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Producing actionable science in conservation: Best practices for organizations and individuals

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Abstract

Many researchers working in conservation aspire to produce "actionable science" to inform conservation practice. In order to understand what it takes to produce actionable science, we interviewed 71 researchers who have worked on producing actionable science in conservation. We asked about the attributes of actionable science and the various factors that, in their experience, aid or hinder its production. We focused specifically on factors that correspond to individual behaviors and those that relate to organizational level policies and practices. Six best practices associated with the production of actionable science emerged from our interviews: four at the individual level and two at the organizational level. Best practices for individual behaviors include: (a) engaging in collaboration; (b) practicing empathy; (c) building trusting relationships; and (d) employing diverse communication methods. Best practices for organizations include: (a) incentivizing actionable science and (b) providing resources for actionable science to early-career researchers. Our analyses provide useful guidelines for conservation researchers and practitioners who are interested in producing actionable science.

KEYWORDS

actionable science, best practices, conservation, co-production, evidence informed decision-making

1 | INTRODUCTION

Many researchers care about the usability of the knowledge they produce (Schwartz et al., 2017; Van Kerkhoff & Lebel, 2015). The challenges of linking knowledge produced by scientists to its ultimate use in practice are well-known, especially in the context of conservation (Fazey et al., 2013; Rose et al., 2018; Schwartz et al., 2019; Toomey, Knight, & Barlow, 2017). Several conceptual frameworks attempt to make sense of the gap between theory and practice, including those relating to the availability, accessibility, and applicability of scientific knowledge (Walsh, Dicks, & Sutherland, 2015); the lack of engagement between scientists and decision-makers (Enquist et al., 2017; Toomey et al., 2017); and the lack of institutional, political, and social support (Cook, Mascia, Schwartz, Possingham, & Fuller, 2013).

Some frameworks that seek to explain the gap between the production and use of science also propose solutions to bridge it. One category of frameworks is based on "knowledge deficit" thinking, which assumes that practitioners simply lack sufficient understanding of the science. Solutions rooted in this paradigm focus on improving both the production of knowledge and its transfer from scientists to practitioners (Stocklmayer, 2012; Walsh et al., 2015). A second category of frameworks embraces the nuanced and complex relationship between knowledge production and use. These perspectives emphasize the importance of social capital development between knowledge producers and knowledge users. Accordingly, solutions rooted in this perspective seek to better develop relationships between knowledge producers and users as a way to bring the production of scientific knowledge closer to its use (Beier, Hansen, Helbrecht, & Behar, 2017; Buschke, Botts, & Sinclair, 2019; Enquist et al., 2017; Miller & Wyborn, 2018). These approaches, variously identified as post-positivist, co-management, or translational research (Enquist et al., 2017; Fazey et al., 2014) move past the language of a knowledge-action gap and embrace the potential of stakeholder collaboration (Beier et al., 2017; Toomey et al., 2017; Van Kerkhoff & Lebel, 2015). For example, some perspectives emphasize the development of relationships between actors through dialogue (Reed, Stringer, Fazey, Evely, & Kruijsen, 2014), the establishment of trust (Young et al., 2016), and promotion of mutual learning (Beier et al., 2017). Many of these undertakings occur with the goal of matching scientific insights to practitioner needs (Bednarek et al., 2018; Enquist et al., 2017; McNie, Parris, & Sarewitz, 2016; Reed et al., 2014; Toomey et al., 2017).

As these frameworks evolve and as our understanding of problems relating to conservation become more complete, questions have emerged as to whether sufficient attention is placed on the production of actionable science in formal and informal professional development for scientists, especially academic scientists (Goring et al., 2014; Schwartz et al., 2017). As actionable science becomes integrated into professional development, there is value in differentiating those factors affecting production of actionable science that fall within the control of the individual from those that fall within the control of the organization in which they are situated. This is our focus.

