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EDITORIAL

Bridging the knowing–doing gap: know-who, know-what, know-why, know-how and know-when

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Summary

1. A widely recognized challenge in applied ecology is the gap between the knowledge generated by scientists and uptake by practitioners. Bridging this gap requires reciprocal and iterative flows of information from both scientists and practitioners prior to research initiation and beyond its completion. Yet current approaches to knowledge exchange ignore the complexity of translating different types of knowledge and the constraints that might limit effective knowledge exchange.

2. Knowing who might use a particular piece of research is the first step when developing projects that might be of value to practitioners, but different types of research often can have quite different audiences. Identifying the precise target for research outputs, whether practitioners, stakeholders or end-users, is essential for successful knowledge exchange, and outputs must be tailored to the knowledge needs of the intended recipients.

3. The scope of many leading applied ecology journals targets use-inspired basic research that aims to develop a theoretical or fundamental basis to support interventions, technologies and policies that lead to improved applied outcomes. This more conceptual approach, while essential to the development of future management applications, is probably not what most practitioners require.

4. In contrast to the explicit knowledge generated by scientists, many practitioners apply their own tacit knowledge when making decisions regarding their conservation goals and interventions. Such knowledge is intuitive, largely experience based and hard to define. As a result is often context dependent and personal in nature. The failure of scientists to translate and consider tacit knowledge may be behind the lack of implementation of their research.

5. Additional challenges to implementation include the continuing interest and relevance of use-inspired basic research, lack of consensus among researchers regarding management options and the need for scientists to remain independent brokers of intervention options rather than conservation advocates.

6. *Synthesis and applications*. Publishing research in peer-reviewed journals will only ever be a small part of closing the knowing–doing gap. Increasingly, conservation organizations, such as NGOs and charities that employ their own scientists, steward their own protected areas, and build long-term partnerships with stakeholders will be central to implementing applied ecological science.

Key-words: advocacy, biodiversity, conservation, consultancy, decision-making, ecosystem services, partnership, policy, problem-solving, restoration

Introduction

Over the last decade it has become increasingly clear that a mismatch exists between the ecological knowledge generated by researchers and that applied by practitioners (Knight *et al.* 2008; Laurance *et al.* 2012; Habel *et al.* 2013). Scientists have been particularly active in documenting the challenges of the 'knowing–doing gap' and have proposed numerous approaches to bridging this disparity including developing alternative formats for science communication outside of formal research publications, improved partnership and participatory approaches

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between scientists and managers, as well as tying the goals of research more closely to applied outcomes. Yet what of the practitioners themselves, what are their views? In 2011, the *Journal of Applied Ecology* launched its practitioner's perspectives articles to give voice to the needs and concerns of stakeholders in securing appropriate implementation of research into practice (Hulme 2011). This initiative has proven immensely popular and, to date, has led to the publication of a dozen practitioner's perspectives culminating recently in a special symposium held as part of the British Ecological Society's centenary celebrations at INTECOL in 2013. The symposium entitled 'Putting applied ecology into practice: knowledge and needs for the 21st century' gave practitioners a platform upon which to share their experience and insights into what they require from applied ecological science and to highlight successful examples of the practical application of science to management. This special profile brings together three of the symposium presentations and, in combination with the key issues raised in previous practitioner's perspectives, provides an opportunity to highlight new perspectives on the challenges posed in closing the implementation gap. Clearly, the process requires reciprocal and iterative flows of information from both scientists and practitioners prior to research initiation and beyond its completion. However, current recommendations as to how to facilitate such knowledge exchange ignore the complexity of translating different types of knowledge and the constraints that might limit partnerships.

