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REFLECTIVE ESSAY

From frustration to fruition in applied conservation research and practice: ten revelations

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Abstract
Applied ecologists and conservation scientists have struggled with generating and sharing new knowledge that is of direct relevance and use to practitioners, managers, and policy makers. The so-called knowledge–action gap remains pervasive, and more is needed to narrow the gap and ensure that the best available science is used to inform environmental decisions. By reflecting on my experiences over a 20-year period, I consider how I have transitioned from a state of utter frustration to one where some successes have been achieved. In this paper, I share ten "revelations" that were derived from extensive reflection. They include: partner early and often; commit to lifelong learning; one research domain is never enough; put it all together; don't assume; learn from your mistakes; embed yourself; look for policy windows; understand scalar influences; there are no guaranteed wins. As an applied ecologist, I am trying to generate science of relevance to end users and train the next generation of scientists on how to do the same or even better than I have been able to achieve. As a scientific community, we need to have open conversations about our successes and failures and include both scientists and practitioners in such discussions. If one is engaged in mission-oriented science (such as addressing the biodiversity crisis or solving environmental problems), I consider it our responsibility to do all we can to ensure that we generate research that is relevant to end users and share it via channels and in formats that they desire. If we fail to do so, not only will it be a source of frustration for the knowledge generators, but it will also be a failure on our parts to help deliver on the promise of evidence-based conservation and environmental management.

Keywords Knowledge–action gap · Applied ecology · Mission-oriented science · Practice · Management

1 On frustration

I am an applied ecologist with great interest in generating new knowledge to inform the conservation of biodiversity and sustainable management of natural resources—a common goal of the applied ecologist of today (Milner-Gulland et al. 2012). Yet, I spent much of the first part of my academic career in a sense of "applied academic despair" when I repeatedly noted that my work was failing to meaningfully inform practice or policy. To be clear, I was committed to mission-oriented science and more than 50% of my research program was specifically directed toward that space. Moreover, the lion's share of my funding came from applied sources so I assumed I was good at it. Yet, I struggled to identify concrete examples of where my research had directly informed practice or policy on a regional, national, or global scale. I could not identify with ease a regulatory change, a new management strategy, nor a change in the way that practitioners did their work that I could attribute to my research. I found this particularly troubling in that I was purportedly training students in applied ecology with the idea that they had the relevant skills to be effective in science advice, environmental management, or the science policy arena. Should I just keep trying? Should I give up on applied science? Should I not care and just do what I thought was important even if it was being ignored by end users? I know that I was not alone: Other applied ecologists have struggled to bridge the so-called knowledge–action divide (see Cook et al. 2013, pp. 669–675).

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Fortunately, I took a pause and began to look to my peers in allied disciplines and reflect on my early training. This led me to recognize that I needed to change how I approached applied science. In some cases, this meant revisiting my expectations, and in other cases, it meant entirely rethinking how I developed, executed, and shared my research. Here, I summarize my transition from a state of frustration to a renewed and genuine sense of fruition where I can now point to many examples of how my work has directly or indirectly informed policy and practice on relevant timescales (see Table 1). I recognize that this is my story. And while your story may be different, as I continue to reflect on my experiences I feel that there are some messages worth sharing with others—particularly early career scientists. I am also humbled that I have had the freedom and opportunity to learn from diverse scholars and practitioners spanning the natural and social sciences. I present what I consider to be "ten revelations" related to achieving success in applied conservation research and practice (see Fig. 1). "Revelation 10" is rather pragmatic in that I also recognize that there is no specific formula that will guarantee a "win." Nonetheless, the guidance provided below should increase the likelihood of yielding meaningful outcomes.

