Ten simple rules to facilitate evidence implementation in the environmental sciences.

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Abstract

There is an implementation gap between environmental researchers and managers. However, there are many strategies to close this gap. Solutions can be made to scale, and we need to better leverage the primary scientific literature. This capacity for environmental and social good can be enhanced by bridging the implementation gap, i.e. strengthening the linkages between basic published science in journals and its ability to inform applied interpretations and decisions. Herein, we provide a list of ten simple rules to support environmental management through better scientific writing and suggest scaffolding for primary publications. These rules can also be used as a checklist for reusing the primary literature when searching for relevant evidence in the environmental sciences. We need to better structure knowledge in papers for connections within sustainable societies.

Keywords

Conservation, decision making, environmental challenges, evidence, challenges, implementation, scientific knowledge, simple rules

Introduction

The scientific literature is an important tool that we use to describe and measure natural systems. It can capture our observations and conclusions for others. Managers typically have scientific backgrounds and routinely navigate the technical literature. However, engagement with scientific literature is non-trivial for all scientists, including practitioners, because of time, restricted access, relevance of the science, and reporting standards (Noorden, 2014). Environmental managers need to be able to easily access primary evidence to inform decisions. Ideally, research scientists work directly with managers to produce key evidence, but this is not always possible or practical (Maillet et al., 2019; Regeer et al., 2009). In principle, stronger relationships between knowledge and its use ensure that sustainability needs are addressed.

Environmental and ecological research is produced globally at fantastic rates. Literature that is defined as applied and published in an environmental science journal is typically used by that community. Nonetheless, basic or fundamental science published in other journals can also inform the environmental sciences provided the papers are written to facilitate discovery and implementation. We can do better in our writing in the sciences to enable this capacity. Evidence-based decision making relies on the findings and direction from research (Cooke et al., 2018). We define 'evidence' here simply as the scientific findings of papers published in peer-reviewed journals. Admittedly, this is a relatively narrow focus, but it is a good starting point because it is a well-established (albeit imperfect) system to describe findings and share conclusions based on observation and experimentation. We define 'solutions' as descriptions in a paper of how a finding can address an environmental concern, but the accessibility of this information can be improved.

There is an implementation gap between basic science and management for at least three reasons. Firstly, the publication reports research on a specific species or system. It is not always clear how to connect specific findings to a demonstrable outcome needed to solve an urgent management issue—even for the same species but in a different context (Iacona et al., 2018; Naidoo et al., 2006). Secondly, the link between the biology or ecology studied and its potential application is not clear. There are notable examples with journals such as the *Journal of Applied Ecology, Basic and Applied Ecology, Facets, The Journal of Environmental Engineering, People and Nature*, and others. Nonetheless, solution development from publications in other journals is an underexploited set of opportunities. Studies from one system can be re-purposed for insights into another (Fischer & Riechers, 2019) when effectively communicated (Freeling et al. 2019). Finally, the capacity to "see the forest for the trees" can be a gap. Science can be very specialized (Baron, 2010), and mobilizing knowledge for solutions requires both detailed expertise, scientific synthesis tools (Lortie, 2014), or a focus on identifying the salient elements associated with a study (Hao, 2018; Lewinsohn et al., 2015). Often, "seeing the forest" also requires sampling many "trees". This leads to the proposal that clear writing to enable synthesis can further help bridge the implementation gap.

Simple rules in science are a blend of opinion and evidence. They are meant to engender discussion, inspire introspection, and challenge how we typically practice our work in the sciences. Published simple rules contributions are mostly written first from principles of logic and reasoning, then summarize the positive practices accepted within the community—including perspectives from experts on how to do better (Bourne and Chalupa 2006). We applied that process here to describe some of the best practices evident in scientific writing that we identified as successful mechanisms to bridge the gap between evidence and implementation. To do so, we used two concepts to structure the rules: challenges and solutions. An environmental management challenge is a 'problem' redefined though the lens of structured scientific thinking such as factor-response or treatment-control principles (Doubleday & Connell, 2020). An environmental challenge can be ethical, legal, or social (Acocella, 2015; Bonebrake et al., 2018). A solution is a desired outcome that can be supported by evidence (Maillet et al., 2019). Typically, solutions represent sustainable paths forward. A solution should also use a tool or methodology that can either identify ways to (a) measure/identify key issues in the formulation of a challenge or (b) provide solutions to directly address a challenge. Any tool can thus become a solution provided we can use it more than once (Baker, 2016). The primary goal of these simple rules is to make papers more practical. We provide evidence and opinions and highlight common practices to inform evidence-based action and policy. It is our responsibility to envision how basic science can be useful.

