Bridging the divide between scientists and decision-makers: How behavioural ecologists can increase the conservation impact of their research?

Sarah M Durant, Rosemary Groom, Bernard Kuloba, Abdoulkarim Samna, Uakendisa Muzuma, Phemelo Gadimang, Rose Mandisodza, Audrey Ipavec, Nicholas Mitchell, Dennis Ikanda, Maurus Msuha

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Effective conservation management is underpinned by science. Yet there are often barriers against the incorporation of up-to-date scientific research into decision-making and policy. Here we draw on experience from a multi-nation approach to conserve cheetah and African wild dogs across Africa, using relationships between scientists and managers established over more than a decade, to better understand scientific information needs of managers. While our analysis focuses on Africa, many of our findings are likely to be relevant to other regions. Managers view science as critical to their decision-making processes and strongly support scientific research, particularly when research directly addresses their information needs. However, managers reported problems in accessing final results and highlighted the need to access raw ecological data from research undertaken within protected areas. Fundamental to improving the management relevance of scientific research is the need for scientists to engage with managers through all steps of the research process, from project design and implementation through to scientific publication and end-of-project agreements. Effective engagement requires open and clear communication; including agreed processes for access to biodiversity data and submission of final results. In order to foster future scientific endeavours and collaborations, systems should be established to better facilitate information exchange, while also safeguarding the rights of scientists to publish their data and protect their academic freedom. Our analysis also calls for a greater awareness of the geo-political context under which science is undertaken, and for increased scientific participation through an inclusive approach that recognises, and gives credit to, a wider diversity of scientific contributions and expertise.

Background

Effective conservation management is underpinned by scientific understanding of the interactions and processes that underlie ecological communities (Simberloff 1988, Cook et al. 2013). Behavioural ecology seeks to understand how living organisms negotiate these complex communities through their behavioural adaptations, and provides a critical building block to understanding the mechanisms driving population and community dynamics (Caro and Durant 1995, Krebs and Davies 1997). The multiple interactions between and within species are increasingly mediated by anthropogenic impacts within highly complex socio-ecological systems, sometimes with problematic outcomes for wildlife and society (Caro and Sherman 2011). Thus, conservation management also depends on an understanding of how ecological communities are impacted by a wide range of human activities, and vice versa, including hunting, livestock grazing, fire management, infrastructure development and resource extraction (Bennett et al. 2017). After over 70 years of ecological research (Odum 1959, Odum 1977), we are only just beginning to appreciate the full complexity of ecological interactions and their impacts on ecosystems (Loreau and de Mazancourt 2013, Johnson et al. 2014, Soliveres et al. 2016), while scientific understanding of the dynamics of wider socio-ecological systems remains in its infancy (Verburg et al. 2016).

Despite the challenges of understanding complex socio-ecological systems, scientists are getting better at monitoring, explaining, and predicting ecological change (Verburg et al. 2016). Yet, if managers are to be able to draw on these scientific advancements, they need access to up-to-date research results, particularly for the areas which they manage (Walsh et al. 2015). Conservation managers often have scientific training but they are, by necessity, generalists. They are therefore unlikely to have covered in depth the multiple disciplines that underpin effective ecosystem management, while rapidly changing scientific advances make it difficult to keep up-to-date. Overly technical language, a focus on theory rather than application, and excessive detail, increases the inaccessibility of the scientific literature for conservation practitioners (Cvitanovic et al. 2016). Moreover, extensive demands on conservation managers' time, often means that they 'simply don't have the time to read the literature' (Caro 2019).

Behavioural ecologists carrying out field research within protected areas have generated a wealth of information over the years, that has improved management of protected areas (Walsh et al. 2015). Moreover, the presence of scientists during field work provides opportunities for developing direct relationships between managers and scientists, which are critical to building trust and understanding. Thus, one key means for conservation managers to access relevant science is through direct contact with behavioural ecologists carrying out field research within the sites that they manage. However, all too often, opportunities to use these relationships to bridge the science management divide are wasted.

