Abstract

Understanding how to improve the relationships between science, policy and practice has been described as one of the critical challenges for sustainable development in the 21st century (UNEP, 2012; UNDESA, 2015). While conservation researchers have long sought to address the challenges of ‘science uptake’ in policy and practice, exploration of how conservation research informs policy and practice is a reasonably nascent area of academic scholarship within the conservation community. This discussion paper draws on a variety of social science research fields to understand what this research has discovered and how that expertise can inform conservation activities. We explore different ‘mental models’ of the relationships between science, policy and practice, and the solutions that correlate with each model. We discuss the strengths, weaknesses and limitations of these models in relation to how each can enable more effective conservation policy and practice.

Reference

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This discussion paper draws on a variety of social science research fields to understand what this research has discovered and how that expertise can inform conservation activities. We explore different ‘mental models’ of the relationships between science, policy and practice, and the solutions that correlate with each model. We discuss the strengths, weaknesses and limitations of these models in relation to how each can enable more effective conservation policy and practice.

EXECUTIVE SUMMARY

1. The relationship between science, policy and practice is often complex. Different communities have characterised this relationship through various mental models that identify a range of challenges and propose different solutions.

2. A linear relationship between science, policy and practice is only applicable in relatively simple systems where there is strong agreement about goals among stakeholders and where problems are largely technical in nature.

3. More complex and large-scale problems require attention to the social and institutional context in which research is used, particularly in the face of: a) controversy (many stakeholders with differing goals); b) complexity (uncertainty about feedback, risks and potential interactions between system drivers such as social, biophysical and ecological change); c) urgency (a need or demand for decision-making within short timeframes).

4. There are many possible approaches that can be used to improve the influence of science in policy and practice. These can be informed by theory and practice from sectors beyond conservation. Any proposed solution must be tailored to the particular problem, location, stakeholders and governance setting.

Understanding why models fail and succeed in different contexts provides a means of defining approaches that are more fit for purpose.
INTRODUCTION

Objectives of this paper

In this discussion paper, we provide an overview of current thinking about the way that science, policy and practice interact, drawing on the work of academics and practitioners who study this interface. The aim is to identify how decision-making can be improved through a more effective and appropriate organisation of conservation science projects, programmes and institutions.

We demonstrate that the way people understand or frame the relationships between science, policy and practice has consequenc- es for the way that science is practiced and mediated. This then shapes its influence on downstream decisions and activities. Many of these perspectives are based on the concept of a linear relationship between science and policy, or a belief that the utility of science will be enhanced when it is clearly separated from politics and policy (Koetz et al., 2009). We detail how different views of the role of science continue to perpetuate a linear conception of the relationship between science and policy, that, in turn create barriers to developing approaches that are suited to the complexity and diversity of contemporary conservation challenges.

Definitions

For the purposes of this discussion paper, we define policy as binding decisions made by groups that have the power to implement these decisions. Such groups include local governments, corporations and community groups, as well as nation states and international bodies. Politics is defined following Harold Lasswell (1958) as the work of defining who gets what, when and how. It is principally concerned with the distribution or redistribution of benefits, costs and risks. While there are many different definitions and interpretations of science, it can most simply be defined as systematic approaches to the creation of new knowledge (Chalmers, 1976). Conservation practice is considered as the actual application or use of methods that lead to the design, implementation, management and monitoring of conservation projects or programmes.

In theory, conservation management or practice can be characterised as the implementation of conservation policy (Game et al., 2015).

In conservation policy and politics, science can flag issues and inform the evaluation of options in terms of costs, benefits, risks and uncertainties. But the more there is at stake in political terms the less science is likely to be able to meaningfully contribute to the resolution of problems. High-stakes problems such as climate change at a global scale or reclamation of wetlands for industrial development are cases in point where science is a relatively small contributor to the resolution of complex political problems.

We demonstrate that, in turn, create barriers to developing approaches that are suited to the complexity and diversity of contemporary conservation challenges.