Recent work has summarized what is involved in the production of "actionable science." Beier et al. (2017), define actionable science as "data, analyses, insights, predictive models, or planning tools based on scientific research that support decision-making in biodiversity conservation." Similarly, Enquist et al. (2017) observe that actionable science "includes not only information but also guidance on the appropriate use of that information." It has also been observed that producing actionable science can be understood as one way of participating in knowledge governance or "the intentional achievement of societal and policy change through the purposeful production and dissemination of knowledge" (Gerritsen, Stuiver, & Termeer, 2013). Taken collectively, we can conclude that the production of actionable science in the context of conservation involves more than just the generation of scientific knowledge; it also involves the development of stakeholders' capacity to use science and is animated by an assumption that the use of such knowledge will result in positive conservation outcomes.

Our objective in this study is to understand the attributes of actionable science and the processes through which actionable science is successfully generated. Our focus on the differential roles that organizations and individuals play in the generation of actionable science is unique and stands to contribute to both theory and practice. We interviewed 71 scientists who have taken part in (at least) one of three fellowship programs that select participants based on their ambitions to produce actionable science in conservation. From these interviews we confirmed that when it comes to the production of actionable science, different roles for individuals and organizations can be identified. We describe six "best practices" which emerged from our interviews. Our empirical approach facilitates identification of behaviors which have been "battle tested," or implemented in the field by professionals and are seen to be effective.

2 | INDIVIDUAL AND ORGANIZATIONAL DETERMINANTS

We distinguish between individual and organizational attributes in order to understand the complex ways actionable science is produced. From a theory perspective, we join the many organization, systems, and behavior scholars who recognize that social enterprises are necessarily shaped by complex interactions taking place at multiple levels (Cash et al., 2003; Foss, 2007; Miller & Munoz-Erikson, 2018).

The ability of an individual to exchange knowledge with others has been shown to be constrained by behavioral factors such as prior experience (Simonin, 1999), degree of socialization (Nonaka & Takeuchi, 1996), attitudes toward collaboration (Lam, 1997), and level of engagement with collaborators (Evely, Pinard, Reed, & Fazey, 2011). This implies that simply informing practitioners about the relevant science (i.e., the deficit model) is unlikely to result in that science being acted upon, and certain individual behaviors are required on the part of the researcher in order to make this process more effective (Reed et al., 2014).

Yet individuals rarely act independently of others, especially in the collaborative realm of conservation. Therefore it is also helpful to understand how relationships, norms, and the rules of formal organizations influence knowledge exchange and actionability (Tidd, 2001). For example, the literature suggests that the ability of an individual scientist to produce actionable science is shaped by such organizational factors as the structure (Meadow et al., 2015), norms (Kinzig et al., 2013), and values of the organization within which they operate (Cash, Borck, & Patt, 2006; Lindenfeld, Smith, Norton, & Grecu, 2014). Following the literature, we contend that organizational factors, as well as individual behaviors, can influence success or failure in knowledge outcomes. We examine the organizational and individual level determinants to understand how actionable science is created and valued within different organizational settings, and which organizational characteristics pose to aid or hinder actionability. These insights are relevant for informing organizational design and internal policy at organizations that wish to create actionable science, including academic organizations, which play a significant role in the production of knowledge.

In this paper, we examine individual behaviors and organizational contexts as two categories where best practices can be identified. The behaviors of individuals and the behaviors of organizations surely interact; however, in this paper we consider them as two separate realms of action and therefore two separate areas of inquiry. The question of how organizational contexts influence and are influenced by the actions of individuals, and how this leads to organization-level outcomes, is explored more fully in the literature on knowledge governance (e.g., Foss, 2007; Minbaeva, 2007).

3 | OUR SAMPLING POOL

We selected our respondents using a purposive sampling strategy. Unlike probability sampling, where study samples are meant to be representative of study populations, purposive samples are designed to select study subjects deliberately based on specified desired attributes (Etikan, Musa, & Alkassim, 2016). We employed purposive sampling strategy instead of probability sampling techniques for two reasons. First, traditional probability sampling techniques require access to communities at scales that are prohibitively large. Second, sampling from the population of conservation scientists had some risk of capturing the perspectives of individuals who have no interest in producing actionable outcomes.