Here we draw on the experience established through the Range Wide Conservation Program for Cheetah and African Wild Dogs (RWCP) and relationships with National Carnivore Coordinators across 10 countries to develop a better understanding of the relationships between scientists and managers, identify strengths and weaknesses, and develop recommendations for improvements. The RWCP is a long-term program, established to halt range-wide declines in cheetahs and African wild dogs. However, because both these species are sparsely distributed and wide-ranging, with most of their distributional range outside protected areas, the RWCP takes a holistic approach to conservation, tackling a wide range of issues, ranging from proximate threats, such as loss of habitat and prey, to underlying drivers, such as problems of capacity and political will (Durant et al. 2018). The RWCP has, from its inception, worked in close cooperation with national wildlife authorities of cheetah and wild dog range states (Durant 2018) to establish a consensus on the way forward for the conservation of these species (IUCN/SSC 2007, 2012, 2015), in line with IUCN/SSC planning processes (IUCN/SSC 2008). Most recently, this has resulted in a training and mentoring program for government appointed National Coordinators charged with implementing national action plans for cheetah and wild dogs, to develop specific skills needed to conserve these species. Discussions during multiple workshops and meetings since the inception of the RWCP and during training programs provide the foundations for our analyses of relationships between scientists and decision-makers. However, this analysis is not restricted to the activities of the RWCP as, over the course of their careers, National Coordinators have accumulated substantial experience in ecological monitoring and protected area management. Hence our analysis, while maintaining a core focus on large carnivores, also moves beyond these issues to reflect wider experiences about relationships between science and protected area management.

Systems and processes for undertaking field research in Africa

There are a wide variety of arrangements for undertaking scientific research on wildlife in Africa. In some countries there is a formal research approval process whereby a scientist provides a proposal for the work they wish to undertake, that is then assessed by relevant stakeholders, including protected area managers, and university and government scientists. A proposal is evaluated on its scientific merits, and may also be assessed against identified national or local research priorities. Approval will be granted or withheld based on this evaluation. Sometimes modifications may be requested, particularly when small adjustments to the proposal will enable it to better address management priorities. For example, in Tanzania, a scientist submits a research proposal to the

Tanzanian Wildlife Research Institute (TAWIRI) who prepare the proposals for the next quarterly meeting of the Joint Management Research Committee (JMRC) of the TAWIRI Board, including representatives from the Tanzanian wildlife authorities with jurisdiction over wildlife study populations. The JMRC review the proposal, including any local training provisions, and provide a recommendation for approval to the Board, which then recommends clearance to the Tanzanian Commission for Science and Technology, which is the national scientific authority that issues research permits. Countries that do not use a formal scientific review process may, instead, rely on agreements, usually memoranda of understanding or collaboration agreements, between the wildlife authority and the university or research institution where scientists are based. These agreements will stipulate areas of cooperation and responsibilities of partners; specifics of research projects may be included as annexes to the main agreement.

A permit or agreement to undertake a specific research project once granted, may impose a number of conditions on the scientist. These are likely to include periodic reporting and submission of final reports and copies of any publications resulting from the research. There may also be requirements for training and skill transfer, such as through the sponsoring and training of MSc or PhD students. In some countries, notably Kenya and Zimbabwe, scientists are expected to participate in regular workshops and meetings. Tanzania holds a scientific conference focused on wildlife research every two years, where managers and scientists meet to discuss current research findings. These fora provide important opportunities for managers to learn about scientific results first-hand, allowing further discussion and analysis, and providing useful opportunities for scientists to learn more about management priorities and other research activities undertaken in the country.

Reflections on relationships between managers and scientists.

Managers are, overwhelmingly, supportive of the principle of scientific research being undertaken within protected areas, as science underpins the approach to management of protected areas across Africa. However, researchers may not always appreciate that decision-makers have to deal with multiple competing interests (Hulme 2014). This means that, although managers listen to scientific advice, their political leaders may not necessarily follow scientific recommendations, particularly when they need to act, despite scientific uncertainty (Cook et al. 2013). This can result in conflicts and frustrations between managers and scientists, which can be exacerbated when there is a lack of transparency and scientific engagement over decision-making processes.

