A typology of barriers and enablers of scientific evidence use in conservation practice

Jessica C. Walsh, Lynn V. Dicks, Christopher M. Raymond, William J. Sutherland

Highlights

- We developed a comprehensive taxonomy of barriers & enablers to research use
- 230 factors limit or enable the use of scientific evidence in conservation practice
- Organization structure & decision-making processes are key barriers to evidence use
- Links between researchers & practitioners strengthen science-practice interface
- Conservation professionals can use this typology to improve evidence use

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A typology of barriers and enablers of scientific evidence use in conservation practice

Jessica C. Walsh[a,*,†], Lynn V. Dicks[a,‡], Christopher M. Raymond[b,c,d], William J. Sutherland[a]

[a] Department of Zoology, University of Cambridge, David Attenborough Building, Cambridge, CB2 3QZ, United Kingdom

[b] Ecosystems and Environment Research Program, Faculty of Biological and Environmental Sciences, University of Helsinki, P.O. Box 65, 00014, Finland

[c] Helsinki Institute for Sustainability Science (HELSUS), University of Helsinki, Yliopistonkatu 3, 00014 Helsinki, Finland

[d] Department of Economics and Management, Faculty of Agriculture and Forestry Sciences, University of Helsinki, Latokartanonkaari 7, 00014 Helsinki, Finland

* Corresponding author

[†] School of Biological Sciences, Monash University, Clayton, 3800, Victoria, Australia (present address) & School of Earth and Environmental Sciences, University of Queensland, St Lucia, 4072, Queensland, Australia.

[‡] School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom (present address)

Emails: jessica.walsh@monash.edu, lynn.dicks@uea.ac.uk, christopher.raymond@helsinki.fi, w.sutherland@zoo.cam.ac.uk

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Abstract

Over the last decade, there has been an increased focus (and pressure) in conservation practice globally towards evidence-based or evidence-informed decision making. Despite calls for increased use of scientific evidence, it often remains aspirational for many conservation organizations. Contributing to this is the lack of guidance on how to identify and classify the array of complex reasons limiting research use. In this study, we collated a comprehensive inventory of 230 factors that facilitate or limit the use of scientific evidence in conservation management decisions, through interviews with conservation practitioners in South Africa and UK and a review of the healthcare literature. We used the inventory, combined with concepts from knowledge exchange and research use theories, to construct a taxonomy that categorizes the barriers and enablers. We compared the similarities and differences between the taxonomies from the conservation and the healthcare fields, and highlighted the common barriers and enablers found within conservation organizations in the UK and South Africa. The most commonly mentioned barriers limiting the use of scientific evidence in our case studies were associated with the day-to-day decision-making processes of practitioners, and the organizational structures, management processes and resource constraints of conservation organizations. The key characteristics that facilitated the use of science in conservation decisions were associated with an organization’s structure, decision-making processes and culture, along with practitioners’ attitudes, and the relationships between scientists and practitioners. This taxonomy and inventory of barriers and enablers can help researchers, practitioners and other conservation actors to identify aspects within their organizations and cross-institutional networks that limit research use – acting as a guide on how to strengthen the science-practice interface.

Key words: environmental decision making, evidence-based conservation, knowledge-action, knowledge exchange, research implementation, science-practice

1. Introduction

1.1 Conservation science-practice interface

The science-practice divide in conservation is a well described phenomenon, and is an ongoing concern among researchers and practitioners (Knight et al. 2008; Sunderland et al. 2009; Arlettaz et al. 2010; Esler et al. 2010; Habel et al. 2013). Numerous studies have shown that practitioners seldom use scientific sources to inform their conservation management decisions, relying mostly on other forms of information including personal experience, anecdotal evidence and advice of colleagues (Pullin et al. 2004; Cook et al. 2010, 2012; Seavy & Howell 2010; Bayliss et al. 2011; Young & Van Aarde 2011; Matzek et al. 2014; Cvitanovic et al. 2014). This means that research is often not used effectively to inform practice (Sutherland et al. 2004; Dicks et al. 2014). Failing to incorporate scientific evidence into decisions could potentially lead to less effective or detrimental conservation management actions (Walsh et al. 2015).

We apply a broad definition of research use, encompassing three types of knowledge use – instrumental, conceptual and symbolic (Weiss 1979; Nutley et al. 2007a), while also recognizing that ‘use’ of scientific evidence could include transmission, cognition, reference, adoption, influence and application of the information (Landry et al. 2001). Evidence is information that supports or refutes a hypothesis, opinion or a course of action (Walsh 2015), and scientific evidence is derived from social or natural science research methods. This study focuses specifically on the integration of scientific evidence into practice; addressing the call for improved research use in conservation (Legge 2015). However, we acknowledge that scientific evidence is just one form of information considered in conservation decisions, alongside expert opinion and local and traditional knowledge (Raymond et al. 2010; Adams & Sandbrook 2013; Tengö et al. 2017).

Many factors limit the fuse of scientific information in conservation decision making and management (van Wyk et al. 2008; Young & Van Aarde 2011; Cvitanovic et al. 2015a, 2016; Bertuol-Garcia et al. 2018). However, a comprehensive detailed list of these disparate barriers and enablers to research use in conservation has not been captured or described within a single framework, making it difficult for conservation actors (including practitioners, researchers and knowledge brokers) to navigate the science-practice space effectively. For example, practitioners may not have access to peer-reviewed publications (Fuller et al. 2014), they have insufficient time to read scientific papers, and they may lack necessary skills or resources to apply the information to their practice (Pullin et al. 2004; Sunderland et al. 2009; Cook et al. 2010). The research produced may be irrelevant, the findings may contradict practitioners' past experience or researchers may not have time, skills or motivation to disseminate their research and interact with practitioners effectively (Roux et al. 2006; Balme et al. 2014; Matzek et al. 2014; Cossarini et al. 2014). Other reasons include when political, social, economic or cultural factors take priority, or where values or attitudes of leaders drive the outcomes. A typology that collates and organizes these factors into a comprehensive list would be a useful starting point for conservation actors to identify the factors that are limiting use of scientific evidence in conservation management, and to better understand how and where to focus their efforts on strengthening the science-practice interface.

1.2 Existing knowledge exchange and research use conceptual frameworks

Before identifying the barriers and enablers, it is important to consider the conceptual frameworks and theories that describe how research is produced, exchanged and used. These can be broadly divided into two bodies of research: (i) knowledge exchange and (ii) the implementation of innovations and technology (Appendix S1). Several conceptual frameworks in the environmental literature describe how knowledge can be produced and exchanged effectively between the research and practice spheres (Reed et al. 2014; Cvitanovic et al. 2016; Nguyen et al. 2017), why the science-practice gap exists (Bertuol-Garcia et al. 2018), and the implementation of evidence-based practice (Pullin & Knight 2009; Dicks et al. 2014). Most of the initial research on knowledge exchange and use of scientific evidence, however, has been developed in other fields, particularly in medicine, healthcare, management practice, social welfare, education and agricultural science (e.g., Mitton et al. 2007; Nutley et al. 2007b; Rycroft-Malone & Bucknall 2010). Common themes arise from conceptual frameworks and theories across these sectors that describe influential factors facilitating research use and knowledge exchange: the nature of the research (or innovation to be adopted), aspects of communication and presentation, characteristics of the practitioner and other knowledge actors; the institutional setting; the links between science and practice; the implementation or decision processes; and the environmental or external context (Appendix S1). Many of these components originate from the 'diffusion of innovations' theory (Rogers 2003) and variations of these themes have been widely applied in taxonomies to specifically categorize barriers and enablers to research use in healthcare (Rycroft-Malone et al. 2004; Kajermo et al. 2010; Zwolsman et al. 2012; Humphries et al. 2014).