We adopted a subject selection strategy that targeted individuals who were likely to have experience conducting conservation science with an explicit interest in fostering actionability. Our sample includes alumni from three competitive leadership programs: Leopold Leadership Program, the Wilburforce Fellowship, and the Pew Fellowship in Marine Conservation. All three programs explicitly aim to encourage the creation of knowledge that can be used to achieve conservation outcomes by providing training, resources, and a supportive community of researchers focused on actionable science (Leopold Leadership Program, 2020; The Pew Charitable Trusts, 2020; The Wilburforce Foundation, 2020). Although we cannot generalize our results to the broader population of conservation scientists nor to the population of those who are interested in producing actionable science, our selection of interview respondents from the ranks of specialized fellowship programs provides confidence that our subjects are interested in and have experience trying to produce actionable science in the field of conservation.

4 | INTERVIEW DATA

Our sampling strategy begins with the identification of programs that match the dual criteria of (a) involving professional development of conservation scientists and (b) requiring that program participants have experience with or interests in producing actionable science. In order to ensure that our insights were not reflective of the experience of participation in only one specific program, we were careful to make sure that our sample drew from multiple programs. With permission and assistance from the management of three identified programs, we aggregated a list of individuals who had participated in each program and for whom email contact information was available. In total, 443 individuals were identified through this process, all of whom were invited via email to participate in the study as interview respondents. Eighty-five of the 443 scientists agreed to be interviewed and 71 interviews were successfully completed in person, over the phone, or through video teleconference (primarily Skype) between January and June of 2018. Audio from interviews was recorded with participant consent. All interview guides and sampling were reviewed and approved by the appropriate Institutional Review Board.

On average, our respondents had 23.6 years of experience (±11.6 years SD) (as measured as years since completion of terminal degree). Respondents received primarily PhD degrees (82%) in a variety of different disciplines, with the majority in biological sciences (including ecology, biology, zoology, specialized zoological and ecosystem sciences, and evolution). At the time of our interviews, respondents were employed in 57 different organizations. The majority of respondents (73%) worked at universities at the time of the interview; though all respondents had, at one point, worked as academic scientists. Most respondents were male (64%).

After five pilot interviews, we finalized a semi-structured interview protocol built around our research questions. The full list of interview questions and corresponding research questions is provided in Table A1. We employed a semi-structured interviewing approach to encourage interviewees to share their expertise beyond the narrow framing of our questions (Leech, 2002). In semi-structured interviews, the interviewee has discretion to put forth relevant information, rather than relying on the interviewer's preconceived notions (Dexter, 2006). This allows for depth and probing while providing more cross-respondent standardization than a fully unstructured format, and is especially well suited to exploration of values, beliefs, and motives (Smith, 1995).

Responses were examined by three reviewers independently, where each reviewer listened to recorded interviews and summarized responses to different aspects of the questions that had been asked. The reviewers coded emerging categories such as types of actions, types of outcomes, and factors that contribute to individual ability to produce (or not produce) actionable science. Each reviewer analyzed overlapping sets of interviews, in order to ensure consistency of interpretation. Responses and emergent categories were also discussed during frequent and regular meetings between reviewers. Two reviewers then brought together codes for each question from across all interviews into categories, by comparing codes and notes from meetings and iterating until a set of themes emerged. These themes were then reapplied to the interviews, and responses for each question were coded using these themes. Finally, we used these themes to ground our identification of key factors that influenced the production of actionable science.

5 | WHAT DOES "ACTIONABLE SCIENCE" MEAN?

Actionable science has been defined in many ways in the literature; here we describe what actionable science means to our respondents. The diversity of ways that respondents conceptualized scientific outcomes reveals the breadth of the "actionable science" concept and some of the challenges in studying it. However, as noted by Fazey et al. (2013), knowledge exchange initiatives—which include the production of actionable science—are often best assessed based on the participant's satisfaction with the process, where a reasonable level of satisfaction means that the participant is willing to continue exchanging knowledge. As each individual has a different threshold for satisfaction with the process, each interview revealed slightly different sets of actionable science outcomes. We have categorized these outcomes into three interrelated themes, listed here in order of how many respondents discussed them: (a) *the adoption or uptake of the knowledge produced by those involved in the decision process*; (b) *achieving desired programmatic outcomes*; and (c) *the sustainability of the knowledge produced and its continued use in decision-making*. It is important to note that these are the desired outcomes from the perspective of the scientists doing the research, rather than from the perspective of those who might use the knowledge produced. When our respondents talked about actionable science, this is what they meant. Therefore, these are the outcomes one can hope for by following the best practices laid out below. These are not mutually exclusive; some respondents discussed two or even all three (Figure 1).