Know-who: practitioners, stakeholders and end-users

The first step in closing the implementation gap is understanding the character and needs of particular audiences. The terms practitioners, stakeholders and end-users are often used liberally and interchangeably in the ecological literature but have subtly different meanings that are important in terms of knowledge exchange. Practitioners are professionals and citizens engaged in leading, managing, researching, advocating, funding, educating or setting policy to achieve goals related to biodiversity conservation and the sustainable management of natural resources. This definition includes citizens involved in community conservation initiatives; individuals employed by conservation organizations (Gibbons, Wilson & Green 2011); ecological consultants (Hill & Arnold 2012; Anderson 2014); research scientists working in academia, industry or government agencies (Goulson *et al*. 2011; Fowler *et al*. 2012); extension specialists (Thorpe & Stanley 2011) as well as local, national and international conservation policymakers (Bainbridge 2014). Critical to each of these roles is an understanding of the ecology and environment of a particular study species or ecosystem and knowledge of the most effective tools and key information to deliver long-term conservation outcomes. All practitioners are stakeholders in that they have an interest or might be concerned by the actions, objectives and/or policies of their own or another organization that might affect their ability to deliver conservation goals. However, not all stakeholders are practitioners. Many conservation challenges involve stakeholders whose main goal, at least initially, is not necessarily conservation outcomes but economic benefit; such stakeholders include recreational fish and game associations (Caudron, Vigier & Champigneulle 2012), development and construction companies (Hill & Arnold 2012), mineral and oil multinationals (Pedroni *et al*. 2013) and primary industries (Quine, Bailey & Watts 2013). These individuals and organizations are often critically important to resolving conservation conflicts, but their information and knowledge needs may be quite different from those of practitioners. Only a subset of practitioners are likely to be end-users of research and actually apply a particular scientific output, be it a computer model, data base, biological control agent or management technique. Yet, such end-users often work within a network of colleagues who are responsible for the authorization, application and/or procurement of research outputs such that any uptake needs to account for a much wider range of perspective regarding the value of research. While these definitions may be viewed as hair-splitting semantics, identifying the precise target for research outputs is essential for successful knowledge exchange and there is no 'one-size-fits-all' approach; rather, outputs must be tailored to the needs and types of knowledge of the intended recipients. Knowing who might use a particular piece or research is the first step when developing projects that might be of value to practitioners, but different types of research often can have quite different audiences.

Know-why and know-what: the value of use-inspired versus pure applied research

The linear model of science juxtaposes basic research (know-why) that targets fundamental theories against applied research (know-what) that develops a subset of these theories towards practical outcomes. Practitioner perspectives suggest much ecological science is still too far removed from application to be of immediate value to ecosystem or species management (Gibbons, Wilson & Green 2011; Anderson 2014). Using the example of peatland restoration in the uplands of the UK, Anderson (2014) highlights that the lack of uptake arises because ecological research necessarily has to simplify the range of treatments, locations and/or species included in field experiments and because these are undertaken across unrealistic temporal and spatial scales determined by research logistics. The result is that there is little consideration as to whether recommendations can be realistically up-scaled to be cost-effective (Costanza, Weiss & Moody 2013; Anderson 2014). To date, the publishing philosophy of most scientific journals has not been to publish innumerable case studies targeting specific management recommendations. Rather, applied ecological research

published by leading international journals aims to tackle more fundamental aspects of conservation and restoration science with an aim of elucidating generalities of wider global significance. For example, *Conservation Biology* states 'manuscripts with relevance to conservation that transcend the particular ecosystem, species, or situation described will be prioritized for publication', and the *Journal of Applied Ecology* seeks 'contributions that use applied ecological problems to test and develop basic theory', while *Ecological Applications* publishes papers that 'develop scientific principles to support environmental decision-making'. Simply put, this more conceptual approach to what is published is probably not what most practitioners require. In reality, the scope of these leading journals is more akin to the concept of use-inspired basic research that aims to develop a theoretical or fundamental basis to support interventions, technologies and policies that lead to improved applied outcomes (Stokes 1997).

The concept of use-inspired basic research was proposed as a means to move away from the simplistic dichotomy of pure basic *vs*. applied research and identify science that could straddle these two perspectives. Use-inspired basic research therefore aims to integrate both the quest of fundamental knowledge and the utility of such knowledge but does not replace the need for pure basic or applied research. Leading international journals attempt to ensure that the research they publish meets high standards of excellence, originality and scientific impact, but with such a strong focus on scientific excellence, these journals face a challenge when assessing the extent to which use-inspired basic research could indeed be translated to application. Journals need to ensure that in the review process, the broader impact of the research is a significant component of any evaluation criteria and should include at least one referee from the practical realm. Should these journals weigh application more than excellence? There is still a need to have a venue for publishing high-quality use-inspired basic research, and in an increasingly crowded publishing marketplace, journals need to retain a level of distinctiveness. If journals lower their standards, then there is a danger that they publish use-inspired research that simply does not deliver original insights but rather presents fairly pedestrian research that is still of limited value to practitioners. The increasing availability of pay-to-publish, open access journals that stress scientific appropriateness and technical soundness as reasons to decide on publication, rather than excellence or impact, highlights that there are other venues to publish sound research addressing more locally relevant conservation issues. The benefits of publishing in these journals is that the material will be readily accessible to practitioners who may wish to use it but do not hold institutional or personal subscriptions to journals. In addition, such journals may be suitable for the dissemination of work undertaken by practitioners, especially ecological consultants whose valuable efforts would otherwise be buried in contract reports that are only read by the contractor (Hill & Arnold 2012).