A lack of cooperation between scientists, and with the wider conservation NGO sector, is a source of frustration to managers. This includes receipt of multiple research applications to work on the same species at the same site from different scientists, when they could, in fact, work together. Wildlife are a limited resource, and interventions, such as immobilisation to fit a radio collar, for example, carry a small, but non-negligible risk, and should only be undertaken when necessary, and researchers should avoid unnecessary duplication of this type of research (Lindsjo et al. 2016). Moreover, opportunities for synergies between scientists working on different species and systems can be lost, either because of a lack of cooperation, or because of a lack of awareness of each other's research activities. The increasing need for multidisciplinary science to understand broader socio-ecological systems, that may include social and cultural dimensions of ecological research, requires scientists from different disciplines to work more effectively together, rather than staying within disciplinary silos.

A regular complaint of managers is that scientists do not submit reports or scientific articles as specified within their research agreement. This is perceived to be a particular problem with short-term foreign researchers when, once the scientist has left, managers have very little recourse available to compel scientists to submit reports and papers. In order to encourage report submission, the Uganda Wildlife Authority charges a fee for a research permit that is only refunded once reports have been received (https://www.ugandawildlife.org/en/wildlife-a-conservation-2/researchers-corner/research-a-monitoring). Communication and reporting compliance is better on long term research projects, which benefit from established relationships between managers and scientists. Research permit abuse was reported to be an occasional, but significant, problem, with examples of scientists receiving permits to undertake research, and then operating in ways that are not authorised by the permit, such as undertaking commercial business. Although such abuses are rare, they can cause serious breakdowns in trust between scientists and managers.

Scientists tend to focus on advances with broad scientific relevance and, in the case of applied research, may over-emphasise wide applicability of new approaches to conservation. However, the environmental, ecological, social and cultural contexts will affect the success of different interventions and scientists need to be careful to tailor advice to the different contexts of each situation. For example, the use of reinforced protective kraals or bomas at night to reduce livestock depredation from nocturnal large carnivores is a system that has been demonstrated to work well in eastern Africa (Lichtenfeld et al. 2015, Mkonyi et al. 2017). However, it does not transfer to arid areas in northwest Namibia, where communities graze livestock at night, to take advantage of night-time dew gathering on the grass, and to avoid the extreme heat in the day (MET 2018). In these situations, daytime livestock kraals will not reduce livestock depredation by nocturnal predators and, instead, the Namibian government recommends other approaches to livestock protection, including lion rangers and improving warning systems of lion presence.

Managers must often respond quickly to requests for information or advice from Ministers or other members of government. Thus, all managers, to some extent, depend on the knowledge they have acquired through years of experience working within protected areas (Hulme 2014) and from their direct interactions with scientists, as well as from reading scientific papers. However, while relevant information may be available in reports and publications, it is often not in appropriate formats for managers when responding to urgent requests for scientific advice. In such circumstances, managers have expressed a need for access to primary data, since such data can be more easily used to address a specific question.

Improving scientist-manager relationships

Behavioural ecological science relies on the careful gathering of data from field sites that can be used to test and evaluate key hypotheses. Such field research provides the most important opportunity for scientists to directly engage with wildlife management authorities, and to ensure that research addresses management needs, as well as delivering planned scientific outputs. However, very often these opportunities are lost, primarily because of a lack of active engagement of managers and decision makers from the beginning of the development of a research project. Scientists may not approach managers and decision makers until the implementation phase of their project, when they are active within their field site and may have frequent interactions with protected area managers. This is too late as, without manager input during the design of the project, it is likely to be difficult to retroactively adapt the project to address important information needs of management. Moreover, by not engaging with managers who understand the practical limitations of working within their sites, scientists may design their project inappropriately, and thus be unable to deliver on their scientific objectives.

Instead, for effective scientist-decision maker relationships, the needs of management should be factored into each step of the research process, from project design through to the end of the project (Fig. 1).

Project design

The first step in the research process is project design (Fig. 1). This is the point where it is easiest to adapt a research project to address important management priorities, as well as delivering planned science outputs. Increasingly, grant proposals require scientists to engage with management authorities in order to secure letters of support. However, it is much better to engage ahead of any such stipulated requirements to allow more time for discussion ahead of finalising the project design (Laurence et al. 2012). Such consultation should include direct discussions with the protected area site managers, who may not be the same individuals responsible for letters of support. Most wildlife authorities have scientifically trained staff who are responsible for ecological monitoring and research, and who are important first points of contact for scientists ahead of initiating research. Staff with scientific remit will have job titles such as 'park ecologist', 'park scientist' or 'head of research' and may be field based or based at the headquarters of the relevant wildlife authority. Once communication is established with these key individuals, it should be maintained throughout the project.