Thirty five percent of respondents identified *the adoption or uptake of the knowledge they produced by those involved in the decision process* as the desired actionable science outcome. This uptake took many forms, from the passive use of data the respondent had produced, to the active involvement of the respondent in the decision-making process, to requests that the respondent testify in court about their work. This suggests that for our respondents, science being *actionable* did not necessarily mean it was *acted upon*—rather, actionable science offered insights into a possible course of action and was considered in the decision-making process. Many respondents indicated that they understood their science to be one piece of information among many—but if it was used for decision-making, it was counted as actionable. This aligns with a sentiment espoused by practitioners of "translational ecology," that "although decisions can be informed by research, decision-making is a social process and therefore scientific concerns may not prevail" (Schwartz et al., 2017, p. 589).

Respondents frequently discussed actionable science outcomes in terms of *having achieved desired programmatic outcomes*, with 21% noting this as a goal of actionable science. However, there was significant diversity in what respondents identified as the desired programmatic outcomes. Some respondents identified the production of reports and assessments for use by conservation decision-makers (ranging from federal agencies to nonprofit organizations) as the desired programmatic outcome. Other respondents characterized the desired programmatic outcome as being personally involved in the decision-making process, by providing expert testimony or by creating tools to inform decision-making. Respondents also

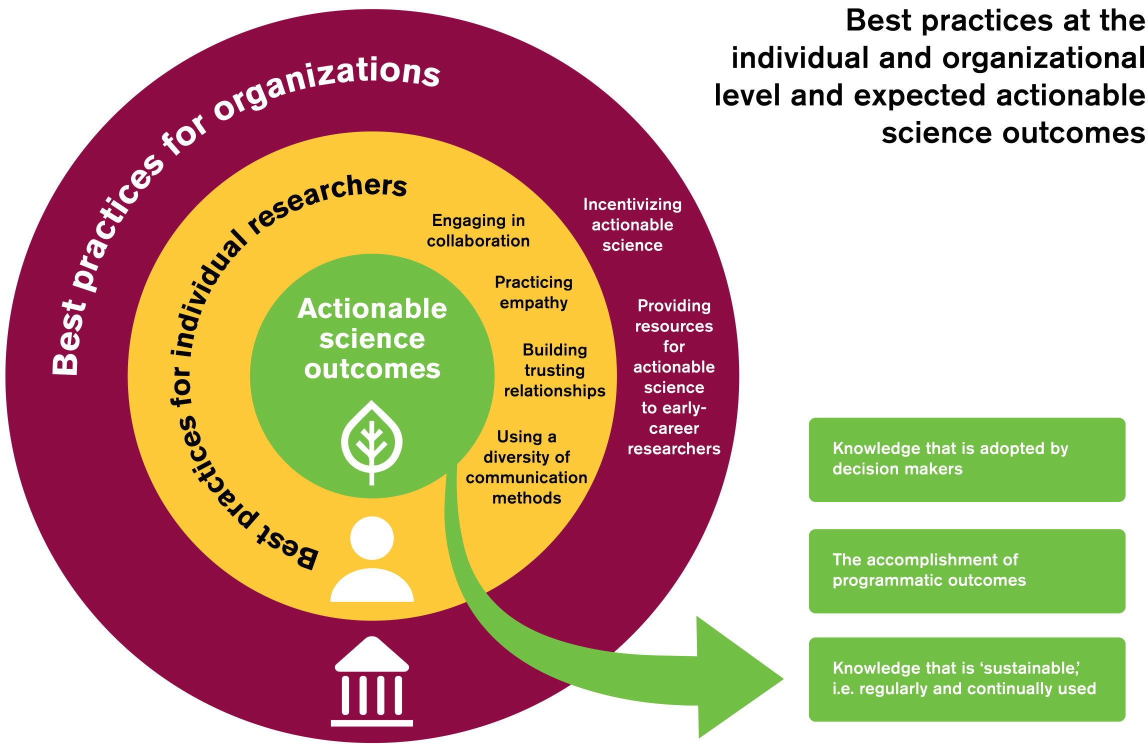

FIGURE 1 Best practices at the individual and organizational level and expected actionable science outcomes