Although an increasing proportion of ecologists may view themselves delivering use-inspired basic research, this is in itself no guarantee of future application. Delivering use-inspired research outputs to practitioners may be premature unless further developed into more applied contexts that are often idiosyncratic and sometimes of only local or national importance. Indeed, an important, though under-appreciated, implementation gap is between use-inspired basic research and applied research. While use-inspired research builds on developments in basic research, it remains unclear how well informed it is by pure applied research. This disconnect between successful applied outcomes and subsequent feedback to developments in more theoretical or predictive aspects of ecology is undoubtedly one of the reasons why an implementation gap exists. This gap should, in theory, be relatively easy to overcome since it involves communication among scientists who have a comparable level of technical expertise, appropriate background, draw upon a similar body of published research and may even be employed by the same organization. Translating use-inspired basic research into practice appears to work best where conservation outcomes are implemented by organizations that employ their own scientists who have a mission to deliver applied research outcomes such as can often be found in many NGOs (Gibbons, Wilson & Green 2011; Sotherton, Aebischer & Ewald 2014), research charities (Goulson *et al*. 2011; Ewen, Adams & Renwick 2013; Kareiva, Groves & Marvier 2014), government research institutes (Caudron, Vigier & Champigneulle 2012; Fowler *et al*. 2012; Quine, Bailey & Watts 2013), research bureaus of government departments (Sergeant, Moynahan & Johnson 2012), as well as land-based universities with a clear remit to deliver research extension.

Know-how: accessing the complex nature of practitioner knowledge

A common dichotomy in the field of knowledge management is that between explicit and tacit knowledge (Gamble & Blackwell 2001). Explicit knowledge is often synonymous with information and is easily codified, stored and retrieved from data repositories, bibliographic data bases, books and journal archives. Research outputs largely comprise explicit knowledge, the factual 'know-what' and underpinning 'know-why' of scientific endeavour. As discussed in the preceding section, the value of explicit knowledge to practitioners will likely depend on where particular ecological research sits along a continuum between use-inspired basic and applied science. However, in addition to explicit knowledge, many practitioners apply their own tacit knowledge when making decisions regarding their conservation goals and interventions. Tacit knowledge refers to intuitive, hard to define knowledge (know-how) that is largely experience based

and as a result is often context dependent and personal in nature (Nonaka & Takeuchi 1995). In contrast to explicit knowledge, tacit knowledge is hard to communicate but is essential to distil and integrate into conservation and ecosystem management. A challenge is that tacit knowledge will differ in both its quantity and quality across different practitioners, but this is rarely appreciated by researchers who are more familiar with appraising explicit knowledge.

Personal or individual knowledge is accumulated directly through first-hand experience or observation and may be relatively resistant to change in the face of external explicit knowledge, such as the facts and figures provided by scientists. Assembling individual perspectives in conservation can be a challenge: for example in England, there may be more than 60 000 woodland owners each with different personal knowledge as to the best way to manage their woods (Quine, Bailey & Watts 2013). At a higher organizational level, place-based or traditional knowledge refers to tacit knowledge embedded in cultural traditions of regional, indigenous or local communities. Scientists rarely have the opportunity to develop place-based knowledge for more than a handful of locations. In the quest to produce management recommendations of international relevance, the opportunity to incorporate a more thorough understanding of particular locations is lost. Nevertheless, Gardner *et al.* (2013) highlight how detailed understanding of the role of traditional ecological knowledge in several specific protected areas in Madagascar can provide more generic insights into how management for multiple uses by appropriately empowered local communities can deliver conservation outcomes and livelihood benefits. Conservation organizations are increasingly moving towards purchasing land to secure conservation outcomes (Gibbons, Wilson & Green 2011; Kareiva, Groves & Marvier 2014), though this possibility is not open to all organization (Goulson *et al.* 2011). There therefore exists an opportunity for such organizations to develop and secure the tacit knowledge about the protected areas they own and integrate this with the explicit knowledge of the scientists they employ.