While the existing environmental management conceptual frameworks mention versions of these concepts (Reed et al. 2013; Cvitanovic et al. 2015b; Nguyen et al. 2017; Bertuol-Garcia et al. 2018), they do not provide a comprehensive list of barriers and enablers associated with the use of scientific evidence in conservation decisions under each of these themes. To complement these overarching frameworks of knowledge exchange and research use, we developed a detailed taxonomy and classification of barriers and enablers, drawing on data collected from a diverse group of conservation practitioners and relevant systematic reviews in healthcare. This inventory and taxonomy could be used to develop a practical checklist for researchers, practitioners and their organizations to diagnose the barriers that are most limiting within their context and identify facilitators that could strengthen the conservation science-practice interface.

The aims of this paper were three-fold:

1. First, to collate an inventory of the enablers and barriers to using scientific research in conservation practice and develop an overarching taxonomy (or typology) to classify these factors. The purpose of the inventory was to provide a comprehensive, organized list of specific factors in one place.
2. Secondly, to explore the salience and applicability of existing conceptual frameworks from healthcare to address the research-practice divide in conservation. While the barriers experienced by conservation scientists and practitioners mirror those found in more developed fields of evidence-based practice (Pullin & Knight 2001), conservation may have other barriers specific to this discipline.
3. Finally, to identify the most common barriers and enablers to using science in practice as perceived by practitioners in the UK and South Africa, to gain more insight into which factors to focus on.

In this study, we focused primarily on the conservation science-practice interface rather than the science-policy interface, as they involve distinct processes, knowledge and actors. However, we acknowledge that these sectors acutely intersect, and that similar issues exist within the policy realm (Rose et al. 2018; Young et al. 2014).

2. Methods

To develop a comprehensive inventory of barriers and enablers, we used thematic analysis to inductively code nodes and themes from interviews with conservation practitioners and from relevant systematic reviews in the healthcare sector. Then, we used central themes from existing knowledge exchange and research use frameworks (Appendix S1) to inform the taxonomy we developed to classify the barriers and enablers.

2.1 Interviews

We conducted semi-structured interviews with 18 practitioners from five organizations in KwaZulu-Natal, South Africa, and 17 practitioners from seven conservation organizations in East Anglia, United Kingdom. We focused on the United Kingdom (UK) and South Africa as examples with distinct conservation and socio-economic contexts, to ensure that the inventory was internationally relevant (Appendix S2). We defined 'conservation practitioners' as people who were involved in the planning, decision making and/or implementation of conservation and environmental management, with the aim of managing and conserving ecosystems, ecological communities, species and environmental services (Gossa et al. 2015). To capture perspectives from a diversity of organizations differing in their management scales, mandates, context, resources and capacity, we interviewed practitioners from local, regional and national government agencies, and regional and national non-government organizations (NGOs) across both countries. We selected the organizations based on their prominence within the study areas and their interest in this study.

Practitioners were selected using purposive sampling, as recommended by key informants, to give a diverse range of perspectives. The factors used to select practitioners included their organization type, their role (i.e. manager or advisor), and their level of decision making within the organization. Participants included managers (N_{SA} = 10, N_{UK} = 11) and scientific advisors (N_{SA} = 8, N_{UK} = 6). We defined managers as professionals predominantly responsible for decision making, planning and implementing conservation work (e.g. protected area managers, reserve wardens). We defined advisors as being responsible for providing advice to managers (usually within the same organization), with some remit for onsite monitoring or research, and often had scientific training (e.g. ecologists, scientific advisors). We were also interested in interviewing practitioners at several levels of decision making within their organization, including on-ground managers and advisors (i.e. operational), those involved in regional or mid-level management decisions (mid-level), and practitioners involved in policy development and strategic oversight of the organization (strategic). While we aimed to interview advisors and managers from each level, it was not possible given the structure and size of the organizations involved in our study. A summary of the demographic information of participants is included in Appendix S2: Table S1.

Interviewees were asked what factors they thought assisted or limited the use of scientific research in management decisions within their organization (Appendices S2 & S3). We gave participants the interview questions one week in advance to prepare answers. We received written consent from practitioners about their willingness to participate and record the interviews. Their responses were confidential. We reached saturation (i.e. no new ideas and concepts arose in the last few interviews) within each country. This research was approved by the University of Cambridge Research Ethics Committee.

2.2 Literature Review

In addition to the interviews, we reviewed categorization schemes of barriers and enablers to using science in practice, developed in the medical, allied healthcare and public health literature. We focused on the healthcare literature due to the initial development and wide-spread implementation of evidence-based practice in this sector (Cochrane 1972; Evidence-Based Medicine Working Group 1992). Given the extensive volume of literature available, we restricted the search to English peer-reviewed systematic reviews (quantitative and qualitative) that provided lists of barriers and facilitators to research use, knowledge transfer and knowledge exchange. We conducted the search in the Web of Knowledge in October 2014, using specific word search terms (Appendix S2: Table S2).

The search delivered a total of 635 papers (after duplicates were removed). After excluding 460 irrelevant or ineligible (i.e. not systematic reviews) articles based on the title, and a further 113 after reading the abstract, 62 articles remained. The medical and healthcare systematic reviews covered a broad range of topics, including barriers that limit general practitioners, nurses and physiotherapists using evidence-based practice, reasons why guidelines are implemented in clinical practice settings, and how political and institutional factors influence the use of science in public health policy. Due to time restrictions, 15 reviews with broad, more generalized scopes were identified as priority for data extraction and analysis. We also included eight additional papers that were not found in the search, a relevant book (Nutley et al. 2007) and a report (Walter et al. 2004), thus generating a total of 25 references (listed in Appendix S2).

2.3 Data analysis: development of inventory and taxonomy

We constructed the inventory of barriers and enablers associated with the use of scientific research in conservation practice using thematic analysis (Braun & Clarke 2006), facilitated with the qualitative analysis software NVivo. Before initial coding, the first author (JCW) read all practitioner interviews in full. The initial stage of code involved the first author systematically analyzing each sentence or section of each interview and creating codes that described the possible factor/s that could limit or facilitate use of scientific evidence. Multiple codes were assigned to sections where relevant. The entire script of each interview was coded, and co-authors reviewed the coding from sections of the interviews that were difficult to interpret.

We then grouped and sorted the individual codes from the interviews into broad themes and sub-themes, using an inductive approach, which formed an initial version of the taxonomy's categories and sub-categories. The themes and sub-themes were based on what or who the influential factor referred to. At this stage the interview data within each code and theme was identified as either acting as a 'barrier' or an 'enabler' (description in Appendix S2), forming the basis of the inventory.

From the 25 healthcare references, the first author coded the barriers and enablers listed following the same process. We analyzed the interview data first to ensure that the initial codes and themes identified from the conservation practitioners were not influenced by those found in the healthcare literature.

The next stage of analysis was to merge the themes and codes from the interviews and literature, categorize and revise the codes and themes to avoid duplications and improve clarity. The interview scripts and healthcare references were then checked to ensure the new versions of the codes and themes matched the raw data. This iterative process was conducted by the first author with in-depth feedback and discussions with other authors to ensure the categorization of the themes and codes accurately reflected the data and that the typology was intuitive.

Then, we overlaid the categories and sub-categories from this initial inductive analysis with the themes commonly found across multiple existing conceptual frameworks and theories of knowledge exchange and research use (Appendix S1). This comparison was to determine deductively whether the existing structure and components of the framework could inform our taxonomy and identify similarities and differences between the themes and sub-themes occurring within the conservation and healthcare sectors. Most of the broad categories aligned, however, the sub-categories and codes were mostly developed inductively by the data on practitioners' perspectives and the healthcare literature. The final version of the taxonomy and inventory of barriers and enablers captured all aspects of existing conceptual frameworks, but used a more detailed categorization of themes and sub-themes to ensure it was comprehensive, self-explanatory, and relevant to the conservation context.