Before any direct communication with managers, scientists need to do their homework to understand information needs that may have already been identified by government. There are an increasing number of resources that lay out national, regional and site-based priorities for conservation management and research. Some wildlife or national park authorities have published their overall research priorities (e.g. South African National Parks https://www.sanparks.org/conservation/people/social/research/priorities.php; Kenya Wildlife Service http://www.kws.go.ke/content/research-priorities-and-programs; Tanzania Wildlife Research Institute http://tawiri.or.tz/wp-content/uploads/2017/05/Research-Priority-areas.pdf), which provide important background information. Management plans developed for protected areas also usually include research and monitoring components, and species based national conservation action plans, such as those in place for cheetah and African wild dogs (IUCN/SSC 2007, 2012, 2015), may provide information on regional and national priorities for specific taxonomic groups.

Research priorities identified by governments will seldom align perfectly with a proposed research project. Instead, priorities are likely to be based around key management issues such as fire, grazing, forest regeneration, tourism impacts or may address species priorities, particularly where a species is the focus of an action plan. However, because of ecological interdependencies, it is likely that, with some adjustment, a research project can be designed to provide relevant information for one or more specified research priorities. For example, Activity 2.3.2 in the southern Africa regional strategy for the conservation of cheetah and African wild dog is to 'Initiate field studies on cheetah and wild dog feeding ecology in different areas' (IUCN/SSC 2015). Thus, a behavioural ecology study of an ungulate species that is prey for cheetah or wild dog could easily be modified to deliver information relevant to this activity. Where there is no clear opportunity to adapt a research program to encompass stated management needs, it is worth assessing whether, with a small amount of additional effort, it might be possible to adjust the methodology to gather additional data that is directly relevant to management. Developing a project design that can address management priorities not only helps contribute to conservation, but also makes it much more likely that the research will gain approval from the wildlife authorities. For example, staff on the Serengeti Cheetah Project, while searching for cheetahs to record demographic data (Durant et al. 2007), also collected geo-referenced records of all small to medium carnivore species seen. These records were some of the only available data on these species and uncovered important patterns in their population dynamics (Sinclair et al. 2013, Byrom et al. 2014), while also addressing information needs identified in Tanzania's conservation action plan for carnivores (TAWIRI 2009).

Once potential synergies between proposed scientific objectives and published management objectives are identified, scientists should contact relevant managers. Improved phone and internet coverage to some of the most remote corners of the globe, means that it has become much easier to contact managers directly, even when they may be based at remote sites. The best approach is to make the first contact by email with the relevant manager, who is often the lead ecologist or scientist for a protected area. The email should summarise the proposed research and clearly explain how the project proposes to address identified management priorities. Subsequent discussions can then be used to obtain clarification on management priorities, to gauge whether there are emerging issues or additional priorities that may not have been published online, and to identify opportunities for cooperation. The discussions should also be used to gain information from managers on the practical limitations of the field site that can help improve the design of the research project and to ensure that research objectives are compatible, and avoid overlap, with ongoing research at the site.

Direct discussions with management ahead of initiating research should also be used to devise mechanisms for the transfer of priority skills. All research projects should embed training opportunities and skill transfer for local people within the project design, as this fosters local ownership of the project and increases capacity, as well as providing access to important local expertise and knowledge for the project (Durant 2013). How this works in practice will vary between different sites, but consideration should be given to wildlife authority ecology and research departments as potential participants in training programs. Local universities may be able to provide a source of students who can contribute to research projects as part of their undergraduate or postgraduate training. Wildlife authorities often have long-term relationships with local colleges, universities and communities that may be useful in identifying and appointing capable and committed staff and students. Citizen scientists, in the form of community game guards or scouts, may be also important potential project participants who may benefit from training.