2 More context—my journey

Before digging into the revelations, I think it important to share some background information on my journey. I started off in high school volunteering and then working for the Grand River Conservation Authority (a watershed-based government agency that manages water and other natural resources on behalf of the one million residents of the Grand River watershed) in roles related to communication, outreach, restoration, and environmental monitoring. I then pursued an undergraduate degree in Environment and Resource Studies (Bachelor of Environmental Studies) where topics such as sustainability, stakeholder engagement, and environmental policy were often discussed. After wanting to dig more into the hands-on aspects of applied ecology, I conducted an M.Sc. and Ph.D. in the realm of natural resources and environmental science. My PhD was done within the Illinois Natural History Survey (an allied government agency focused on understanding biological resources in Illinois and beyond), with my two co-advisors working for that agency. I then did my postdoctoral research with an applied conservation research group where fundamental experimental science underpinned the work we were trying to do in conservation and natural resource management. I was fortunate to work alongside and publish with a variety of government, NGO and industry scientists and government fisheries managers.

I joined the professoriate in 2005 in an Environmental Science and Biology unit. I recall my early days in the professoriate hearing from the old guard that we were "better" than those folks working in environmental studies on the other side of campus. As a pre-tenure researcher, I kept my mouth shut, but I have since (after tenure) been able to fully embrace the idea that environmental problems require diverse perspectives and ensure that other pre-tenure faculty in my unit can work and think across boundaries (Cooke and Vermaire 2015). I now hold a zero-time academic appointment (meaning one has academic privileges in a unit but is not paid nor required to teach) in the aforementioned environmental studies unit. I have also become engaged in academic leadership and have had the opportunity to help revise our environmental science program (at Carleton) to be more relevant to students and employers and recently helped to obtain Senate approval for a new undergrad program in interdisciplinary science and application. Also of importance is that I connected with several social scientists and individuals working in the socio-ecological systems space. This extended to the level where I have co-supervised a handful of graduate students with an environmental sociologist with interest and expertise in knowledge mobilization (i.e., Dr. Nathan Young at the University of Ottawa). These experiences were formative in that it provided me with an opportunity to codify what I was doing and anchor it in theory, making connections to my early training in sustainability science. The journey described here is in some ways a full circle. I began with a foundation that involved the human dimension and big picture that then moved on to focus largely on the biology and then came back around to acknowledge that biology alone is insufficient for solving complex conservation problems (sensu Balmford and Cowling 2006, pp. 692–694), given that humans are almost always at the center. Reflecting on the new *Socio-Ecological Practice Research* journal, I have had ten revelations that I share here.

3 The ten revelations

3.1 Partner early and often

In today's world, applied ecology demands partnerships (Hulme 2011, pp. 1–2). I would argue that it is impossible to be effective as an applied ecologist if one does not develop rich and meaningful partnerships with relevant stakeholders (e.g., anglers, bird watchers, environmentalists, members of the public) and end users (e.g., resource managers and policy makers in various sectors including government, NGO, and industry; Braunisch et al. 2012). There is a growing body of literature (confirmed by my own experiences; see Cooke 2011) that partnership begins well before any science is