There were two layers of subjectivity in this analysis: (i) the practitioners' perceptions of what they regarded to be barriers and enablers, and (ii) our interpretation of the interview data. Practitioners may have been more likely to identify barriers that were easier to observe and explain, and symptoms rather than underlying causes of the science-practice divide. Practitioners may have different baseline standards of acceptable practice, which would affect whether they considered a factor (e.g. level of access to research) to be a barrier or an enabler. They may also have been less likely to report barriers that could damage their organization's reputation. To reduce this subjectivity, we interviewed a diverse range of people from different levels and roles, ensured confidentiality to the interviewees and supplemented these data with barriers and enablers found in medical field. To address the subjectivity of our interpretations, we reported all barriers or enablers that practitioners explicitly mentioned, even if we did not necessarily agree with each statement.

2.4 Major barriers and enablers in practice

We identified the most common barriers and enablers for practitioners in the UK and South Africa, by quantifying the number of practitioners who mentioned or alluded to barriers and enablers within each sub-category of the taxonomy. This was based on whether each influencing factor was referred to in a positive or negative context (Appendix S2). We emphasize that these results are qualitative in nature, providing a relative indication of which barriers and enablers are the most obvious and readily expressed by practitioners. The small sample of practitioners interviewed was selected to capture diverse perspectives, and their views were not intended to be representative of conservation practitioners in each country, or globally.

3. Results

3.1 Taxonomy of barriers and enablers to using scientific evidence in conservation management decisions

The overarching taxonomy and inventory of barriers and enablers for using scientific evidence in conservation management decisions is broadly supported by existing frameworks and theories on knowledge exchange and research use (Appendix S1 & S2). The taxonomy is structured into eight categories and 27 sub-categories (Fig. 1). The categories are: (1) the nature of the evidence; (2) the links and relationships between researchers and practitioners; (3) context of the decision; (4) characteristics of researchers and research organizations; (5) characteristics of the practitioners; (6) characteristics of the management organizations; (7) other stakeholders; and (8) the wider conservation context. The full inventory of 230 barriers and their corresponding enablers is provided in the Supporting Information (Appendix S4).

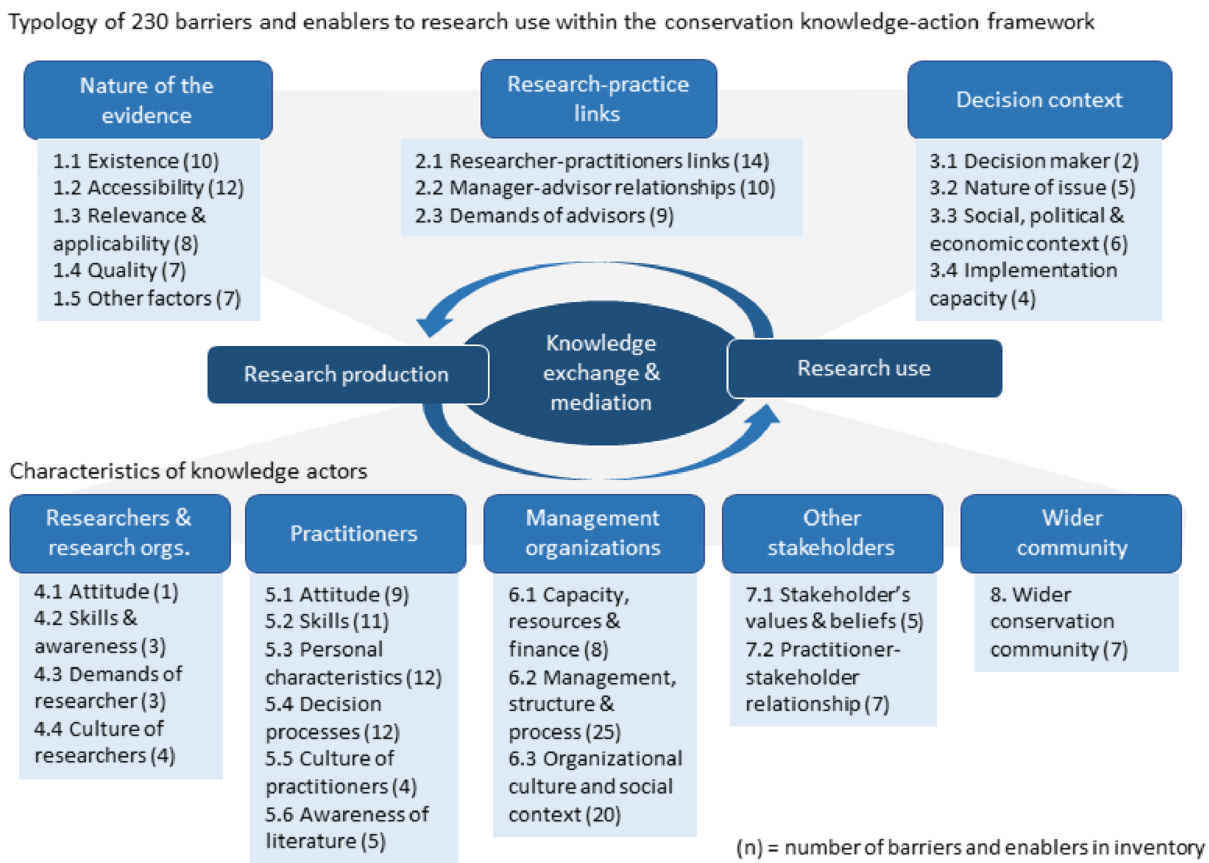

Figure 1: The taxonomy of barriers and enablers to using scientific evidence in conservation management and planning decisions, with 8 categories and 27 sub-categories, relating to the processes of knowledge production, exchange and use (Reed et al. 2013; Nguyen et al. 2017). The full inventory of 230 barriers and enablers are listed in Appendix S4. [color online only, 2 column width]

Barriers and enablers associated with the nature of the evidence are influenced by: the existence of scientific evidence; its accessibility; relevance and applicability; quality; and other inherent factors of science and research (Fig. 1, Appendix S4: categories 1.1-1.5).

The links and relationships between researchers and practitioners are key factors influencing the use of scientific evidence in conservation management and the facilitation of knowledge co-production, knowledge exchange and the feedback loop from practitioners to researchers (Fig. 1, Appendix S4:

categories 2.1-2.3). We identified three sub-categories present in the interview data, including: (i) the divide between academic researchers (usually external to the management organization) and practitioners (both managers and advisors); (ii) the divide between managers and scientific advisors (usually within the same organization); and (iii) the unique pressures and demands that scientists embedded in management organizations (i.e. advisors, ecologists and internal researchers) face, working at the science-practice interface.

The likelihood of applying research in conservation practice can relate to the decision context and depend on: who the decision maker is; the nature of the issue; the social, political and economic context; and the implementation capacity (Fig. 1, Appendix S4: categories 3.1-3.4). Many of these factors are inherent and are unlikely to be shifted from a barrier to an enabler.

Barriers or enablers associated with characteristics of researchers and their organizations include: the researchers' attitudes towards science dissemination; their communication and awareness skills; academic pressures; and the academic culture (Fig. 1, Appendix S4: categories 4.1-4.4).

The characteristics of practitioners (i.e. managers and advisors), including: their attitudes; skills; individual characteristics; decision-making processes; workplace culture; and awareness of the scientific literature, can influence the extent to which they use scientific information to inform their conservation decisions (Fig. 1, Appendix S4: categories 5.1-5.6).

The use of scientific evidence in conservation decisions can depend heavily on a conservation management organization's: financial and resource capacity; the internal management, decision-making processes and underlying organizational structure; and the organizational culture and social context (Fig. 1, Appendix S4: categories 6.1-6.3).