sometimes described programmatic outcomes as the achievement of a specific conservation goal that was part of the project at hand. The diversity of results grouped under "programmatic outcomes" speaks to the influence of organizational dynamics on actionable science—the ideal of actionable science can be seen as becoming entangled with the practical goals of the projects in which respondents are engaged. These are win-win scenarios, where programs with outcomes such as those listed here also qualified, for our respondents, as pursuing actionable science. While our respondents were quick to highlight these types of projects, they also indicated that they are not the norm (see organizational factors, below). This theme differs from the first in that here the uptake of knowledge by decision-makers is considered a part of, rather than external to, regular research activities.

A third characterization of actionable science outcomes (observed in 11% of respondents) was *the sustainability of the knowledge produced and its continued use in decision-making*. For many respondents the goal was not that their knowledge played a role in a single decision, but rather that their involvement helped to motivate and define a new norm within the decision-making process. This reflects recognition that the process of influencing policy change can be long, but that the knowledge which is created and shared can become an integral part of the long-term change-making process. Others described sustainability in terms of increased interest in their work by broader communities. This interest often manifested as increased inclusion in and integration into communities of practice outside of the academy and traditional research circles. Unlike the theme one, which focused on the use of particular knowledge products in particular contexts, respondents discussing the sustainability of knowledge focused more on how their work changed the decision-making process in durable ways.

Any inquiry into conditions of success is improved with an understanding of corresponding failure. In our study, instances where actionable science was *not* accomplished were identified by 43% of respondents as situations where knowledge was *not* used and/or when programmatic outcomes were *not* achieved (despite science being used). A subset of respondents discussed this in terms of their own shortcomings in communicating the science effectively and/or communicating it to the right people. At times, these shortcomings stemmed from a lack of connection with the individuals who would use the information. Several respondents discussed being unable to achieve actionable science because they were operating in a social or organizational environment that was resistant to considering the knowledge that they produced. Respondents brought up instances where the political atmosphere, conflicting interests, and/or lack of organizational capacity ultimately determined what decision was made and whether programmatic outcomes were achieved.

6 | BEST PRACTICES FOR INDIVIDUALS

Respondents described engaging in many behaviors in order to successfully produce actionable science. The best practices we have identified here are broad categories of behaviors rather than prescriptive steps. This is partly a result of the wide variety of contexts in which science is acted upon. The transition from knowledge produced by scientists to knowledge used by practitioners is the transition from the tidy, controlled world of research to the more chaotic, tactical world of application. The path knowledge takes from production to application varies in every instance, and this was reflected in our interviews.

We identify four categories of individual behaviors that emerged from our interviews: a willingness to engage in collaboration with other stakeholders, practicing empathy, building long-term trusting relationships with other stakeholders, and using a diversity of communication methods. Below we elaborate on these themes (Table A2).

6.1 | Engaging in collaboration

The vast majority of respondents (88%) discussed the value of collaboration in producing and communicating actionable science. Collaboration was identified as important for several reasons. Respondents discussed how collaborating with others helped them formulate or reformulate research questions and approaches in order to better reflect the realities of the decision-making context. Collaboration allowed them to see from the perspective of those who were engaged in conservation and could potentially use their science, thereby allowing them to create products that were accessible, useful, and helpful for everyday practice. Engaging in collaboration also facilitated seeing problems from multiple perspectives and understanding the feasibility of various conservation strategies. Collaborations also allowed access to necessary field sites, technologies, and resources.