Early engagement and preliminary discussions with protected area managers at the project design stage will help ensure that the proposed research is well aligned to government research and training agendas when undergoing research approval processes. Where there is no formal research approval process, it is good practice, at this stage, to develop and sign agreements with the relevant wildlife authorities that lay out the proposed research, and agree on areas of collaboration. Research permits or agreements will normally be subject to a number of conditions, including meeting reporting requirements. A payment may also be required that will vary from country to country.

Implementation

The implementation period, when scientists are in field sites collecting data, is the stage of the project that provides the best opportunities for direct engagement and contact between scientists and protected area managers. Hearing about research directly from scientists, rather than via papers or reports, is useful for managers, as it provides opportunities for discussion and clarification that are not available via written media. It also enables managers to provide feedback to scientists that can reveal issues that may have been overlooked or identify new avenues for research. There may be organised fora for such interactions, such as meetings and workshops, where scientists can talk about the progress of research to managers and other stakeholders, but where there are not, managers and scientists should consider initiating new fora to provide opportunities to increase scientist-manager engagement. Regular engagement between scientists and managers results in better overall coordination, including timely technical support to managers from scientists to address practical management issues that may emerge around study species, such as controlling problem animals and mitigating human-wildlife conflict.

Regular reports, usually required by wildlife authorities as part of the research agreement, provide an important document of the work that has been undertaken at the site, that may be referenced decades after the research has taken place. Reports also provide a valuable opportunity to lodge data that may not be used in scientific papers, including raw data, that can be useful to managers and subsequent scientists working at the site. Reports should document the full range of data collected, summarise results where they are available, document any findings relevant to management , and provide information about what data are likely to be available as the project progresses.

Writing up

Periods of overlap between field work with data analysis and writing provide useful opportunities for scientists to engage with managers about preliminary results, to obtain their insights on what their findings may mean. At this stage it is also important to consider coauthorship. Managers have an important perspective on the practical relevance of research, and their coauthorship increases the likelihood of making relevant practical recommendations (Britt et al. 2018), and hence improving the management or policy significance of scientific articles. Co-writing manuscripts also fosters scientist-manager co-ownership of the results, making it more likely that the research has management or policy impact.

Coauthorship with managers helps address managers' concerns about a lack of consultation about the publication of scientific papers, and identify potential problems over the framing of results. Scientists, rightly, are concerned about their scientific independence and their academic freedom to publish their results without interference. Independence of thought and careful interpretation of data, grounded in theory, is key to scientific progress. However, within scientific writing, particularly in the introduction and discussion, there is wide scope for multiple alternative framings of research findings, which can strongly influence their overall effectiveness in guiding decision-makers (Carmen et al. 2018). This power of different framings can be illustrated by the following simple example. Let us suppose that a study of a protected area system in Africa has identified a high mortality in adult elephants, with substantial evidence of illegal killing as the principle cause of this mortality. Such results can be framed in multiple ways.

Framing 1

High elephant mortality was recorded in this study because park authorities are not doing enough to stop illegal killing of elephants.

Elephants are a high-profile species, and hence are likely to attract substantial media interest. It is easy to imagine what might happen when this framing of the observed results, along with the scientific article, and associated media reports, falls onto the relevant Minister's desk. The manager responsible for the protected area may be summoned in order to explain these findings, and their job may even be put at risk. In reality, however, the manager was likely doing their best to combat illegal wildlife trade but, as is common in low income countries, had insufficient resources and capacity. It is easy to see how Framing 1 risks creating antagonism between the Minister and protected area manager, as well as with the scientist who undertook the study. Thus, rather than resulting in positive action to halt decline, Framing 1 may undermine trust between scientists and managers, which could damage existing efforts to combat illegal hunting within the protected area.

Imagine, then, an alternative framing:

> *Framing 2*
>
> *High elephant mortality was recorded in this study because the park authorities do not have sufficient capacity and resources to effectively combat illegal hunting.*

Framing 2 is may be as valid as Framing 1, but is likely to produce a different response. This time, if the Minister summons the protected area manager to explain the situation, the manager can use the study to argue that there is a need for more capacity and resources to combat the threat to elephants. The scientific article, rather than undermining trust between managers and scientists, can provide an impetus to spearhead change. Thus Framing 2 increases the likelihood of an effective management response to address illegal killing of elephants, especially if the manager is a co-author to the study and hence co-owns the results.