Characteristics of other stakeholders (i.e. the public, landowners and local communities), such as: their values and beliefs; and their interactions with practitioners, can limit or facilitate the use of scientific research (Fig. 1, Appendix S4: categories 7.1-7.2). In addition, the external context and the wider conservation community can have an overarching influence on the use of scientific evidence in management and policy decisions (Fig. 1, Appendix S4: category 8).

Despite attempts to minimize overlaps within the typology, several interactions and links across categories and sub-categories should be acknowledged. In particular, factors associated with the decision context such as the nature of the decision maker (category 3.1) relate to the characteristics of practitioners (category 5); the capacity to implement a decision (category 3.4) is likely to be affected by a management organization's capacity and finances (category 6.1); and the links between research and practice (category 2) are directly or indirectly influenced by the characteristics of the researchers, practitioners and management organizations (categories 4-6). We emphasize that the process of knowledge exchange and research use is not linear, but iterative and messy.

3.2 Comparison between barriers and enablers in healthcare and conservation

The eight broad categories described in our typology were well aligned from multiple conceptual frameworks of knowledge exchange and research use, with a few distinctions described in Appendix S2). At a finer scale, the categories and sub-categories of barriers and facilitators suggested by conservation practitioners in our case studies and the systematic reviews in the healthcare literature were similar, with one main exception.

The healthcare systematic reviews rarely mentioned factors associated with the links and interactions between researchers and practitioners (category 2, three of the 25 references included this theme: Appendix S1). However, the link between science and practice was a dominant theme mentioned often by conservation practitioners (Fig. 2). This included the collaborations between academic researchers (external to the management organization) and practitioners (category 2.1), and the relationships between managers and advisors, usually within the same conservation organization (category 2.2). Many of the managers who had access to internal ecologists said they relied heavily on their advice to learn about new research and scientific ideas, demonstrating their value to the organization: "*we're very, very reliant on the ecologists to digest this information and … feed it down [to us]*" (UK reserve manager). However, several practitioners identified a lack of mutual respect between the managers and advisors/scientists for their respective roles, priorities, skills or values: "*scientists not respecting practitioners, [and] practitioners being cynical or suspect, [and] suspicious of scientists as these blue sky idealists*" (South African strategic advisor). Importantly, several advisors and scientists positioned within management organizations mentioned the difficulties of having sufficient time and capacity to provide up-to-date advice to managers, while also struggling to maintain credibility as respected scientists (category 2.3). This sub-category was completely absent from the healthcare literature. We also found many differences at the level of individual barriers between the barriers and enablers found in the medical and conservation fields, which are presented in Appendix S2.

3.3 Major barriers and enablers to using scientific evidence in the UK and South Africa

From our interviews with conservation practitioners in the UK and South Africa, the three most common sub-categories describing barriers to using science in practice were management organizations' limited capacity and available resources (category 6.1), aspects of the organizations' structure, management and decision-making processes (category 6.2), and practitioners' decision-making processes (category 5.4), where each was mentioned or alluded to by over 85% of interviewed practitioners (Fig. 2, Table 1, further described with quotes and examples in Appendix

S2). However, in total, interviewed practitioners mentioned more enabling factors than those limiting their use of science in practice (Fig. 2) and they gave many examples of how scientific research had been influential in their management decisions. Over 85% of practitioners mentioned the following factors as enablers, including the existence of the necessary evidence (category 1.1), management organizations' structure and processes (category 6.2), aspects of their organizational culture and social context (category 6.3), practitioners' attitudes (category 5.1), the processes and information practitioners use to make management decisions (category 5.4), and positive relationships between academics, managers and advisors (category 3.1, Fig. 2, Table 2, further described with quotes and examples in Appendix S2).

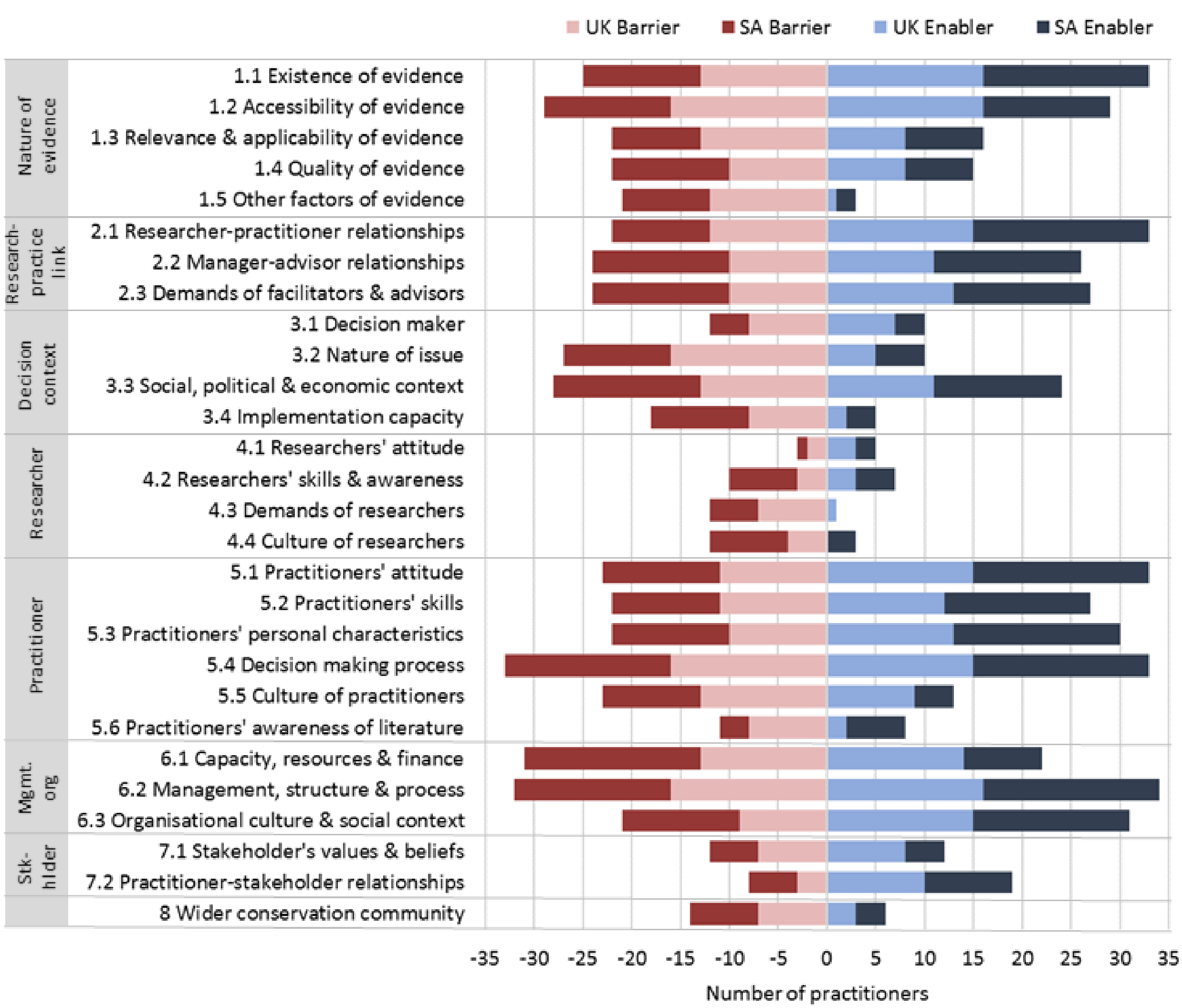

Figure 2: The number of South African and UK practitioners who mentioned each broad sub-category, either as a barrier (left side) or an enabler (right side). South Africa (SA): dark bars, n=18. United Kingdom (UK): light bars, n=17. [color online only, 2 column width]

Management organizations play an important role in facilitating or limiting research use, demonstrated by the high diversity of individual factors within these decision-making institutions (n = 53, i.e. 23% of all factors in the inventory, Fig. 1) and by the frequency of these factors mentioned by practitioners. All three sub-categories within the 'management organization' category were considered by over 85% of practitioners as enablers and/or barriers to using scientific evidence in decisions (Fig. 2). Within the organizations included in our study, financial resources and capacity were considered by practitioners to be mostly limiting, while the organizational cultures and social contexts were reported to be overall facilitating research use (Fig. 2). For example, 20 practitioners thought there was a lack of funding for conducting internal research, monitoring and knowledge exchange activities within their organization (Table 1), yet 23 practitioners mentioned that their organization recognized the value of internal scientific staff (Table 2).