The interface between science, policy and practice in conservation

The interactions between science, policy and practice are sometimes referred to as the ‘science-policy interface’ or ‘science-practice interface’. Here we refer to the science-policy-practice interface (SPPI) as a catchall term to describe the processes and settings in which decision makers in government, civil society, and business use, misuse, or reject scientific research in forming their thinking, analyses or decision-making (van den Hove, 2007).

SPPIs are characterised in different ways, ranging from a linear delivery of information from scientists to decision makers, to an iterative back-and-forth negotiation of problems, research agendas, relevant information and capacity to use that information within a specific context. In the former, roles are clearly demarcated and simple. In the latter, they are much more complex and continually negoti- ated. As outlined below, the processes, interactions and roles at the interfaces between science, policy and practice vary widely. While the knowledge products are the common focus of these interfaces, the processes are often just as critical to outcomes (Clark et al., 2006).

To date, the way these interfaces have been thought about and intentionally developed in biodiversity conservation has been limited. Koetz et al. (2011, pg. 5) argue that development of SPPIs in biodiversity conservation ‘is still largely based on conventional assumptions that science produces hard facts and that these inform value-laden political decisions.’

More recently, Toomey et al. (2016) have-
How we understand and conceptualise the influence of science on policy and practice can shape the way that science is practiced and how it is used to address conservation challenges. In the following sections, we introduce six characterisations of how science interacts with policy, drawing particularly on the typology of Michael Pregernig (2014). We also provide biodiversity and conservation science examples to clarify these types. In the discussion we suggest different ways of improving the uptake and influence of science through each of these types.

The linear model

Here, policy-making is framed as a problem-solving challenge in which knowledge production is separated from use, facts kept distinct from values, and decision-making is based on scientific knowledge. In this frame, fundamental knowledge is produced by basic science, which is then built on and made useful by applied scientists, and subsequently used by decision makers. The linear model has a long history, most of which is characterised by critique (Balconi et al., 2010; Godin, 2006; Sarewitz, 1996). Yet its appeal lies in creating a simple and well-ordered story about distinct roles and responsibilities of different groups, from pure scientists to decision makers. This model underpins classic thinking about ‘evidence-based policymaking’. It leads to the proliferation of models, assessment reports and decision-support tools in the field of biodiversity – and elsewhere – underpinned by the sense that ‘science compels action’ (Beck, 2010). However, scientists who operate within this approach are often frustrated when decision makers do not act ‘rationally’ according to their expectations, prioritising social values over assessments of biodiversity; and, indeed, over science itself. In short, the linear model is premised on the assumption that once scientific certainty or consensus is found, knowledge is passed over to (rational) decision makers who will undertake specified actions. There is a growing recognition that large challenges in environmental governance are, at least in part, attributable to the idea that science can feed into policy processes in a way that is independent, linear and unproblematic, and uncontested (Koetz et al., 2009).

Linear science delivery is evident in many formal processes of conservation planning and assessment, and especially in the conduct of science itself. In formal processes it is typified by ‘doing the science first’ as a means of gaining understanding about the biophysical systems. This approach works in what Pielke (2007) has characterised as ‘simple problems’ where:

- The choice of scope is unambiguous, discrete, and bounded;
- No ambiguity exists about the desirability of different outcomes;
- No ambiguity exists about the relationship between alternative actions and desired outcomes;
- And improving information on which decisions are based will provide insight into understanding the relationships between actions and outcomes.