Collaborative knowledge production was important for ensuring that the knowledge produced would remain useful over time. Respondents reported that co-development of research approaches fostered collective buy-in. In particular, respondents noted the importance of understanding the situation they are studying from many perspectives and of pursuing research that most stakeholders agree could have a material impact. Respondents emphasized the need for strong links to different dimensions of the situation they are working with. They also consistently discussed the importance of engaging with collaborators across sectors from the very beginning of the decision-making process, in order to ensure there was ample time for iteration and co-evolution of both the research and the relevant conservation actions. Respondents indicated that it was a general openness to collaboration, rather than a focus on any specific partnerships, that led to actionable science.

6.2 | Practicing empathy

The ability to empathize (an ability to listen to, understand, and accept different perspectives on a problem beyond one's own) was frequently identified as important by respondents. Respondents noted that it was important for all stakeholders to come to the table with an open mind and a willingness to respectfully listen to others' points of view. Several respondents discussed how approaching stakeholders with empathy allowed the researchers to recognize that other stakeholders held valuable knowledge which could inform the research and make it more actionable. It was noted that empathy must be present from the start of a project, so that scientists can understand from the beginning what the needs and desires of the other stakeholders are. Empathy was also noted to be important during the project's operations, as it is essential for being able to work with stakeholders during field research, and for successfully resolving conflicts. Empathy was regarded as critical for fostering atmospheres that were receptive to incorporating scientific knowledge, and for being able to find common ground with decision-makers. This in turn allowed for effective communication, collaboration, and the creation of scientific products that were accepted and used by stakeholders.

6.3 | Building trusting relationships

Respondents discussed the importance of establishing trust and building lasting, meaningful relationships with decision-makers and other stakeholders. Trusting relationships were identified as an important prerequisite for scientists to be included in the decision-making process, and for including stakeholders in the scientific process. Collaboration enabled respondents to develop the foundational relationships needed to broaden and deepen the reach of their science. Respondents discussed the importance of developing and maintaining relationships across sectors and disciplines, in order to build trust between stakeholders. This trust was particularly critical for creating inclusive atmospheres where individuals from all sides could feel comfortable asking questions, sharing thoughts, and debating ideas and options without risk of negative and/or unintended consequences.

Trusting relationships were noted to be essential both for the production and promotion of actionable science in decision-making. Many respondents expressed that they had found "helicopter science" rarely worked because it was hard to get people excited about their work. Sustained and regular face-to-face interaction with stakeholders was essential for both building trust in their research and remaining attentive to the issues on the ground. Respondents were clear that irregular visits and/or a reliance on email and phone communication were insufficient for building effective relationships.

Establishing trust was frequently expressed as important for more than just the project at hand; several respondents identified building trust as a core element of what it meant to be a scientist. Respondents conceptualized doing science as building relationships outside of academia in order to ensure that the science being done is responsive to the needs of those who will use it. Trusting relationships were also noted to be essential for collaborative brainstorming future projects, framing questions in productive ways, and understanding what conservation actions are plausible.

In addition, respondents discussed the importance of ensuring that communications do not unintentionally alienate certain groups, cast blame, or be seen as biased, as this can undermine collaboration and trust. They reported that it is important to ensure that science is not used to disempower or disenfranchise any specific group. Even when an undesirable outcome can be attributed to a specific actor, respondents stressed the importance of not treating any stakeholder as a villain, as this destroys trust and disincentivizes that group from participating in conservation.

6.4 | Using a diversity of communication methods

Overwhelmingly, respondents indicated the importance of science communication, though descriptions of science communication differed among the respondents. However, many emphasized the importance of using forms of communication specifically tailored to different audiences. Respondents stated that the way science was communicated can and should be adjusted to fit different situations, rather than adhering to specific models or strategies. The only limit was staying true to what the science did and did not determine, and clear about what actions the science supports and does not support.

While our respondents were based at both academic and nonacademic institutions, the type of organization the respondent worked at had no statistically significant effect on which best practices they discussed.

7 | BEST PRACTICES FOR ORGANIZATIONS

Most respondents described how their organizations had both helped and hindered their efforts to conduct actionable science. For the most part, academic organizations were described as neither actively encouraging nor discouraging efforts around actionable science, but rather as being mostly apathetic. Others clarified that as long they fulfill their obligations to their institution (e.g., high-impact papers, consistent and large-value grants), their universities do not particularly care what else they engage in (Table 1).