Almost every practitioner identified aspects of the organizational management, structure and decision-making processes (category 6.2) as both enabling or limiting the use of science in practice (Fig. 2, Appendix S2). Problems with communication across organization departments was the most common barrier in this category (Table 1), yet similar numbers of practitioners mentioned that collective decision-making including input from scientists, and having scientists, advisors and knowledge brokers embedded within the organization enabled research use (Table 2). These institutional decision-making processes are closely linked with the individual practitioners' behaviors and decision-making processes (category 5.4), which also featured as common barriers and enablers in the interviews.

Table 1: Examples of barriers within the sub-categories most commonly mentioned by practitioners in the UK and South Africa about using scientific research to inform conservation management decisions

Common barriers to research use	Number of practitioners who mentioned barrier
5.4 Practitioner's management decision process and behavior	
• lack of time to read scientific papers & reports	23
• trust common sense, trial and error or 'gut feel'	14
• rely on personal experience	13
• assume guidelines and advice are based on science	13
6.1 Management organization capacity, resources and finance	
• lack of funding for conducting internal research, monitoring and knowledge exchange activities	20
• lack of staff capacity (time and skills)	15
• inadequate resources, administrative support and facilities required to implement changes in practice and behavior	14
• lack of funding for general management operations	12
• poor databases or dysfunctional/inefficient information management systems	12
• lack of resources to provide access to scientific research	5
• poor internet connection	5
6.2 Management organization structure, process and internal management	
• internal communication problems e.g. managers and advisors working in silos	19
• adaptive management and planning cycle not functioning or not adopted	11
• no department or staff to conduct internal experiments & research	8
• no internal policy to encourage use of science	6
• decisions are made with no input from scientists	6

* For detailed explanations see Supporting Information Appendices S2 & S4.

Table 2: Enablers within the sub-categories that were most frequently mentioned by practitioners in the UK and South Africa that facilitate the use of scientific research in conservation decisions

Common enablers of research use	Number of practitioners who mentioned enabler
1.1 Existence of scientific information	
• management outcomes are recorded and evaluated	10
• data and research about specific management questions exists	9
• trials are set in place to test effectiveness of management	7
2.1 Academic researcher-practitioner links and relationships	
• formal collaborations exist with other management organizations and practitioners	25
• practitioners support research where possible and work with academic experts in field	13
• formal collaborations exist between management & research organizations	16
• strong interactions, personal networks, partnerships and relationships exist between researchers and practitioners	6
• information channels, forums and networks exist between and within organizations	11
• students conduct research projects within management organization	12
• practitioners actively seek out academics’ advice	6
• practitioners are affiliated with universities	5
• practitioners are involved in academic research (opportunities exist)	5
5.1 Practitioner’s attitude	
• positive attitudes to research and using science in decisions	26
• belief that science benefits practice	20
• open and willing to change and try new things	12
• trust scientific information	5
5.4 Practitioner’s decision-making process and behavior	
• rely on several sources of scientific and experiential information	14
• have time to read scientific papers & reports	7
6.2 Management organization structure, process and internal management	
• collective decision-making including input from scientists	22
• embedded scientists, advisors and knowledge brokers	19
• dedicated department or staff to conduct internal experiments & research	13
• outcomes of management are monitored	14
• adaptive management and planning cycle in place & functioning	14
• management plans are efficient and reviewed frequently	8
• internal policy exists to ensure or encourage use of science	7
6.3 Organizational culture and social context	
• recognize benefits of scientific staff within organization	23

• leaders, senior management and administration support use of scientific evidence	11
• organizational culture in workplace supports research use and change	8
• strong organizational culture, staff satisfaction and high morale	10
• monitoring is an important aspect of management	7

* For detailed explanations see Appendices S2 & S4.

4. Discussion

Without fully understanding the barriers that researchers, practitioners and their organizations face when integrating research into management, the conservation community has limited capacity to efficiently improve the integration of scientific evidence into decision making. Building on a combination of frameworks from the healthcare and environmental management sectors (Appendix S1), we developed (i) an inventory of 230 factors that limit and facilitate knowledge exchange and research use (Appendix S4), and (ii) a typology – or classification scheme – that organizes these factors into categories and sub-categories (Fig. 1). At a broad level, the categories were consistent with, and thus reinforce, the components of existing conceptual frameworks (Appendix S1). Indeed, the major themes and most barriers and enablers captured in this study, such as limited capacity, resource constraints, institutional barriers and lack of time (Fig 1, Tables 1 & 2) have been previously found in other contexts (Pullin et al. 2004; Sunderland et al. 2009; Esler et al. 2010; Young & Van Aarde 2011; Matzek et al. 2014; Cvitanovic et al. 2015a). However, the novelty and value of our study is in the comprehensiveness and level of detail provided by the inventory and typology. This typology could assist researchers, practitioners, their institutions and the wider conservation community to navigate through this vast array of factors and help identify the areas within their contexts that could be improved.

We provide three other insights that contribute to the wider understanding of barriers and enablers to research use in conservation. First, we demonstrate the importance of addressing the finer details of each sub-category and individual barrier, rather than considering the broad categories superficially. Without providing details about the three sub-categories and 53 potential barriers associated with organizations, it would be difficult for managers to know where or how to improve research use within their institutions. Similarly, through our development of sub-categories within the science-practice links category, we identified the need to provide advisors with sufficient support and resources to improve their capacity as effective knowledge brokers and change agents (category 2.3). The second development from our study is the identification of complex and diverse factors associated with the decision-making processes at the individual, institutional and wider context levels (categories 5.4, 6.2 & 3), which addresses a knowledge need identified by Nguyen et al. (2017). Third, we identified which aspects of the typology the conservation community could look to the healthcare literature for guidance, which we discuss below.

4.1 Relevance of healthcare evidence-based frameworks for conservation

We found that most issues faced in conservation overlap with the healthcare sector suggesting that their longer history of evidence-based practice and extensive research on how to improve research use is relevant for conservation management (Appendix S2). Several enablers present in the healthcare field could be adopted by conservation organizations and practitioners to increase the uptake of evidence-based decision making. These include providing decision makers with best-practice guidelines, role models, training courses and educational materials to boost their skills, while ensuring the management organizations encourage the use of scientific evidence through supportive policies, funding and capacity (Appendix S4).

Our comparison of literature on barriers and enablers in healthcare with the views of interviewed conservation practitioners led to a key difference. The links and relationships between researchers, practitioners and advisors were an important component of conservation decision making (category

2, Figs. 1 & 2). This category was largely absent from the healthcare literature, perhaps due to their stronger focus on 'knowledge transfer' from medical research to health practitioners – rather than 'knowledge exchange'. Health professionals may have more access to scientific evidence that has been synthesized, appraised for quality and relevance, and presented in formats that can be quickly accessed, digested and applied, such as systematic reviews, synopses or guidelines (Dicks et al. 2014), thus reducing the need for direct contact between researchers and clinicians. The medical field also has wide-spread recognition, dedicated resources and demand for systematic reviews, evidence summaries and decision support tools. In contrast, efforts to collate the existing conservation literature is still in progress (Pullin & Knight 2009; Sutherland et al. 2019), and there is large potential for evidence synthesis in conservation to expand in the future.