This approach largely applies in situations where a single entity, for example a government agency, wishes to implement a conservation programme to maintain an isolated population of a particular species that is only found within a jurisdiction for which they have complete control, or a landowner wants a better understanding of where particular birds nest on their property to exclude these areas from grazing regimes. Pulling species back from the brink of extinction has sometimes worked through fairly linear processes when the species is found within existing reserve systems. However, for many contemporary conservation issues, which are plagued by complexity and uncertainly and generally affect a diverse section of society, this approach has limited impact. For example, Beck (2010) argues that the Inter-Governmental Panel on Climate Change (IPCC) was initially premised by a linear model of science delivery in which basic climate science and monitoring would lead to understanding of climate drivers and scenarios to be presented in assessments that would in turn influence policy responses. However, while the IPCC and affiliated research has provided ever-increasing certainty about climate science and the projected impacts of climate change on society, this has not been sufficient to mobilise the intended responses through the Kyoto Protocol and related agreements, and in many countries climate policy remains hotly debated at national and local levels. This lack of progress and increasing politicisation of climate policy has led some commentators to argue that delivery of science via these early reports has been counterproductive to the original intent (Beck, 2010; Jasanoﬀ and Wynne, 1998). However, as we go on to explore in the discussion, linear approaches do not always fail...
The knowledge transfer model

In this model it is the transfer of knowledge from the scientist to the decision maker – that is seen as the primary challenge in overcoming a fundamental problem: the lack of knowledge of decision makers. Typically, the failure of decision makers to act rationally is attributed to their lack of understanding of the science, and this is a result of science being badly communicated. For instance, scientific information may be seen as technical or internally inconsistent, overly focussed on uncertainties, and presented in inaccessible formats – shortcomings that lead to a ‘science-policy gap’ across which the scientists need to find a ‘bridge’. The solution to this problem is often assumed to be better, clearer and simpler synthesis that is less uncertain and more specifically targeted to the perceived needs of the decision maker, coupled with active transfer or knowledge brokerage. This explains the proliferation of global assessments which collate and distill knowledge to settle on scientific certainty or consensus, and intermediary individuals and institutions that seek to enable the production of credible, salient, and legitimate knowledge (Cash et al., 2003). It also explains why scientists are often encouraged to undertake media training. Over time, what started as a focus on one-way transfer of knowledge has shifted to emphasise the importance of two-way exchanges between scientists and decision makers, together with a call to build the capacity of all relevant actors to engage effectively with one another.

The Millennium Ecosystem Assessment (MA) is an apt example of an effort where broad stakeholder advisory boards, Teams had an outreach and communication process that was embedded throughout, a multi-stakeholder advisory board, and the process was tied closely to various international environmental conventions (the Convention on Biological Diversity, the Convention on Migratory Species and the Ramsar Convention). While the conceptual framework is heralded as a significant step forwards in understanding, the MA did not have a significant impact on policy within the expected timeframe. Like the GBA, it has been criticised as being a one-shot effort without follow-up or sustained connections to governmental or policy process, and demonstrating an inability to support structured dialogue between scientists and policymakers (Perrings et al., 2011; Langlade and Mooney, 2009; Loreau et al., 2006).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the latest effort to assess the global state of biodiversity and ecosystem services, learned from the GBA, MA and IPCC that broad stakeholder dialogue, an effort to evaluate the implications of different policy options, and building scientific capacity is critical to ensuring scientific assessments have policy relevance. With this shift, IPBES is starting to move the global biodiversity assessment process into a different model of the science-policy interface that explicitly includes exchange and integration of science with other knowledge and perspectives that will be discussed below. It is too early in the process to tell whether IPBES will be able to overcome the shortcomings of these other models. However, scholars of global environmental assessment processes have suggested cause for both optimism (Beck et al., 2014) and concern (Heffernan, 2016).

Completed in 2005, the Millennium Ecosystem Assessment synthesised the state of knowledge on the consequences of ecosystem change for human well-being in five technical volumes with six synthesis reports that assessed conditions and trends at global and regional scales.

The model of diffusion and utilisation

This model recognises the varied and often unexpected ways in which science influences policy. While science is, in this instance, viewed as having influence, the immediate and direct application of a ‘scientific solution’ to a ‘policy or management problem’ is viewed as unlikely, particularly in complex, contested conservation issues, where impacts of actions are uncertain. Instead, the policy environment itself is changed by the diffusion or ‘osmosis’ of scientifically derived ideas.