Rules

1. Reframe the problem as a challenge. "Doom-and-gloom" is a pervasive theme in media discussions of ecology and environmental sciences. It reduces our productivity and capacity to solve problems. It can shut down even the most motivated through compassion fatigue, burnouts, and psychic numbing (Pihkala, 2019). Reframing a problem as a *challenge* can illuminate solutions despite disheartening information so that researchers create their own "bright spot" within a research topic that may frequently frustrate (Reid 2019). For example, human-wildlife conflict is a pervasive issue for managers and researchers that requires tact and a deep understanding of the relationships between people and wildlife (Conover, 1998). Instead of defining a problem as, "people and wildlife are in danger when they interact," re-frame the issue as a *challenge,* such as, "our goal is to improve safety of wildlife and humans in areas with high human-wildlife interactions." It is not us versus them. A challenge statement creates a clear objective for scientists and is more goal-oriented. This perspective will refine communication, enhance creativity, and promote innovation (Johnson and Adams 2011; Mahoney 2011). Additionally, this small change in semantics has profound implications in social contexts for stakeholders, managers, and researchers because it promotes action-based thinking and collaborative work. A subtle shift in writing to re-frame findings and link to a positive management goal will significantly bridge the gap between a problem and a solution.

2. Describe the scope and extent of the challenge. In most ecological studies, the spatial extent is often described, but moving across scales in application is a common challenge in many disciplines of basic and environmental science (Sandel, 2015). Proposing a spatial scale, using common terms, and describing the breadth of the challenge will accelerate interdisciplinary solutions (i.e. the wildlife-human challenge above is ecological *and* societal). The challenge can be relevant for local, regional, or global scales. When we link scales, we unite different instances of an environmental issue and suggest that they can be similarly addressed. However, understanding the geographical extent also allows us to pinpoint differences. This is an important boundary to this rule. The example of human-wildlife conflict is a global issue, but the *extent* is conflict-specific because it is directly observable in Southern California coastlines, Tanzanian park boarders, or Ontarian roadways (Dickman, 2010; Dupuis-Désormeaux et al., 2019; Schakner et al., 2019). Most introductions and methods sections in peer-reviewed publications include scope and extent as a description of what was done in their study, but many do not include the potential impacts to stakeholders at any scales.

3. Explicitly link the basic science to management implications and policy. It is our opinion that a simple description and definition of the scientific evidence and how it can be linked to evidence-based decision making for environmental challenges is a useful tactic to consider when writing about most basic environmentally relevant science. In the wildlife-human challenge, perception of loss and actual losses are not necessarily equivalent, and culture is shaping subsequent conflicts (Dickman et al., 2014). Consequently, a clear and balanced statement of evidence can highlight limitations in the science relative to the social acceptability of a solution (Bonebrake et al., 2018). Do not overstate the link or stretch the implications too far. When this happens, it can undermine legitimate links between evidence and implementation.

4. Propose implications of ignoring this challenge. A description of the impact an unchecked challenge will help clarify the severity of the challenge. This practice is common in scientific literature when the topic examines societal or economic impact including invasion biology or global change. However, we propose that the trickle-down effects and indirect implications that are not immediately evident must also be examined and discussed. There is compelling evidence that further anthropogenic pressures on carnivore populations will lead to severe declines in populations including potential extinction of keystone species (Bagchi & Mishra, 2006; Johnson et al., 2006; Towns et al., 2009). Despite this, anti-carnivore sentiment will only grow as climate change pressures further confine pastoral herders (Jones & Thornton, 2009; Lindsey et al., 2009). Therefore, failure to bridge the implementation gap can impact food security regionally in this situation (Fernández, 2016; Kates et al., 2001). Hence, the implications and trickle-down effects are pertinent not only to the direct stakeholders but also society at large. Scientific conversations should thus consider implications that include human needs.

5. State the direct human needs associated with this challenge. It is not common to state the direct needs of humans as part of the process of generating solutions for environmental challenges in many basic science publications. The intrinsic value of the ecosystem is impossible to quantify (Davidson, 2013), but linking the challenge and its solutions to direct human needs makes it less likely to be dismissed and ignored. This rule would be a novel addition to many basic scientific papers that are not directly coupled to an environmental issue. Bridging the gap between evidence and implementation can also be accomplished by including a proposed strategy for engagement with stakeholders as a mechanism to inform benefits and solutions (Colvin et al., 2016; Reed, 2008). Benefits to stakeholders include cultural ecosystem services, and these will in turn further sustainable local planning and more directed science (Tew et al., 2019). Not every study has to have global scope or large societal implications, and practical application is rarely simple (Regeer et al., 2009). This is an important boundary to this rule and suggests that it need not apply to every study; but articulating human needs in more ecological system papers will go a long way to filling the gap between acceptable science and collaboration. It will also improve the perception of science by the public. Mentions of human needs or at least recognition that there are human stakeholders associated with almost every natural ecosystem globally can reduce an ivory-tower effect.

6. List at least one limitation of the study and explain. There is no perfect experiment (Ruxton, 2018) or synthesis (Kotiaho & Tomkins, 2002). Critically reading the study associated with the challenge can mean the difference between success and failure of a derived management solution that otherwise follows all other rules presented. A clearly written analysis of causation and correlation in our papers will help avoid fatal missteps in readership and will ensure effective framing of expected outcomes, including environmental interventions for managers. We are proposing a change from the norm in scientific writing wherein many papers end with a call for additional research on that specific topic. Provide a specific statement of the relative strength of evidence and gaps in the research. Be truthful and transparent. Describe the extent that these findings can be generalized. These statements will provide a future direction for additional research and for appropriate decision making. This rule is not based on evidence but on preference.