Two-way interactions between scientists and decision makers have been repeatedly emphasized in the conservation and environmental management literature, suggesting that these relationships are more complex and influential than in healthcare (Roux et al. 2006; Young et al. 2014; Reed et al. 2014; Cvitanovic et al. 2015b; Nguyen et al. 2017; Bertuol-Garcia et al. 2018). Research in the agricultural sector could inform this space in the future, given its strong focus on extension workers, social networks and communities of practice. For example, providing opportunities for decision makers to be involved in knowledge and research co-production and recognizing the diversity of cultures and perspectives (Blackstock et al. 2010), could be useful strategies for understanding and influencing behavior change. A better understanding of how to effectively engage across the social network structure of advisors could also enhance knowledge exchange (Klerkx & Proctor 2013).

4.2 Pathways towards evidence-informed conservation practice

The reasons for the science-practice divide are complex (Nguyen et al. 2017; Bertuol-Garcia et al. 2018). Conservation professionals could use the typology (Fig. 1) and inventory of influential factors (Appendix S4) as a guide to systematically identify the unique factors that limit or enable research use within their organization or specific decision contexts. Appendix S4 describes the relevant barriers and enablers for each group of conservation actors, including conservation funders, publishers, educators and policy makers.

Practitioners and their organizations could focus on sections associated with the relationships and links with scientists (category 2), their attitudes, skills, decision processes, culture and awareness (category 5) and all aspects of the management organization (category 6). Management organizations can be instrumental in facilitating research exchange and research use across all levels of staff, through the culture, visions and policies, their organizational structure, planning processes and resource allocation (category 6, Table 2). For example, embedding scientists and advisors within decision-making organizations and boundary organizations have been suggested as effective solutions (Cook et al. 2013; Cvitanovic et al. 2015b).

Researchers could use this typology to identify opportunities for facilitating existence, accessibility, relevance and quality of scientific information (categories 1.1-1.4), building links with practitioners (category 2.1) and improving their attitudes, skills, academic demands and culture (category 4). In all cases, overcoming the existing barriers remains challenging. Solutions to address these barriers will need to be tailored and multi-faceted, depending on the context and situation to increase success.

4.4 Limitations of the inventory and taxonomy

Some barriers and enablers may have been missed, as our review on healthcare systematic reviews was not itself systematic and the interviews were conducted with a small, but diverse, subsection of the global conservation community. Reporting frequencies of people mentioning barriers and enablers is not a true measure of importance, given the nature of qualitative data and our sample was unlikely to be representative of all practitioners. The barriers and enablers frequently mentioned may not be those of greatest concern, but rather a description of the factors that are easily observed and described. Absence does not imply a barrier is not important, as practitioners may not have mentioned factors they assumed were obvious, ones they forgot or dismissed as irrelevant. It is possible that practitioners interviewed in this study were more inclined to speak positively about their use of scientific evidence, which may explain why we identified more enablers than barriers overall.

At the conceptual level, our study investigated how and why knowledge is a limiting factor in conservation practice, but we acknowledge that many other factors are involved in decisions, such as power relationships between individuals and groups and different value lenses (Raymond et al. 2019), and the links between knowledge, values and rules (Colloff et al. 2017), that lead to different priorities in conservation management. Despite these limitations, our qualitative data provide a solid platform to further develop and expand the inventory of barriers and enablers to using science in practice.

4.5 Future steps

Further research is needed to understand which barriers are driving the science-practice divide, rather than simply focusing on symptoms of an underlying cause; how the barriers are causally linked or interdependent; and trade-offs between barriers and enablers in specific organizational contexts. There is scope to expand the classification scheme and the inventory of barriers and enablers to include aspects of the science-policy interface, which suffer from similar limitations (Rose et al. 2018). Most critically, research is needed on which solutions effectively transform each barrier into an enabler, and how each of these enablers facilitate the use of scientific evidence in conservation practice. This would outline actions for individual practitioners and researchers, organizations, and international consortiums, such as the European Union knowledge synthesis project EKLIPSE (EKLIPSE 2019) or the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

4.6 Conclusion

By compiling the barriers and enablers from healthcare and conservation perspectives, this study presents a comprehensive inventory of the factors contributing to the use of scientific evidence in conservation. Even though many barriers occur simultaneously in each conservation setting, this list enables practitioners and researchers to break down the problem into manageable pieces and identify possible methods of overcoming these issues.

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6. Supporting Information

A summary of knowledge exchange and research use conceptual frameworks (Appendix S1), additional methods and results (Appendix S2), interview script (Appendix S3), and the inventory of barriers and enablers to using scientific evidence in conservation decisions (Appendix S4) are available online.

7. Literature cited

Adams, W. M., and C. Sandbrook. 2013. Conservation, evidence and policy. Oryx **47**:329–335.

Arlettaz, R., M. Schaub, J. Fournier, T. S. Reichlin, A. Sierro, J. E. M. Watson, and V. Braunisch. 2010. From publications to public actions: when conservation biologists bridge the gap between research and implementation. BioScience **60**:835–842.

Balme, G. A., P. A. Lindsey, L. H. Swanepoel, and L. T. B. Hunter. 2014. Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. Conservation Letters **7**:3–11.

Bayliss, H. R., A. Wilcox, G. B. Stewart, and N. P. Randall. 2011. Does research information meet the needs of stakeholders? Exploring evidence selection in the global invasive species community. Evidence and Policy **8**:37–56.

Bertuol-Garcia, D., C. Morsello, C. N. El-Hani, and R. Pardini. 2018. A conceptual framework for understanding the perspectives on the causes of the science-practice gap in ecology and conservation. Biological Reviews **93**:1032–1055.

Blackstock, K. L., J. Ingram, R. Burton, K. M. Brown, and B. Slee. 2010. Understanding and influencing behaviour change by farmers to improve water quality. The Science of the Total Environment **408**:5631–5638.

Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. Qualitative Research in

Psychology **3**:77–101.

Cochrane, A. 1972. Effectiveness and efficiency. Random reflections on the health service. Nuffield Provincial Hospitals Trust, London.

Colloff, M. J. et al. 2017. An integrative research framework for enabling transformative adaptation. Environmental Science and Policy **68**:87–96. Elsevier Ltd.

Cook, C. N., R. W. B. Carter, R. A. Fuller, and M. Hockings. 2012. Managers consider multiple lines of evidence important for biodiversity management decisions. Journal of Environmental Management **113**:341–346.

Cook, C. N., M. Hockings, and R. W. Carter. 2010. Conservation in the dark? The information used to support management decisions. Frontiers in Ecology and the Environment **8**:181–186.

Cook, C. N., M. B. Mascia, M. W. Schwartz, H. P. Possingham, and R. A. Fuller. 2013. Achieving conservation science that bridges the knowledge-action boundary. Conservation Biology **27**:669–678.

Cossarini, D. M., B. H. MacDonald, and P. G. Wells. 2014. Communicating marine environmental information to decision makers: enablers and barriers to use of publications (grey literature) of the Gulf of Maine Council on the Marine Environment. Ocean & Coastal Management **96**:163–172.

Cvitanovic, C., C. J. Fulton, S. K. Wilson, L. van Kerkhoff, I. L. Cripps, and N. Muthiga. 2014. Utility of primary scientific literature to environmental managers: an international case study on coral-dominated marine protected areas. Ocean & Coastal Management **102**:72–78.

Cvitanovic, C., A. J. Hobday, L. van Kerkhoff, and N. A. Marshall. 2015a. Overcoming barriers to knowledge exchange for adaptive resource management; the perspectives of Australian marine scientists. Marine Policy **52**:38–44.

Cvitanovic, C., A. J. Hobday, L. van Kerkhoff, S. K. Wilson, K. Dobbs, and N. A. Marshall. 2015b. Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: A review of knowledge and research needs. Ocean and Coastal Management **112**:25–35.