Thus, the study of island biogeography in the 1960s shifted our understanding of landscape function, which in turn very gradually led to the mainstreaming of ideas such as corridors and connectivity conservation in policy. While in this case the progress of science has led to shifts in conservation policy and practice, the use of connectivity science to inform conservation efforts has not always been straightforward and has been contested in many landscapes around the world (Wyborn, 2015; Evans, 2010; Goldman, 2009; Ervine, 2007).

In this example, like many other cases of diffusion, the influence of science was less about applying a particular finding to a decision, but more a shift in the emphasis of policy and practice over long periods of time.

There are clear examples of this gradual influence of science on society and decision-making, which can stem from both breakthroughs and incremental development within a field of science. Returning to the example of the Millennium Ecosystem Assessment above, the rise of ecosystem service assessments, and the proliferation of initiatives such as The Economics of Ecosystem and Biodiversity, The Natural Capital Project and The Natural Capital Protocol, illustrate that the conceptual framework has had a significant impact on conservation policy and practice, however not in the direct and linear way that it was intended (see case study on page 10).
The model of two worlds

This model sees scientists and decision makers in ‘parallel universes’ with different motivations, mandates, capacities, and incentive structures. While they may be focussed on similar challenges of sustainability, scientists and decision makers have divergent approaches, priorities and agendas. The timeframes of their activities are often misaligned, as are their perceptions of evidence and their belief in what is sufficient certainty upon which to act. In addressing the challenges envisaged by this model, improved communication does not help a great deal on its own. Instead, entrenched cultures and institutions are often seen as inevitable. Rather than challenge the ways that science and policy are organised, interventions are needed to ensure policy is ‘properly’ informed by science. These revolve around knowledge brokering, often through intermediaries who facilitate knowledge exchange where individuals are brought together to share information, and exchange ideas and evidence to develop a shared understanding of a problem (e.g. Fazey et al. 2014). For example, Fraser et al. (2006) conducted an assessment of the seasonal migratory habits and population biology of brook charr (Salvelinus fontinalis) in Quebec that combined evolutionary biology (population viability analysis and behavioural ecology) with traditional ecological knowledge (of fish behaviour, breeding grounds and migratory patterns). This process was supported by review and synthesis of scientific literature, interviews, workshops and collaborative fieldwork to enable government agencies and local communities to ‘find common ground’ when determining appropriate management and policy responses. Other activities related to this model include efforts to build the ‘science literacy’ of decision makers, or educate scientists about policy processes through workshops, seminars or fellowships. This model typically shows up the incompatibilities between science, policy and, less often, practice (see Table 1). One example of how the two worlds model manifests in conservation is in the so-called ‘implementation crisis’ (Sensus Knight et al., 2006).

As Turner (2006, pg. 721) notes: “The new priorities for protecting public lands, focussed on the protection of endangered species, conservation of biodiversity, and networks of habitat, differ significantly from the anthropocentric arguments that most often guided roadless area advocacy historically.” Such long-run change through diffusion can create a shift in values as the basis of policy. In this case, Turner argues, the key success for conservation science came through gradual shifts in policy from instrumental appraisals of areas to scientific assessments of those areas in terms of biocentric values.

The model of science and power

This model is based on the assumption (and observation) that the delivery of science into decision-making turns empirical evidence into political tools. This is especially (but not only) the case in decisions involving a range of values or interests that are strongly contested. Under these circumstances the diversity of disciplinary perspectives, scales of analysis and uncertainty inherent within science can result in issues becoming ‘scientised’ – meaning that science is used by different political actors to advance their own interests. Here, empirical claims are used as a source of authority or legitimacy to, for instance, influence the outcome of negotiations or delay difficult decisions. Conversely, science may be used as a scapegoat in unpopular decisions (Sarewitz, 2004). In some cases, scientists themselves choose to ‘play the game’ to leverage policy outcomes about which they feel strongly, through trading on their credibility and analysis of the evidence. In the model of science and power, attention is paid to these uses of knowledge as power. Much attention in this approach is given to the ‘appropriate’ role for scientists in policy; should they deliver ‘pure’ science via academic papers, act as science arbiters defining which science is pertinent and credible, act as issue advocates, or be honest brokers, objectively assessing alternative policy options?