About a quarter of our sample (27%) had experience working at nonacademic organizations, including conservation/environmental nonprofits, regulatory agencies, philanthropies, and research organizations. These individuals specifically characterized both the production and use of actionable science as a central value for their organizations, which provided structured incentives for them to pursue this type of work. This indicates that the type of institution in which a researcher works has significant bearing on their ability to produce actionable science, with the organizational environment of academic organizations being significantly less conducive to actionable science than that of nonacademic organizations.

Our interviews revealed two best practices for organizations that are interested in producing actionable science. These are also best practices which individual researchers can advocate for at their organizations, in order to enable their own pursuit of actionable science.

7.1 | Incentivizing actionable science

Producing actionable science often requires extended relationship building, constant presence and dialogue, and conducting research over long timescales. Thus, actionable science requires a substantial and consistent

TABLE 1 Best practices for producing actionable science

Best practices for individual behaviors
Engage in collaboration
Practice empathy
Build trusting relationships
Employ diverse communication methods
Best practices for organizations
Incentivize actionable science
Provide resources for actionable science to early-career researchers

time investment, which is often difficult to come by in the highly demanding and norm-driven culture of universities. Respondents raised issues with the reward structure within these organizations, noting that engaging in actionable science efforts often did not result in any type of professional reward or career advancement. Respondents saw this as the result of the normative values of the academy, such as a disregard by both departments and peers for applied research, and a narrow focus on publications as a metric of success. Multiple respondents discussed how the pace and nature of actionable science research do not fit well to the format and aims of peer-reviewed academic research journals.

7.2 | Providing resources for actionable science to early-career researchers

In contrast, respondents overwhelmingly indicated that their organizations have been most helpful when they provide dedicated time, resources, and/or support for actionable science efforts. Respondents acknowledged that their organizations supported more nontraditional activities (e.g., outreach, collaborations, partnerships) as they progressed in their career. However, they noted that this type of support was not always available to them when they first started and/or for current early-career faculty.

8 | DISCUSSION

Our empirical evaluation of attributes of actionable science revealed six best practices associated with the production of actionable science which emerged from our interviews. We characterized these attributes as individual and organizational factors that lead to actionable science. Here, we synthesize these insights to identify considerations for conservation scientists and practitioners who are committed to doing impactful science.

8.1 | The importance of relationships

Our results suggest that researchers' willingness to build strong, long-term, trusting relationships with other stakeholders engaged in conservation practice is a key factor contributing to the production of actionable science. The majority of our respondents (88%) indicated that lasting and meaningful collaborations were key to ensuring that the science produced is salient, incorporated into the decision-making process, and valued. This finding aligns with the findings of other work on conservation (Clark, van Kerkhoff, Lebel, & Gallopin, 2016; Enquist et al., 2017; Pretty & Smith, 2004; Winter & Cvetkovich, 2010; Young et al., 2016) and on the relationship between scientists and practitioners (Carrera et al., 2019; Irwin & Wynne, 1996; Suryanarayanan & Kleinman, 2013).

Cultural differences between knowledge producers and users were identified as a potential barrier to establishing strong, trusting relationships, and therefore a barrier to actionable science. In the absence of a strong collaborative relationship, friction, distrust, and frustration can arise between knowledge producers and knowledge users when negotiating which evidence ultimately influences the extent to which knowledge is taken up into the decision-making process (Briske, 2012; Irwin & Wynne, 1996; Roux, Rogers, Biggs, Ashton, & Sergeant, 2006). Individual scientists can begin to break down this barrier by building sustained and meaningful relationships across organizational and disciplinary boundaries (Enquist et al., 2017). Establishing relationships through dialogue and interaction also enhances the social capital of the researchers; this capital can then be deployed to facilitate agreement and establish transparency, common agendas, and collective goals (Cheruvelil et al., 2014).