When managers are actively engaged in the writing process, it is more likely that scientific results are framed in ways that can catalyse positive change, and avoid frames which alienate managers and politicians and undermine trust in the scientific process (Britt et al. 2018). Where results have important policy implications, it is also worth considering providing a brief summary targeted at decision makers, in the form of a policy brief. Such a document allows communication of key results in a short and accessible format that is relevant to policy makers (Balian et al. 2016).

Scientists tend to focus their writing to appeal to those high-ranking journals publishing high impact science that are key to their institution and career development. However, while such research undoubtedly has global significance, its relevance to a particular site or species can be obscured. Publications that focus on a specific species or site are often more useful to protected area managers, but these are discouraged by many journals. Fortunately, there are new journals which encourage such publications, including Conservation Science and Practice, a journal that has been specifically designed to increase the publication of management relevant science.

In the case of purely theoretical science, results may be useful for fostering public engagement in science, particularly in the realm of animal cognition and behaviour, which is often a focus of public fascination. Many protected areas have interpretation and visitor centres that can be used to communicate interesting scientific findings from research undertaken within the protected area. Public interest in scientific advances in our understanding of animal behaviour drives support for wildlife and, ultimately, for conservation. In order to take advantage of outreach opportunities, scientists can engage with park managers responsible for tourism and community outreach to help develop relevant interpretative materials.

End of project

Many research projects are of short duration – funding cycles are normally three to five years – and hence once the project is over and the results written up, communication between scientists and managers may cease. However, very often the data gathered during the project will be used to explore other issues that were not envisaged under the original project framework. Where new articles are published, then it is important that copies should be sent to wildlife management authorities, preferably ahead of publication, no matter how many years, or decades, have passed since the end of the project.

Closure of a project raises a wider issue around the use of the raw data gathered during the project. Most protected areas are subjected to only a handful of research projects, and any data gathered has potential long-term value to protected area management. Increasing anthropogenic impacts on ecological processes and animal behaviour confer greater value to such data, as these data provide important baseline information needed for assessment of change (Caro and Sherman 2011). Obtaining access to data, once the project has finished, is therefore an issue of major concern to managers. Staff changeovers may mean that the scientist or manager has moved on, and previous personal connections may be lost, making it difficult for managers to track down data beyond the end of the project. Scientists, however, have legitimate concerns about the use of data that they have invested substantial time and resources in collection. Scientists need to maintain rights to scientific publication of their data since this is their means to justify spending time and resources on field data collection. Removing data ownership risks disincentivising field work, at a time when field-work and primary data collection is in danger of being relegated to second place in conservation science (Ríos-Saldaña et al. 2018), and when data are needed more than ever to inform efforts to sustain biodiversity through the Anthropocene.

Data, if it is to be useful to managers, needs to be stored in well-designed biodiversity databases, that are managed and maintained by trained database curators, else data are likely to get lost, or, become impossible to interpret (Durant 2013). Establishing and maintaining such databases is no easy task. Data access rights need be carefully managed according to formal agreements on data use in order to protect scientist rights to publish their data, while ensuring that managers have access to important, and often rare, data. Some data, such as social survey data, is sensitive, and needs to be stored in compliance with data protection legislation where confidentiality is safeguarded. Other data that may need special attention include data on species involved in the illegal wildlife trade, where locations may need to be kept secret. These complexities mean that, in the short to medium term, searchable web-based platforms hosting project reports may be a better mechanism to improve data availability at relatively low cost and with minimal impacts on staff time. In the longer term, attention can be given to the wider issues around data storage, database management and protection, to develop better mechanisms that can ensure that protected area managers can have access to the best available data to support effective conservation management.

Long-term projects avoid end of project issues. Managers' experience of working with scientists working on long term projects is generally much better than with short term projects, as the long time span involved provides important opportunities to establish relationships of trust and understanding, including the development of platforms for data sharing. In such situations, scientists can tailor research results to directly provide the statistics needed by managers. Long-term projects also provide opportunities for skill transfer and training to increase capacity in scientific research at field sites. Given these advantages, managers could do a lot to support research at their site by encouraging longer term programmes, which can, in turn, provide long term data in a format that is directly relevant to management.