Such approaches recognise that because knowledge forms the foundations and justification of decision-making, it is itself a form of power (see case study in page12). Calls to include indigenous and local understandings alongside science are not founded on the idea that all knowledge is equal, but rather stem from concerns about concentrating power and displacing democratic principles by including only scientific and technical
The model of science engagement

The last model we recognise – that of science engagement – envisages a much stronger engagement of the public in the design, production and delivery of scientific research and, at the more extreme, calls for science to play a fundamentally different role in society. The scientific engagement model is perhaps the most diverse in that it encompasses a range of levels of engagement across different communities, and can be applied with diverse scientific methods or approaches.

Higher levels of engagement between scientists, citizens and policymakers or practitioners, such as working in collaboration or partnering, raise a variety of challenges for science projects, programmes and organisations. These range from the practical and pragmatic issues of having the time, resources and skill sets to engage well and manage the expectations of stakeholders, to more moral, ethical and political challenges of scientists deciding who should be involved, when and how (Reed et al., 2009), and how they deal with the diverse-interests and stakes involved in conservation issues (Leith et al., 2014; Turnhout et al., 2007).

These issues, being specifically related to power relationships and the ways these are dealt with by individuals, as well as through appropriate rules, cultures and processes, often challenge scientists to think very differently about their roles and responsibilities. For example, where the results of a research process are likely to have consequence for powerful elite stakeholders, these groups will often do what they can to subvert or control that process or its outputs. There are often relatively straightforward principles and practices that can be employed to do this work; however, these are often not taught within mainstream training for conservation scientists. Moreover, there are skilled practitioners such as facilitators and mediators who can work effectively with scientists to ensure these outcomes.

There is partial evidence that effectively convening, mediating and facilitating the processes that link scientific knowledge with policy and practice for sustainability can work well (Leith and Vancil, 2015; Cash et al., 2003). Yet demonstrating the connections between these collaborative scientific practice and conservation outcomes remains a challenging area of research (Young et al., 2013), in part because these outcomes depend on socio-political processes in which feedback is fundamentally unpredictable (Schut et al., 2013). As with all complex adaptive systems (Levin 1999), feedback and emergence lead to failures of scientific prediction and an imperative for adaptive action that leads to learning, often by treating the policy and practice of connecting science and decision-making as experiments. To conduct research and meta-analysis on the success of such arrangements within the diverse settings of science engagement will require the development of consistent frameworks and approaches not dissimilar to those used by Ostrom and colleagues in understanding why and how common pool resources can be managed sustainably (Poote et al., 2010; Ostrom, 1990).

The most prominent and visible science engagement approaches come under the banner of ‘transdisciplinary research’ and ‘knowledge democratisation’ of science and encompasses citizen science, participatory science, transdisciplinary research, knowledge co-production and other such ideas and processes. The purpose of this engagement is generally formulated along the lines that we need to rebalance the notions of a privileged and separate place and path for science in society because, as the hypothesis goes, it is precisely these characteristics of modern science that act as barriers to its effective influence in public decision-making. In this model, science will, somewhat ironically, have more influence on policy if it is integrated with non-scientific expertise and knowledge. This model encourages participatory approaches to the design and delivery of scientific research and, at the more extreme, calls for science to play a fundamentally different role in society. The science engagement model is perhaps the most diverse in that it encompasses a range of levels of engagement across different communities, and can be applied with diverse scientific methods or approaches.

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The spectrum of citizen science engagement

CASE STUDY
The spectrum of citizen science engagement

Evans et al. (2005) describes how Project NestWatch set up a citizen science project that drew on volunteers to repeatedly visit and record activity in nests, submitting it to an online database across the United Kingdom. Social science research conducted alongside this project demonstrated substantial benefit to the scientific knowledge, in addition to the development of relationships and partnerships with volunteers. The project built capacity, and even empowered citizens to act to protect nesting habitat on the basis of their increased ecological knowledge within their own local settings. Larger-scale citizen science projects with more participants require much less engagement commitment or attention to methods on behalf of volunteers. They are comparatively less likely to create such outcomes.

