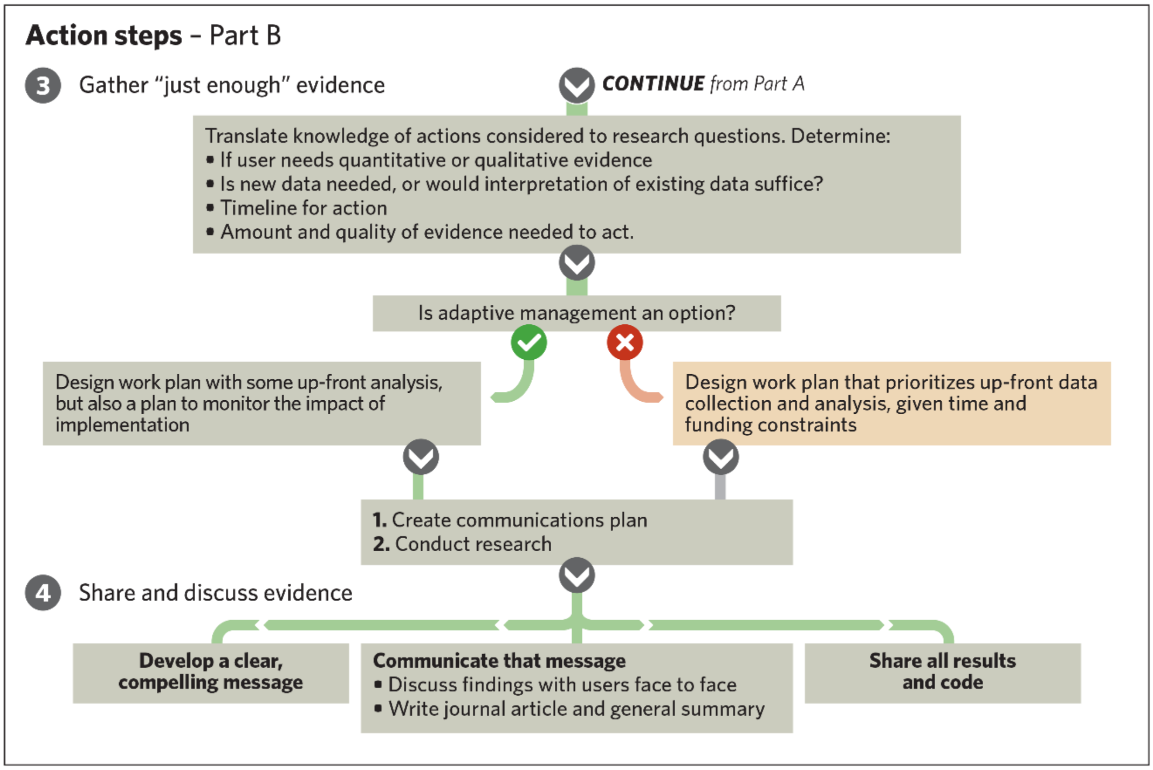


Figure 2. A potential decision tree for following the guidelines in this paper.




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