Table 1 Successes in socio-ecological practice research

Success[a]	Details	Key references
Developed guidance for deriving estimates of Pacific salmon fishing mortality	Pacific salmon are encountered by commercial, recreational, and aboriginal fishers, yet for various reasons (e.g., to comply with regulations, due to conservation ethic), some fish are released. Accurately quantifying release mortality is essential for generating management targets. Working with Federal government scientists, fishers, NGOs, and other partners in British Columbia, we have developed guidance for deriving estimates of Pacific salmon fishing mortality across sectors, fishing gears, and species	Patterson et al. (2016, 2017)
Identified opportunities for improving fish passage for lake sturgeon	Lake sturgeon populations have suffered from fragmentation, but fish passage facilities offer opportunities for restoring connectivity. Yet, when fish passage facilities have been developed for sturgeon, they have often failed to successfully pass fish. Studies combining ecology and hydraulic engineering revealed that turning basins may be a source of confusion for fish but that issue can be mitigated with simple changes in fish passage design	Marriner et al. (2014), Thiem et al. (2016)
Developed strategies for reducing freshwater turtle bycatch mortality	When commercial fishing traps are deployed in freshwater lakes of eastern Ontario, a variety of imperiled turtles are captured incidentally. Turtles drown in such nets when not provided access to air. Behavioral observations and physiological sampling were used to identify strategies that excluded turtles and prevented drowning which have been shared with fishers and used to inform policy. Social science surveys were used to determine the extent to which the various bycatch reduction strategies were acceptable to fishers	Larocque et al. (2012a, b), Cairns et al. (2013)
Identified thermal thresholds for migratory Pacific salmon	Water temperatures in the Fraser River of British Columbia have been rising which makes upriver migration of Pacific salmon challenging. Physiological studies have revealed species- and population-specific thermal tolerances which are associated with performance impairments or mortality. These thermal thresholds have been used to refine management adjustment models used by Fisheries and Oceans Canada make risk-averse management decisions	Cooke et al. (2012), Eliason et al. (2013)
Informed restoration of nearshore habitats in Lake Ontario	The nearshore regions of the Laurentian Great Lakes have been degraded as a result of anthropogenic activities. Great efforts and significant financial resources are devoted to restoring degraded habitats. Telemetry studies of fish in the nearshore regions of Lake Ontario (e.g., in Toronto Harbour) have refined the type and configuration of habitat restoration initiatives undertaken by the Toronto and Region Conservation Authority	Brooks et al. (2017), Rous et al. (2017)
Developed and refined strategies to improve welfare of fish that are angled and released	Each year millions of fish are captured and released by recreational anglers. Working closely with anglers and the angling industry, science has been conducted to identify opportunities for improving the welfare and survival of released fish. The findings have been shared with anglers via outlets that enable broad dissemination using trusted sources	Brownscombe et al. (2017), Danylchuk et al. (2018)

Table 1 (continued)

Success[a]	Details	Key references
Informed water release practices at hydropower facilities	Balancing water releases at hydropower facilities to achieve power generation that minimizes negative outcomes on aquatic ecosystems is common goal of utilities. Science can be used to guide water release strategies by understanding how fish respond to various flows. Studies of fish behavior have revealed flows that minimize energetic expenditure, a prerequisite for refining water releases. BC Hydro, one of our partners on this work, has used our findings as part of their relicensing process	Burnett et al. (2014), Taylor et al. (2014)
Raised the profile of inland fisheries on the global scale	Inland fisheries face many threats yet are essential for supporting livelihoods and contributing to nutritional security. In many ways, the benefits derived from inland fisheries are hidden and undervalued given the inherent challenges in quantifying their value. A plan for achieving responsible inland fisheries was tabled at the UN FAO and more recently the role of inland fisheries in achieving the 2030 Sustainable Development Goals were developed. There is still much more to do but inland fisheries are increasingly finding their way into policy discussions and instruments	Cooke et al. (2016), Lynch et al. 2017

[a]The "successes" presented here vary in the extent to which they have influenced policy and practice. All of the examples emanate from the Cooke Lab and acknowledge that there were many researchers and partners involved with each

done—it involves co-creation of the research agenda (termed by some as inclusive knowledge production; Colloff et al. 2017). Such models imply bidirectional knowledge exchange (Reed et al. 2014, pp. 337–342) and ensure feedbacks and ongoing interactions (Bainbridge 2014). Partnership can extend throughout the entirety of the research process such that partners are assisting with data collection (perhaps in the form of citizen science or as resource professionals themselves in a more formal scientific collaborative manner—see Caudron et al. 2012). And of course, sharing and interpreting research findings is best done in an open and transparent manner. Some partnerships may require significant time and effort to orchestrate and maintain (which requires frequent bidirectional communication), but this is worthwhile and essential if researchers want the knowledge they generate to have impact.

3.2 Commit to lifelong learning

The concept of lifelong learning has been espoused for decades (Field 2000) yet still rings true for being effective in applied ecology. The reality is that our knowledge base is growing and how knowledge generators interact with knowledge users is ever changing. Much of the learning I have done has been a result of my students and associated collaborations where I am brought together with a colleague who is outside of my normal research sphere. With student interactions, I openly acknowledge that I don't know it all—the job of the professor and mentor is no longer to be omniscient but rather to be a guide, willing to acknowledge what they don't know and to learn from ones trainees (Cooke and O'Connor 2014). When one opens the door to lifelong learning, one is opening the door to opportunities to be more effective in applied ecology.