The Range Extension Database and Mapping project (Redmap) in Australia is one such example. It provides a platform for fishers and divers to upload georeferenced photos of species at the edges of or outside their normal range, thereby helping scientists track range changes in marine species (Martin et al. 2016). While providing useful data and allowing recreational anglers to see what species are ‘on the move’, its next app- and web-based platforms and low transaction cost methods tend to enable a simple approach to informing, rather than empowering or building capacity among, volunteers.

The variety of forms and functions of the interface between science, policy and practice for conservation are numerous. Attempts to typify them, such as above, are generally inadequate to express the real diversity across different conservation issues. However, they do provide a useful focus for reflection about what works, where and why at the science-policy-practice interface. We suggest that the diverse models above offer a menu of options that can be used – not necessarily in isolation – to strengthen the linkages between conservation science and policy and practice. As we discuss below, different approaches are more or less appropriate to different settings and problem contexts.

Problems and possibilities of linear approaches
Of the mental models above, the two linear models that see science as delivering solutions to conservation challenges are potentially effective, where the primary focus is increasing understanding of ‘what is’.

The linear approach, for example, can be successfully applied where there is clear agreement on goals, and ways of addressing them are also agreed to be primarily technical (Hoppe, 2010). For example, planning investment in restoration or rehabilitation to support adaptation to climate change within an existing reserve system is likely to be a much less contested conservation problem and therefore one in which a linear science approach is more likely to be applicable. Or when an individual or organisation – for example a government agency – that has the mandate and capacity to commission research to address the knowledge gap that is impeding the delivery of a policy or programme.

Linear approaches are misplaced in many conservation contexts that require answering questions about what we should do about a particular problem. Science is very good at giving us an understanding of a problem, identifying a range of types of solutions and their possible implications, but it cannot tell us what ‘should be’. These are questions for social, policy and political processes, in which science should play a role in helping to understand policy choices and their implications rather than dictating the solutions. To put this in context, climate science has identified an issue that has significant implications for biodiversity and for society. That understanding has provided compelling impetus that a change in policy is required; however, the science used to identify the problem (namely climate modelling) provides little guidance on the ecological, social or economic impacts of climate change, and has even less to say about policy and management responses that will enable adaptation. Even in those places where there is a strong acceptance of the need to adapt to climate change, adaptation has proved to be far more challenging and politicised than would be expected (Wyborn et al., 2016; Erickson et al., 2015).

In other words, the idea that filling knowledge gaps or delivering robust science can address problems often neglects the essential political nature of complex problems (Sarewitz, 2004; Funtowicz and Ravetz, 1992). A key point here is that information is often rejected when it does not align with values. Part of the explanation for this is indicated by longstanding work from psychology that highlights how all people have a confirmation bias that draws us to information that confirms our existing opinions and values (Nickerson, 1998). Climate
Doing diffusion successfully

The diffusion model is not a prominent framing of the science-policy interface, possibly because the timescales of change are long and do not reflect an easy cause and effect relationship between knowledge and action. Rather, diffusion suggests ongoing, dogged work that gradually changes how people understand a problem, requiring persistence and patience in engagement rather than academic excellence. Options for action thus do not align well with academic success metrics. The processes of change are non-linear and often cannot be attributed to single actors or actions. Rather, change occurs through networks of actors (academic and non-academic) and iterative engagement that shifts how problems are understood and thereby what policy and management options are seen as legitimate. Nevertheless, the useful insight of diffusion models is that scientific knowledge can and does gradually gain traction with communities, policymakers and practitioners and thereby shifts debates across scales and sectors.