Tacit knowledge of what is politically and administratively feasible in organizations, particularly local, regional and national government bodies, is often described as strategic knowledge. Strategic knowledge is evident in organizational culture and procedures, rules and regulations as well as codes of conduct. While these appear to be unambiguous sources of information, they do not necessarily ensure that the underlying strategic knowledge (the rationale and benefits of such procedures) is self-evident. Indeed, it is quite possible for policymakers to understand the procedures without any experience of actual practice. Bainbridge (2014) describes the challenges inherent in using ecological science to influence conservation policy in Scotland. The policy development process not only includes natural and social science perspectives but also elements of ethics, political philosophy, societal values and political judgement. Scientists must therefore become familiar with tacit strategic knowledge which includes policy needs and direction, organizational structure, chains of command and decision-making hierarchies. Critical to success is the credibility of any scientific recommendations which will be a function of the certainty attributed to research outcomes, the perceived independence and trustworthiness of the researchers themselves and the accountability of their host organizations. Thus, while practitioners may feel that there are no clear mechanisms for translating scientific evidence into government policy (Goulson *et al.* 2011), this may simply reflect that uptake of explicit scientific information has to go hand-in-hand with an understanding of the tacit strategic knowledge of policymakers.

Know-when: rules of engagement in the implementation of research

For many scientists and practitioners, the simple answer to closing the implementation gap is to develop collaborative research that merges scientific methods and management planning (Caudron, Vigier & Champigneulle 2012), brings together consultants, managers and researchers to work on joint problems (Thorpe & Stanley 2011; Hill & Arnold 2012; Ewen, Adams & Renwick 2013) and/or develops partnerships between researchers, conservationists and industry (Pedroni *et al.* 2013). Few would argue that this would not be a useful way forward in addressing many conservation challenges, but there exist a number of hurdles to reach such partnerships.

First, a fundamental question is the extent to which most researchers are prepared to engage with practitioners. It is likely that many ecologists are quite content publishing use-inspired basic research that stresses fundamental excellence rather than develops a realistic route-map for uptake (Arlettaz *et al.* 2010). Use-inspired basic research is an essential component in conservation and restoration ecology, without it the conceptual basis of many novel management approaches could be lost, including new biological control approaches (Fowler *et al.* 2012), optimized survey and monitoring designs (Sergeant, Moynahan & Johnson 2012; Hayward & Marlow 2014) or models of endangered species population dynamics (Gibbons, Wilson & Green 2011; Sotherton, Aebischer & Ewald 2014). Thus, mechanisms to transfer the insights derived from use-inspired basic research to applied research are required, rather than necessarily shifting support away from use-inspired basic research. It should be accepted that not all use-inspired basic research will necessarily lead to successful uptake, just as it is expected that not all ecological theories and predictions will necessarily find support in real ecological systems. Thus, suggestions to overhaul the way research is funded or its impact assessed (Born, Boreux & Lawes 2009) should not be considered lightly in case existing longer-term benefits of user-inspired basic research of

general relevance are lost in a move towards a more participatory, interdisciplinary approach targeting applied problems of local relevance.

Secondly, there are many areas of conservation science where there is no consensus among researchers as to what might be the best recommendation to practitioners. This is often the nature of use-inspired basic science where alternative theories and ideas are presented to be subsequently tested. Some of the issues that have resulted in fairly vociferous debate include whether managed realignment of coastal areas is effective in restoring ecosystems (Mossman, Davy & Grant 2012), the benefits and risks of assisted colonization (Thorpe & Stanley 2011), the importance of dispersal corridors in population connectivity (Gilbert-Norton *et al.* 2010), the role of apex predators in conserving native fauna (Hayward & Marlow 2014) and the use of fire to manage ecosystems (Tng *et al.* 2014). Diverse viewpoints are essential for the development of a self-critical ecological science, but such mixed messages are difficult to translate into action. Much of the debate may simply reflect that the most appropriate recommendations can often be context dependent and specific to particular areas or circumstances.