3.3 One research domain is never enough

The complexity of environmental problems is such that one discipline is insufficient for developing meaningful solutions (Mallegowda 2013; Dick et al. 2016, pp. 67–74). This does not mean that everyone must themselves be an expert in multiple domains, but one does need to know how to engage in collaborative team work. Doing so requires mutual respect, a willingness to listen, and the identification of common interests (Dick et al. 2016). There are numerous barriers to engaging in various forms of multiple disciplinary research and collaboration, ranging from institutional impediments (e.g., lack of reward structures) to more pragmatic barriers (e.g., lack of common language), but they can be overcome by connecting with the right collaborators (Rhoten and Parker 2004). It is entirely acceptable to shop around until you find a collaborator with whom you connect—it may not be the most esteemed or most senior person—instead, it

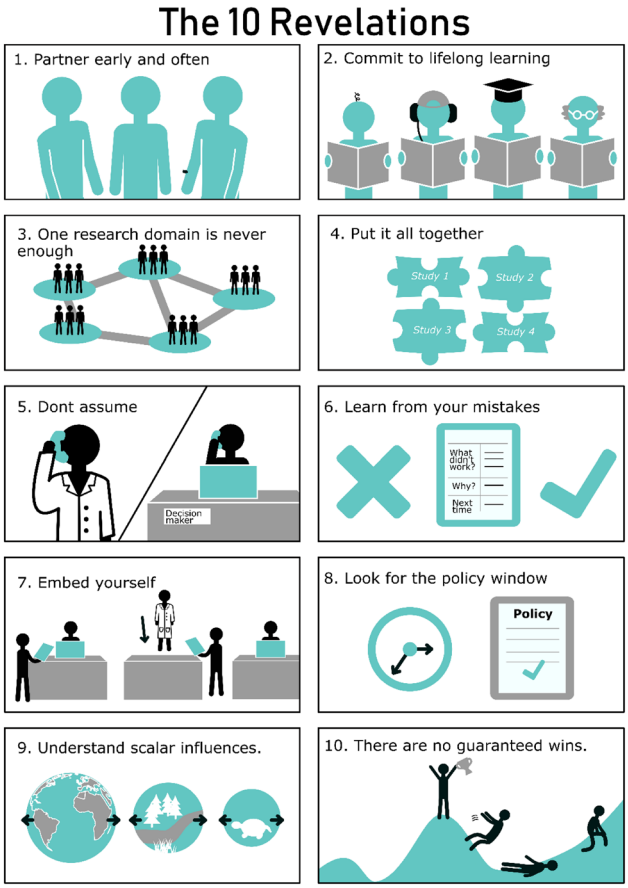

Fig. 1 Visual depiction of ten revelations for engaging in applied conservation research that informs policy and practice

may be the person for whom the collaboration will involve a "give and take" relationship and that will enrich (rather than insert stress and conflict to) your professional life.

3.4 Put it all together

Research is inherently reductionist; we tear a big problem into its pieces. Yet, decision makers have to think about the big picture. There is much need and opportunity to think about how the individual pieces of knowledge (evidence) come together to yield the comprehensive knowledge base needed to act in an evidence-informed manner (Sutherland et al. 2004, pp. 305–306). Recall that even when a single study is bulletproof, the reality is that it is still just a single study. Amassing and synthesizing high-quality research is critical to evidence-based decision making (in the health and environmental sciences) and something that is often left to the managers. Yet, it is the science community that is best equipped to critically appraise different pieces of evidence and decide what is worthy of inclusion in decision making (Dicks et al. 2014, pp. 607–611). Taking the time to synthesize data while acknowledging bias and limitations in a transparent manner will almost always be welcomed with open arms by end users. A weight-of-evidence approach trumps a single empirically based research paper any day. However, at times there may be need to make decisions with speed such that there is insufficient time to engage in the evidence synthesis described here. Rapid evidence synthesis methods show promise for such instances (see Ganann et al. 2010).