Geo-political dimensions

The experience drawn on in this article comes predominantly from Africa, where a substantial proportion of field research is conducted by foreign scientists based in foreign institutions. While many aspects of our analysis are of wider relevance, the dominance of foreign institutions in delivering scientific information on biodiversity within many countries Africa adds an additional layer of complication to scientist-manager relationships (Sobratee and Slotow 2019). The global power imbalance between low-income and high-income countries results in an imbalance in the generation of scientific knowledge, with data collected within low-income countries, yet analyses often conducted in high-income countries, sometimes without any input from scientists from the countries where fieldwork was undertaken (Barber et al. 2014, Livingston et al. 2016). Thus, much of the data generated by scientific research in Africa is lodged in high-income countries that often fund the research, while the managers of the reserves from where the data originates may have little access to such data. These imbalances in access to scientific data and knowledge threaten to undermine effective collaboration between scientists and managers, particularly where there is little skill transfer to local scientists and institutions. Individual scientists can do little to change the wider global power imbalances, but scientists should be sensitive to these imbalances, and work to diminish, and not to perpetuate, existing inequities (Griffiths and Dos Santos 2012). Scientists from high-income countries, working in low-income countries, should thus make careful effort to counteract current power imbalances, through effective scientific collaboration (including coauthorship); engagement with local research institutions and contributing to skill transfer; and training of a diverse cadre of future scientific leaders.

Now, more than ever, we need scientific leaders and communicators from all countries of the world who are able to inform and inspire us all to increase global efforts to sustain biodiversity through the Anthropocene.

Conclusions and the way forward

While this analysis has focused on Africa, many of our findings are likely to be relevant to other regions. Managers overwhelmingly value science and scientific data as a tool for informing conservation management and decision-making. However, because of underlying problems in communication, scientific information is not being used to its full effect. Our analysis has identified a set of recommendations as to how scientists can improve relationships between science and management (Box 1). Active engagement of park management at all stages in the research, from project design through to project completion, is likely to improve delivery of management-relevant science with better interpretation and framing of results.

With the growth of citizen science, scientific research can be used as a tool for community and stakeholder engagement that extends beyond government wildlife authorities (Ellwood et al. 2017). For example, in Nakuru National Park in Kenya, following disagreement about local pollution and its impact on Lake Nakuru and its biodiversity, the Kenyan Wildlife Service (KWS) took the unprecedented step of involving local communities and other stakeholders directly in the ecological monitoring of the lake and wildlife. Through this, KWS were able to establish trust in the results of monitoring, and obtain buy-in from stakeholders in taking steps to address the problem of pollution (Ogutu et al. 2012, Ogutu et al. 2017). Similar findings have been shown elsewhere, where community-based biodiversity monitoring increases the effectiveness of conservation management interventions (Danielsen et al. 2005, Danielsen et al. 2007).

A rise in engagement of public and local community citizen scientists, as well as the increasing involvement of wildlife managers in science, has a potential to provide spaces for wider scientific engagement (Toomey et al. 2017) and break down the divide between those that produce science, and those that use science. By participating in data collection and the scientific process, citizens and conservation practitioners can provide a cost-effective means of providing valuable management relevant data while building an understanding of natural systems, and gaining ownership of the data that are used to inform difficult decisions and negotiate between hard choices. In this way, science can be used as a tool to steer a way through politically contentious issues, such as human wildlife conflict, access to protected areas, and management of grazing regimes. Improved engagement between scientists and managers, and the wider public, ultimately leads to better science and better conservation.