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

Dicks, L. V., J. C. Walsh, and W. J. Sutherland. 2014. Organising evidence for environmental management decisions: a "4S" hierarchy. Trends in Ecology & Evolution **29**:607–613.

EKLIPSE. 2019. EKLIPSE: Knowledge and learning mechanism on biodiversity and ecosystem services. European Union.

Esler, K. J., H. Prozesky, G. P. Sharma, and M. McGeoch. 2010. How wide is the "knowing-doing" gap in invasion biology? Biological Invasions **12**:4065–4075.

Evidence-Based Medicine Working Group. 1992. Evidence-based medicine: a new approach to teaching the practice of medicine. Journal of the American Medical Association **268**:2420–2425.

Fuller, R. A., J. R. Lee, and J. E. M. Watson. 2014. Achieving open access to conservation science. Conservation Biology **28**:1550–1557.

Gossa, C., M. Fisher, and E. J. Milner-Gulland. 2015. The research–implementation gap: how practitioners and researchers from developing countries perceive the role of peer-reviewed literature in conservation science. Oryx **49**:80–87.

Habel, J. C., M. M. Gossner, S. T. Meyer, H. Eggermont, L. Lens, J. Dengler, and W. W. Weisser. 2013. Mind the gaps when using science to address conservation concerns. Biodiversity and Conservation **22**:2413–2427.

Humphries, S., T. Stafinski, Z. Mumtaz, and D. Menon. 2014. Barriers and facilitators to evidence-use in program management: a systematic review of the literature. BMC Health Services Research **14**:171.

Kajermo, K. N., A. M. Boström, D. S. Thompson, A. M. Hutchinson, C. A. Estabrooks, and L. Wallin. 2010. The BARRIERS scale - the barriers to research utilization scale: a systematic review. Implementation Science **5**:32.

Klerkx, L., and A. Proctor. 2013. Beyond fragmentation and disconnect: Networks for knowledge exchange in the English land management advisory system. Land Use Policy **30**:13–24.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell. 2008. Knowing but not doing: selecting priority conservation areas and the research-implementation gap. Conservation Biology **22**:610–617.

Landry, R., N. Amara, and M. Lamari. 2001. Climbing the ladder of research utilization. Science Communication **22**:396–422.

Legge, S. 2015. A plea for inserting evidence-based management into conservation practice. Animal Conservation **18**:113–116.

Matzek, V., J. Covino, J. L. Funk, and M. Saunders. 2014. Closing the knowing-doing gap in invasive plant management: accessibility and interdisciplinarity of scientific research. Conservation Letters **7**:208–215.

Mitton, C., C. E. Adair, E. McKenzie, S. B. Patten, and B. W. Perry. 2007. Knowledge transfer and exchange: review and synthesis of the literature. The Milbank Quarterly **85**:729–768.

Nguyen, V. M., N. Young, and S. J. Cooke. 2017. A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. Conservation Biology **31**:789–798.

Nutley, S. M., I. Walter, and H. T. O. Davies. 2007a. What does it mean to "use" research evidence? Pages 33–60 in S. Nutley, I. Walter, and H. Davies, editors. Using evidence: how research can inform public services. The Policy Press, Bristol.

Nutley, S. M., I. Walter, and H. T. O. Davies. 2007b. Using evidence: how research can inform public services. The Policy Press, Bristol, UK.

Pullin, A. S., and T. M. Knight. 2001. Effectiveness in conservation practice: pointers from medicine and public health. Conservation Biology **15**:50–54.

Pullin, A. S., and T. M. Knight. 2009. Doing more good than harm - building an evidence-base for conservation and environmental management. Biological Conservation **142**:931–934.

Pullin, A. S., T. M. Knight, D. A. Stone, and K. Charman. 2004. Do conservation managers use scientific evidence to support their decision-making? Biological Conservation **119**:245–252.

Raymond, C. M., I. Fazey, M. S. Reed, L. C. Stringer, G. M. Robinson, and A. C. Evely. 2010.

Integrating local and scientific knowledge for environmental management. Journal of Environmental Management **91**:1766–1777.

Raymond, C. M., J. O. Kenter, C. J. van Riper, A. Rawluk, and D. Kendal. 2019. Editorial overview: theoretical traditions in social values for sustainability. Sustainability Science **in press**.

Reed, M. S. et al. 2013. Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. Land Degradation and Development **24**:307–322.

Reed, M. S., L. C. Stringer, I. Fazey, A. C. Evely, and J. H. Kruijsen. 2014. Five principles for the practice of knowledge exchange in environmental management. Journal of Environmental Management **146**:337–345.

Rogers, E. M. 2003. Diffusion of innovations, 5th edition. Simon & Schuster, London.

Rose, D. C. et al. 2018. The major barriers to evidence-informed conservation policy and possible solutions. Conservation Letters **11**:e12564.

Roux, D. J., K. H. Rogers, H. C. Biggs, P. J. Ashton, and A. Sergeant. 2006. Bridging the science-management divide: moving from unidirectional knowledge transfer to knowledge interfacing and sharing. Ecology and Society **11**:4.

Rycroft-Malone, J., and T. Bucknall. 2010. Models and frameworks for implementing evidence-based practice: linking evidence to action. Wiley-Blackwell, Chichester, United Kingdom.

Rycroft-Malone, J., G. Harvey, K. Seers, A. Kitson, B. McCormack, and A. Titchen. 2004. An exploration of the factors that influence the implementation of evidence into practice. Journal of Clinical Nursing **13**:913–924.

Seavy, N. E., and C. A. Howell. 2010. How can we improve information delivery to support conservation and restoration decisions? Biodiversity and Conservation **19**:1261–1267.

Sunderland, T., J. Sunderland-Groves, P. Shanley, and B. Campbell. 2009. Bridging the gap: how can information access and exchange between conservation biologists and field practitioners be improved for better conservation outcomes? Biotropica **41**:549–554.

Sutherland, W. J. et al. 2019. Building a tool to overcome barriers in research-implementation spaces: the Conservation Evidence database. Biological Conservation **238**:in press. Elsevier.

Sutherland, W. J., A. S. Pullin, P. M. Dolman, and T. M. Knight. 2004. The need for evidence-based conservation. Trends in Ecology & Evolution **19**:305–308.

Tengö, M., R. Hill, P. Malmer, C. M. Raymond, M. Spierenburg, F. Danielsen, T. Elmqvist, and C. Folke. 2017. Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. Current Opinion in Environmental Sustainability **26**–**27**:17–25.

van Wyk, E., D. J. Roux, M. Drackner, and S. F. McCool. 2008. The impact of scientific information on ecosystem management: making sense of the contextual gap between information providers and decision makers. Environmental Management **41**:779–791.

Walsh, J. C. 2015. Barriers and solutions to implementing evidence-based conservation. Thesis. University of Cambridge.

Walsh, J. C., L. V. Dicks, and W. J. Sutherland. 2015. The effect of scientific evidence on conservation practitioners' management decisions. Conservation Biology **29**:88–98.

Weiss, C. H. 1979. The many meanings of research utilization. Public Administration Review **39**:426–431.

Young, J. C. et al. 2014. Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. Biodiversity and Conservation **23**:387–404.

Young, K. D., and R. J. Van Aarde. 2011. Science and elephant management decisions in South Africa. Biological Conservation **144**:876–885.

Zwolsman, S., E. te Pas, L. Hooft, M. W. Waard, and N. van Dijk. 2012. Barriers to GPs' use of evidence-based medicine: a systematic review. British Journal of General Practice **July**:e511-521.