Thirdly, while there has been increasing recent interest regarding the importance of knowledge sharing and exchange in ecology (Groffman *et al.* 2010; Cook *et al.* 2013; Young *et al.* 2014), there has been little recognition of the need to make tacit ecological knowledge explicit. The emphasis to date has been the reverse, in that explicit ecological knowledge can be transferred through stakeholder summaries of scientific papers, manuals, workshops, policy briefings and factsheets. Making tacit knowledge explicit is more challenging and requires dialogue involving face-to-face communication where different parties can share beliefs so as to learn how to better articulate their thinking (Nonaka & Takeuchi 1995). Researchers who pin their hopes that having large numbers of followers on their Twitter accounts or 'likes' on their Facebook pages is an indication of the success of knowledge exchange are, unfortunately, kidding themselves. Different approaches will be required where the interest is in exchanging the tacit knowledge of individuals, places and communities or government organizations. Thus, while knowledge exchange is important, there is a real need for knowledge translation as well. Ewen, Adams & Renwick (2013) illustrate this problem when examining interactions among members of Species Recovery Groups in New Zealand, in that the focus is primarily on how to get the explicit scientific knowledge integrated into management as opposed to looking at mechanisms to make the tacit knowledge of managers more explicit. This absence of knowledge translation and exchange probably explains why the utility of these species recovery groups has been questioned, even though threatened species management suffers from a lack of coordination.

Finally, scientists are often expected to be honest brokers of policy alternatives rather than advocates supporting particular interest groups (Pielke 2007). Partnership and collaboration with practitioners can often blur the line between independent scientific advice and advocacy. For example, organizations with strong interests in conservation such as the Royal Society for the Protection of Birds (Gibbons, Wilson & Green 2011), the Game and Wildlife Conservation Trust (Sotherton, Aebischer & Ewald 2014), the Nature Conservancy (Kareiva, Groves & Marvier 2014), Fauna and Flora International (Pedroni *et al.* 2013) and WWF (Gardner *et al.* 2013) are all advocacy organizations involved in lobbying government and business on behalf of the interests of their membership. While many scientists undoubtedly endorse the aims and objectives of such organizations and may even be affiliates themselves, involvement in long-term partnerships with advocacy groups may give the impression of a lack of impartiality regarding recommendations, particularly where this involves prioritization among different management alternatives. Partnerships can lead to problems of accountability, quality assurance and objectivity regarding decision-making. It should be noted that policymakers can view the advice of advocacy groups as less trustworthy than that from academia (Bainbridge 2014) and that productive partnerships with one set of practitioners may hinder knowledge exchange with a different set that hold dissimilar values.

While not an exhaustive list of constraints to closer partnership between scientists and practitioners, it would be naïve to think that the research of all ecologists publishing in conservation and restoration journals needs to be driven by immediate goals of implementation by practitioners. Perhaps the oft-quoted value that only around one-third of papers published in leading conservation journals lead to implementation (Knight *et al.* 2008) is neither surprising nor unwarranted given the aims and scope of these journals and their emphasis on use-inspired basis rather than applied research. Indeed, some aspects of use-inspired basic research may be more valuable in addressing future problems that are as yet unforseen and for which there is limited appreciation among practitioners.

Towards implementation through a changing conservation research landscape

The research landscape has changed dramatically over the last 30 years with an increasing proportion of conservation-relevant research being undertaken and published by scientists working outside of universities. Today, NGOs and conservation charities such as the Royal Society for the Protection of Birds, Fauna and Flora International or WWF are at the vanguard of conservation implementation, fund their own research programmes, work at a global scale, establish partnerships with a wide range of practitioners and stakeholders, include independent scientists on their boards of governance, advocate for conservation, publish their own journals and are stewards of

protected areas. In addition, many such organizations have established their own metrics and mechanisms to estimate the impact of their research (Sotherton, Aebischer & Ewald 2014) In their review of the history and accomplishments of the Nature Conservancy (TNC), Kareiva, Groves & Marvier (2014) point out that this huge organization employs almost 4000 staff that includes around 600 scientists who publish more than 200 peer-reviewed papers per year highlighting a philosophy that publishing peer-reviewed literature is an important way to validate and disseminate new ideas to practitioners. TNC is also committed to future development of scientists through postdoctoral fellowship programmes. In addition, TNC has vast landholdings that largely comprise protected areas which secures the future of many endangered species and cultural landscapes. To achieve many of these goals, TNC has had to build long-term relationships with corporate and finance sectors and as a result has received some criticism in academic circles. This highlights the different *modus operandi* of the TNC to university scientists, but clearly engagement with business cannot be avoided, if the goal is to make their operations more sustainable (Pedroni *et al*. 2013). It is therefore likely that over time conservation goals will be increasingly delivered though organizations such as the TNC and that the applied ecological literature will hopefully both continue to inform and also reflect their successes.

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