3.5 Don't assume

Early in my career I assumed that publishing papers was the best way to influence policy and practice (see Fazey et al. 2005, pp. 63–70 for a discussion on the flaws in my early thinking). It is widely understood that peer-reviewed papers are the "accepted" means of sharing new knowledge. Yet, we also now know that there are many factors that influence if, when, and how practitioners and decision makers access, consume, and apply new knowledge. Something as simple as lack of access to pay-walled literature can be a significant impediment to knowledge transfer (Cvitanovic et al. 2014). The status quo is not an easy thing to change given how safe it is to do what one knows and there can be institutional inertia that further impedes adoption of new knowledge. Many of the assumptions that I held about how resource managers and policy makers evaluated and used new knowledge were quickly overturned as a result of social science studies that we did in the area of knowledge mobilization (see Young et al. 2016a, b). What a manager might consider to be important in influencing the reliability and applicability of a given piece of knowledge may differ from other stakeholders and the knowledge generator (Cvitanovic et al. 2016; Dunn and Laing 2017). Rather than making assumptions, the best choice is to read extensively on how knowledge moves and is (or is not) applied and to simply ask practitioners how you can be most relevant to them (Knight et al. 2008, pp. 610–614).

3.6 Learn from your mistakes

Along the way, I have repeatedly found that I learn much more from my mistakes than from my successes, in the same way I have learned as much from my worst mentors (do the opposite) as I have from my best mentors (follow their lead). To that end, it is critical to reflect on one's mistakes and dissect them like a meticulous pathologist. What didn't work? Why didn't it work? What could I have done differently? What are the lessons I need to take away? For academics, this requires having a level of humility where one needs to acknowledge failure and accept some level of personal responsibility. A defensive reflection will do little to inform one's approach, yet a thoughtful and nuanced self-reflection can be transformative.

3.7 Embed yourself

Although it is easy for academics to pretend we know what end users want or need, this is rarely the case. The only way to truly understand their perspectives is to find ways to embed oneself in institutions and their processes such that we can learn more about how they work and ensure that the work we do is relevant to their mission (Balmford and Cowling 2006, pp. 692–693). This can take many forms—a sabbatical working in a natural resource management agency; a short-term policy internship; an ongoing collaboration where one is able to begin to understand agency culture. Whatever the path, it requires commitment from the scientist. Moreover, it requires interacting in formal and informal settings. Sitting across the lunch table from practitioners is more valuable than only interacting with them in formal meetings. No matter how many degrees or publications one has, the most important aspect is recognizing that different members of a team bring different expertise and ways of thinking, knowing, and doing to the table.

3.8 Look for policy windows

Policy windows are often regarded as being serendipitous, but Rose et al. (2017) argue that scientists can "create, identify and seize on policy windows." Policy windows represent time-sensitive opportunities to inform decision makers during periods when they are receptive to (and even desperate for) new knowledge. Rose et al. (2017) provide a useful framework for taking advantage of policy windows. Although historically it was understood that the role of the scientist was to simply generate the knowledge, there is increasing recognition that scientists can and should play a more direct role in enabling conservation actions (Arlettaz et al. 2010; Milner-Gulland et al. 2010). Knowing when to act and how to do so is critical for turning a policy window into a meaningful change in policy or practice (Hulme 2014, pp. 1131–1139).