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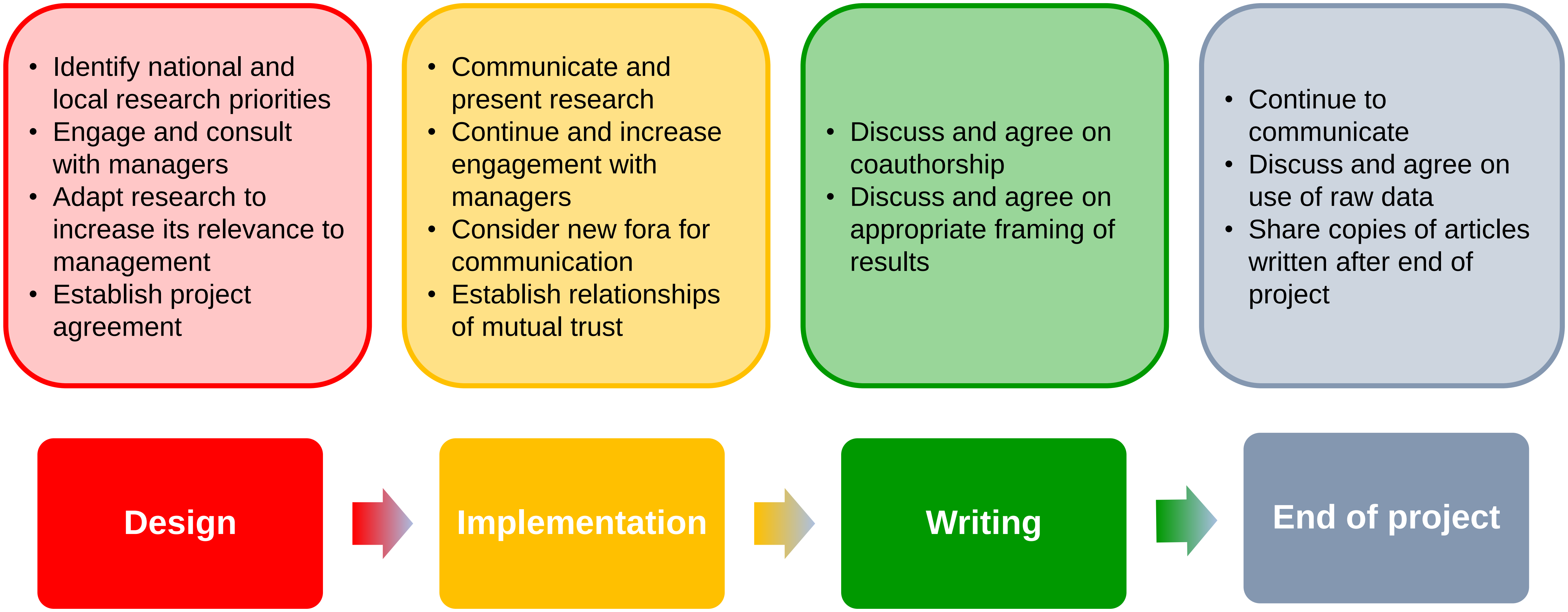
Box 1

Recommendations for scientists

1. Identify research priorities laid out by government (e.g. published research priorities; management plans; national conservation action plans and regional strategies etc.)
2. Adapt research plans, as much as possible, to address management information priorities
3. Engage with relevant wildlife authorities as early as possible in the design of the research project
4. Develop and sign an agreement between scientists and managers that outlines expectations, including end of the project management
5. Establish good working relationships with wildlife managers, founded on transparency and trust
6. Provide concise, accessible and timely reports of high quality that can be posted on web-based report libraries
7. Provide training and skill transfer to wildlife authority staff, students, early career scientists and local communities
8. Make use of opportunities to present progress and results to protected area managers and, if such opportunities do not exist, establish them
9. Where possible, consider coauthorship with managers, and frame results accurately and constructively
10. Continue to publish species-based and site-based research, which are likely to be of most use to managers
11. Work to diminish, not perpetuate, global inequities in scientific knowledge
12. Throughout, remember that conducting research within protected areas is a privilege, granted in order to deliver biodiversity knowledge as a public good

Fig. 1 How scientists can factor in management at each stage of the scientific research process.



• Identify national and local research priorities
• Engage and consult with managers
• Adapt research to increase its relevance to management
• Establish project agreement
• Communicate and present research
• Continue and increase engagement with managers
• Consider new fora for communication
• Establish relationships of mutual trust
• Discuss and agree on coauthorship
• Discuss and agree on appropriate framing of results
• Continue to communicate
• Discuss and agree on use of raw data
• Share copies of articles written after end of project
Design
Implementation
Writing
End of project