7. Explore the benefits of minimal intervention for stakeholders. Resources are limiting, and, at times, the business-as-usual model can provide a guide to intervention for some environmental management challenges (Ferguson, 2015; Mosnier et al., 2017). At the minimum, exploration of a hope-for-the-best strategy or minimal intervention is critical due to cost limitations. Business-as-usual models can also provide an economic mechanism to value ecosystems services (Fu et al., 2018; Karttunen et al., 2018), and while this is not without debate, this can expand the range of invested stakeholders and potential investors in a solution for a particular challenge. The best and worst-case scenarios are not always clear or equal between strategies or in severity, but navigating the likelihood of these implications can provide perspective to researchers and stakeholders. There is a boundary to using this rule to bridge an evidence-implementation gap—some studies are not amenable to costing because we have not developed the valuation framework or do not yet have the means to implement a solution even if we understand the biology or ecology of a system.

8. Be transparent in reporting methods. Typically, there is at least one general category of tool that the researchers used to explore a challenge in a given study. We propose that scientific tools in basic biology and ecology relevant to environmental management, such as species identification, habitat use, diet analyses etc., can bridge a gap between evidence and implementation when they can be replicated in another system or similar challenge - provided they are clearly described. It is not always easy to reverse engineer how treatments were applied in a study particularly in some journals that focus more on findings and less on methods. This rule is vital because it can also be difficult to translate treatments tested in a scientific study into practical applications. Be specific in your methods and general in your proposed application.

9. Be explicit in linking to potential outcomes. A scientific tool from a study can collect data, detect patterns, directly solve an environmental challenge, demonstrate an intervention, or inform policy. If the paper is a direct test of basic ecology for an environmental challenge, this can be very straightforward. For instance, the paper titled "Odonata (Insecta) as a tool for the bio-monitoring of environmental quality" (Miguel et al., 2017) explicitly provides a means to measure and detect, and this capacity is clearly described right in the title. The evidence in the scientific literature strongly suggests that this is a common practice in many contexts and thus a sound rule. Nonetheless, there are many useful studies where the link to the environmental outcomes is less evident. Studies that inform policy for instance are sometimes more indirect and synthetic or focus on key drivers of anthropogenic change without clearly implicating the policy outcomes. This may seem like a lot to ask, but any of the tools described in previous rules help us better link to outcomes. Some tools that fit most squarely include economic incentivization models (Tilman et al., 2018), human health impact studies (Chiabai et al., 2018), and human well-being monitoring associated with environmental interventions (McKinnon et al., 2015).

10. Apply the tool to another challenge. This rule primarily applies to follow-up studies or stakeholders implementing science. Apply the primary tool to another challenge to show that it can be a link between primary evidence and practical use. At least speculate how it can be applied in the follow-up studies. This promotes efficiency when tackling novel environmental challenges as they emerge, and it also supports the overarching assumption that we cannot afford to ignore basic science for better decision making.

Implications

These rules distribute scientific communication and implementation between scientists and stakeholders more evenly and enable better two-way interactions with the scientific knowledge described in publications. These rules are a blend of opinion, exemplary evidence, and common practices in the field. There are likely many other rules, but this is a representative set of some of the more robust bridges between evidence and implementation in writing and using papers to inform solutions to many environmental challenges. Consider these rules when writing, not *all* all of the time, but *some* some of the time. We can make basic natural science more practical and expand the scope of environmental knowledge. We propose that more basic science can be used in applied contexts. These ten simple rules will enable better identification of overarching patterns from disparate papers provided we embrace some of the scaffolding developed here such as common language for challenges and solutions, identification of tools, mention of direct human needs, and consequences within each system of minimal interventions. A few new norms in scientific writing that align with practical application will facilitate linking evidence together for scientific syntheses and more applicable theories.

A core tenet of adaptive management is that managing and learning should be connected and iterative in the natural resource sciences (Williams & Brown, 2016). Decision making adjusts as understanding improves both through doing and through learning. This is not a new approach to managing the environment but requires a well-articulated framework within publications to become an active process for stakeholders to improve long-term conservation outcomes through evidence (McDonald-Madden et al., 2010). Making the primary research literature more functional through these rules for writing and structure will accelerate the learning phase of adaptive management. We can make deliberation (i.e. planning) and iteration (i.e. testing) integrate with evidence by practicing at least some of these rules (Williams & Brown, 2016). Spanning this gap is not the sole criterion for useful science nor should it be, but professional advocacy and knowledge mobilization are increasingly important for universities and scientists (Pace et al., 2010). Evidence-informed decision making is a critical area for growth and knowledge in many disciplines (Aarons et al., 2011; Roy-Byrne et al., 2010; Tranfield et al., 2003)—not just environmental management. Increased consumption and production of scientific evidence with managers and better writing that is more accessible to a broader audience will make scientific papers more practical.

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