3.9 Understand scalar influences

If one wants to generate science to inform global biodiversity policy, one must do big science. If one wants to generate science to inform the recovery of imperiled turtles in a given swamp, then one must do work on turtles in that swamp. Understanding that not all science can be scaled up or down is important. Identifying a tractable problem is key—something about which you can generate clear answers and deliver knowledge to the individual who can use it to determine exactly which habitat features in the aforementioned hypothetical swamp could be enhanced to benefit turtle populations. If one wants to influence global biodiversity with science, then it is important to understand the ways in which decisions are made at such a scale (e.g., via intergovernmental bodies that have representatives from most countries, typically selected by or representing national governments) and recognize that no single piece of evidence will be sufficient to yield change (Pullin and Knight 2003, pp. 83–88). It is also important to understand the temporal dimension. For example, in the turtle example above, a practitioner may be able to act rather immediately and rally volunteers to engage in habitat restoration. In other cases, the issue may be contentious and extensive consultation would be needed prior to any management action even being possible. There can also be institutional processes that retard the movement of new science into practice and policy (Young et al. 2016a, b). Working across spatial and temporal scales allows one to be able to target issues that might be addressed with relative ease and speed, while also working on the long game (maybe 10 years or even a career) to tackle some of the "bigger" issues (Cooke et al. 2014). Having a diverse portfolio of scalar projects allows one to achieve regular successes while working toward a really big "win."

3.10 There are no guaranteed wins

Having spent years reflecting on what works and learning from my mistakes, I have also recognized that there are no guaranteed "wins." I can follow the advice I outline above (and as reviewed by others such as Chapman et al. 2015; Cvitanovic et al. 2016; Young et al. 2016b), and sometimes, it is simply not enough. For anyone with social science training, this will not be a surprise—humans are complex and there are many factors that influence values, motivations, perspectives, and behaviors of individuals and communities. There is immense heterogeneity within superficially similar individuals and complex and interacting social networks can disrupt well-intentioned plans. The key here is to not give up—to consider these failures as simply opportunities to learn (or what some call "failing forward" (Maxwell 2007). Perhaps more nuanced understanding of knowledge mobilization and adoption in applied ecology, environmental science, and conservation science will emerge as more research is conducted on this important topic.

4 On Fruition

As an academic, I am proud of my publications, but I am even more proud of the growing number of examples to which I can point where our science has had a direct influence on resource management, conservation policy, and environmental practice (see Table 1)—or what I call the "influence" of my peer-reviewed publications (see Donaldson and Cooke 2014). The majority of these successful examples are regional (e.g., site-specific for a given fish

passage facility or waterbody), but there are also a growing number of examples both nationally and internationally. I encourage other applied ecologists to take the time to reflect on their own successes in this respect and consider if any of the revelations I have shared here could influence the frequency with which they occur. I still firmly believe that peer-reviewed publications are and should be a core component of knowledge contributing to evidence-informed policy but there are other sources of knowledge that are equally valid.

The body of knowledge we generate as scientists, and the students and postdoctoral fellows we train are all impressive legacies. However, as an applied ecologist, I am also trying to generate science of relevance to end users (see Laurance et al. 2012; Habel et al. 2013; Chapman et al. 2015 for detailed discussions of how to be more relevant) and train the next generation of scientists on how to do the same or even better than I have been able to achieve. As a scientific community, we need to have open conversations about our successes and failures (See Evans and Cvitanovic 2018) and include both scientists and practitioners in such discussions (Young et al. 2014). This is very much an active area of scholarly inquiry (understanding and measuring research impact and increasing the relevancy of research such that it can be of maximal benefit to end users) that could be bolstered by incorporating aspects of knowledge mobilization research (see Cvitanovic et al. 2015; Nguyen et al. 2017) and research impact assessment into one's research program (through collaboration with relevant social scientists). Indeed, the science of science impact and knowledge mobilization is itself fascinating and has much to offer the aspiring applied ecologist.

My journey continues. I have been fortunate to work closely with practitioners and decision makers on a near daily basis. I am humbled by the opportunity to potentially be a force of change by bringing evidence to bear on environmental decisions. Yet, we know that many of the decisions that are made are not informed by the best available evidence. Among those who are engaged in mission-oriented science in the environmental realm, I think it is our responsibility to do all we can to ensure that we generate research that is relevant to end users and share it via channels and in formats that end users desire. If we fail to do so, not only will it be a source of frustration for the knowledge generators, but it will also be a failure on our parts to help deliver on the promise of evidence-based conservation and environmental management. The discussions that we are having as a community today combined with the next generation being committed to developing solutions (e.g., Chapman et al. 2015, pp. 334–344) give me optimism that the applied ecology and conservation science of tomorrow will give practitioners what they want and need.

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