The Stern Review provided an interesting example of how research can shift policy debates in diffuse ways. The Review had a major impact in shifting climate change from being viewed as an environmental problem to one that is an economic challenge with wide-ranging costs associated with inaction. While many other reviews of the economic impacts of climate change had been done in the past, part of the power of this report came from the legitimacy that it was given by being commissioned by the UK Government. This suggests that part of the power of the review came from its closeness, rather than separation from the policy process. While there are only a few studies that provide insight into how, where and under what institutional conditions such diffusion has occurred (see Wyborn 2015 for an example in connectivity conservation), a recurring theme across them is that persistent engagement between scientists, policymakers, communities, industry and practitioners within policy networks can lead to change in larger policy framing of problems and solutions (Pegernig, 2014).

Bridging the gap between two worlds

Conservation examples of remedying the gap or implementation crisis suggest scientists should be more involved in networks of policy and practice (Knight et al., 2008). This might mean some conservation scientists go beyond communicating to being involved in making and implementing policy. Of course, individuals working in conservation policy and practice often do have scientific training, just as many scientists have a policy background. But the differences across the gap are typically linked with differing cultures, norms and institutional incentives on either side. For example, policy windows mean that scientific evidence may only be relevant if it is communicated in a timely and effective manner to the right people. Being effectively engaged therefore requires capabilities and sometimes incentives that counter the ‘publish or perish’ culture and the rules, norms and metrics that perpetuate it.

Alternative activities and outputs that could be given greater kudos include synthesis material written in ways that are appropriate and timely for decision makers, and more proactive dialogue among scientists, policymakers and practitioners. A common call to overcome the implementation gap is to employ knowledge brokers. The role of these individuals varies from being a relatively simple role of acting as a match-maker, linking the needs of decision makers with appropriate science or experts (Cvitanovic et al., 2014), to facilitating dialogue between these groups to potentially broaden or shift policy framings and relevant scientific understanding (Turnhout et al., 2013; Stirling, 2012).

In tackling the ‘two worlds’ problem, scientists can take at least some responsibility for addressing the challenge by acknowledging, managing and in some cases replacing the rules, norms and concepts that entrenched the separation. These efforts can reduce the divide. However, at the root of the two worlds model are attitudes that result in deep-rooted tacit support for the separation between cultures. Like the linear approaches, the mental model that identifies two separate cultures can provide a convenient demarcation of responsibilities, and appeals to people wanting to identify with a particular group (cf. Jost et al., 2004). This problem is evidenced when scientists, policymakers or practitioners blame the other group for failures rather than working to address the systemic, cultural, institutional and attitudinal foundations of the divide. Again, linear and knowledge transfer ideas are often the red flags here: scientists might see policymakers and practitioners as needing to be educated in order to better understand the problem, with an assumption that they draw too much on practical experience or their common sense. Comparably, policymakers and practitioners might blame the inability of scientists to provide information that is relevant, timely and useable (Cash et al., 2003).

Embracing science and power together

Recognition that science advice is a negotiated part of policy processes leads to recognition that power is in play and that providing science advice is potentially a politicised activity. This, in turn, has led to some reflection on the differing roles and types of science used in decision-making, and especially of the role of individual scientists. What should a scientist do? Options tend to fall into two camps: 1) ‘play the game’, build consensus and seek leverage through science and political processes; or 2) articulate the appropriate role for scientists in policy process or providing advice. As the former tends to be seen as blatant advocacy and therefore inherently political, there has been more attention to the latter. A common starting point is Pielke’s (2007) four ‘ideal types’ of roles that scientists play in policy processes: pure scientist, science arbiter, issue advocate, and honest broker of policy alternatives. Although
Doing science engagement

More participatory and inclusive approaches that come under the banner of science engagement are commonly promoted as the most appropriate means to address more complex and contested conservation challenges. Funston and Ravetz (1993) suggested that such problems require science to work with a broad diversity of stakeholders with different perspectives to assess a problem from multiple perspectives beyond those of normal scientific peer review. Similarly, Nowotny et al. (2001) argued that there are increasing demands on science to be ‘socially robust’.