Figure1

Typology of 230 barriers and enablers to research use within the conservation knowledge-action framework

Click here to download Figure: Fig1_Conceptual-framework-taxonomy.pdf

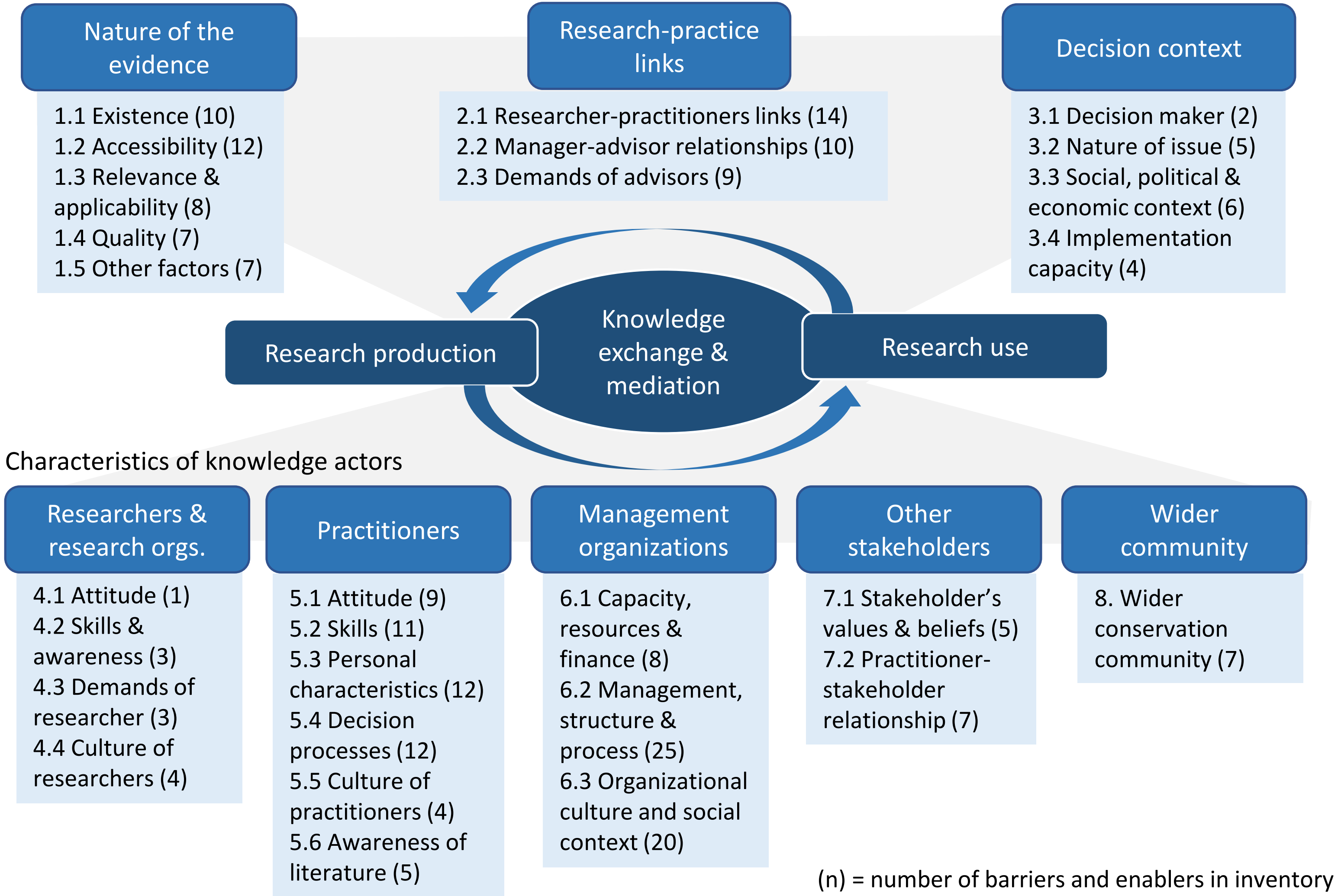

Figure2

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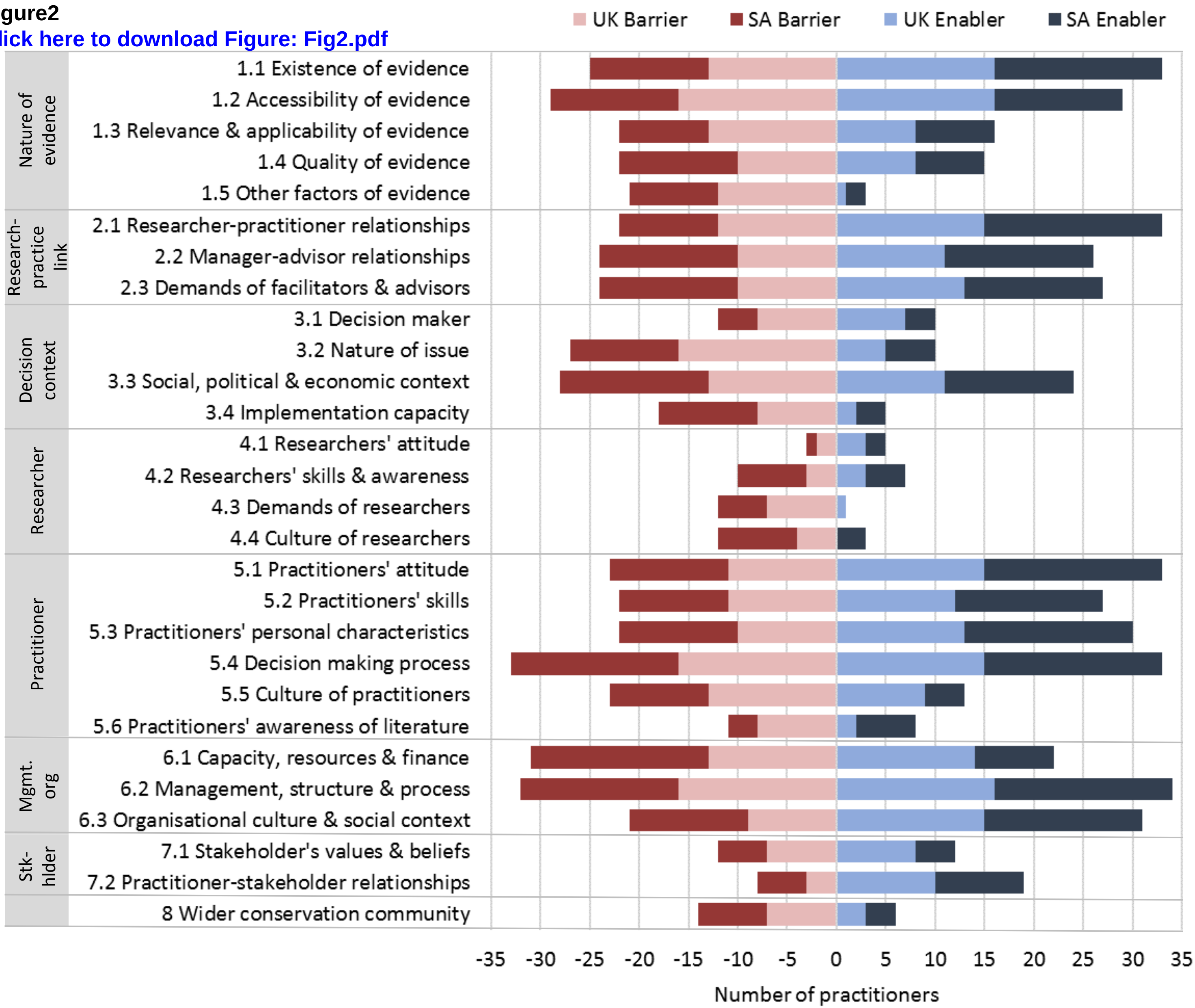

Appendix S1

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Appendix S3

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Appendix S4

Click here to download e-component: AppendixS4_Barriers_Enablers_Science_Practice_Typology.xlsx