Approaches ranging from citizen science to collaborative research instigated by and for specific communities have become increasingly popular and potentially applicable to a wide array of conservation problems (Nel et al., 2016; Reyers et al., 2010). Science engagement arrangements are diverse and often comprise multiple parallel approaches within a single setting (Koetz et al., 2009) borrowing elements from many of the above types and solutions. For instance, very specific technical components of problems may be dealt with through more linear scientific investigation and top-down process, while more collaborative civic approaches are used at higher and more holistic levels. Such approaches require coordination and capacity building across networks of research and policy, often among multiple organisations and jurisdictions to draw on different sources of knowledge and design strategic engagement with decision-making processes.

Science engagement will often require redesign of the way science, policy and practice relate to one another at various levels: individuals, projects, programmes, and organisations. Rising to this challenge, large-scale sustainability research initiatives such as FutureEarth attempt to work with partners to ensure that research programmes and policy review processes are aligned in terms of scope, timelines, accountability and staffing. Alignment requires consideration of how the parts work together, and the design of structures and incentives of overcome barriers and differences in culture among groups (e.g. the two worlds model). It will require decisions about how to include (and exclude) voices of stakeholders (Reed et al., 2009), and consideration of how power and politics are dealt with and how the roles of different groups and individuals are defined and allowed to change over time (Schut et al., 2013). This work may seem unscientific, but the ability of conservation science to engage effectively with the socio-cultural contexts of conservation challenges appears to have a direct relationship with the effectiveness of that science. For example, in a meta-analysis of conservation interventions, Waylen et al. (2010) identified that engagement of projects with local cultural context and the existence of a supportive institutional environment were closely correlated with the success of initiatives. Similarly, scientists have a higher likelihood of influencing policy processes through long-term, deep engagement with policy negotiation and the networks of actors involved in them (Rietig, 2014; Weible et al., 2012). These findings, among others, highlight the importance of relationships and networks of trust in the production and use of knowledge (Reid et al., 2009; Kristjánsson et al., 2009). Such understanding and a growing empirical evidence base is increasingly leaning to a rejection of older linear models of scientific practice (Clark et al., 2016; Mauser et al., 2012) well beyond conservation.

**CONCLUDING COMMENTS**

Conservation has come to be seen as something that needs to be done with people, across societies. In parallel, more diverse conceptions of the role of science and scientists have developed. Science that can contribute to addressing complex conservation challenges needs to move beyond linear models, to:

- Engage with and gradually influence long-run changes in policy and political narratives about problems (the diffusion model);
- Take seriously the politics and power involved in scientific advice and move beyond simple dichotomies of science and advocacy (the model of science and power);
- Carefully consider who is included and excluded and the processes by which scientists and science projects, programmes and organisations engage with stakeholders (model of science engagement).

These more sophisticated models embrace different theories of change and embed them in scientific practice. These approaches variously reflect research findings from fields as diverse as neuropsychology, behavioural economics, social psychology, policy sciences and anthropology and the practice of fields in health, international development and the provision of government services. They move beyond ideas that facts are needed to inform rational decision making and see science as an integral contributor to important debates and to building capacity to tackle complex problems within circles of policy and practice, as well as within broader society. These approaches do not provide blueprints or templates for action but do suggest a variety of options that can contribute to building effective, efficient and equitable interfaces between science, policy and practice.

Conservation practice that achieves outcomes depends on rigorous and appropriately targeted science being well integrated within fit-for-purpose processes that situate science within, rather than separate from, society. Making these processes work will often create a need to renovate or change the spaces where scientists, policymakers, practitioners and civil society meet. It is clear from the diversity of approaches outlined above that no ‘one shot’ solution exists for fixing the relationships between conservation science, policy and practice. Instead, these interactions are akin to ecosystems, which differ across geographies and scales, where individuals and organisations occupy different spaces, fulfil different functions and interact in sometimes non-linear ways in a complex adaptive system where the whole is more than the sum of the parts. Efforts to accelerate the impact of science in conservation require us to think outside the box, to try new approaches and accept that science may need to proceed with humility and respect for other perspectives if it is to contribute to addressing the conservation challenges of the 21st century.
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