Our results support the claim that the linear or deficit model does not produce successful or sustained conservation outcomes (Beier et al., 2017; Nguyen, Young, & Cooke, 2017; Reed et al., 2014; Shackleton, Cundill, & Knight, 2009; Toomey et al., 2017). Science is made actionable and transferred to practitioners through their relationships with researchers. Empathy and a willingness to learn, both through personal reflection and by interacting with stakeholders, appears to be important for developing these relationships, and therefore important for a sustained and effective process of connecting knowledge with action (McNie et al., 2016; Reed et al., 2014).

8.2 | Supportive organizations and boundary organizations

It has been observed in our study and elsewhere (Goring et al., 2014) that the ability of individual scientists to employ behaviors that lead to actionable science is often amplified or constrained by the level of organizational support behind them. Organizational cultures and rules can make it difficult for scientists to collaborate with stakeholders, and therefore difficult for them to produce actionable science. Organizational structures and disincentives can also serve to reinforce cultural differences between knowledge producers and knowledge users

(Shanley & Lopez, 2009). Our results are consistent with previous work which suggests that organizational barriers such as lack of professional rewards, organizational support, time, funding, and recognition, often stand in the way (Cvitanovic, Marshall, Wilson, Dobbs, & Hobday, 2014).

Producing actionable science in conservation may require significant structural changes to the way organizations incentivize and measure success. Since many researchers work within academic organizations, this in turn requires a challenge to the norms of the academy (Cook et al., 2013; Goring et al., 2014). Specifically, in order for academic researchers to build collaborations across sectors, it is necessary for the scientific cultures and organizations they are embedded in to value and incentivize the achievement of outcomes which contribute to the common good—such success in wildlife conservation—over outcomes which indicate the achievement of the individual scientists—such as the publishing of academic papers. Clarkson University in Potsdam, New York, was identified in our interviews as an exemplary organization in the regard, as the administration encourages actionable science: funding is available for pursuing actionable research, and this type of work is considered as part of faculty reviews, tenure guidelines, and promotions.

In response to organizational barriers in academia, boundary organizations have been identified (Guston, 2001) as a novel organizational approach to facilitating information flow and to building relationships between knowledge producers and users. They have been studied in fields such as agriculture (Cash et al., 2003), natural resource management (Clark et al., 2016), ecology (Safford, Sawyer, Kocher, Hiers, & Cross, 2017), and conservation and sustainability (Cook et al., 2013; Suni et al., 2016). These organizations sit in the space between science and policy, and host key actors who can speak across both worlds (Cash et al., 2003; Cook et al., 2013). While the number of boundary organizations is growing rapidly, there is still much to learn about their effective design and management (Crona & Parker, 2012). Our results offer two contributions in this regard.

First, our research indicates that many scientists who seek to produce actionable conservation science are based primarily at academic research organizations rather than within a boundary organization. This means that one way to realize the potential of boundary organizations is for universities to initiate formal value and culture changes in order to adopt features of boundary organizations. In order to take advantage of the boundary organization model, universities would have to allow greater flexibility to researchers' time, as building social capital and cohesion between knowledge producers and users requires significant time and effort (Goring et al., 2014; Safford et al., 2017). The expansion of what is considered "valid" science in the eyes of the academy (Cook et al., 2013; Jacobson, Butterill, & Goering, 2004; Schwartz et al., 2017) would also have to occur, shifting to include products that are intelligible both within and outside of academia (Benn, Edwards, & Angus-Leppan, 2013; Guston, 2001). This would have to be accompanied by a shift in the structure of professional incentives (Royal Society, 2006). The right incentives and metrics for performance at the organizational level can encourage pro-actionable science behaviors and help establish new social norms, similar to how organizational-level incentives can be harnessed to encourage and mainstream pro-environmental behaviors (Kinzig et al., 2013).

Second, in order to promote the production of actionable science, efforts need to move beyond building the capacity of individuals (e.g., trainings on communications) and toward encouraging organizational learning within boundary organizations themselves. While boundary organizations have demonstrated tremendous capacity for connecting previously disparate worlds, these organizations cannot easily meet demand for new knowledge, or learn from past efforts (Van Kerkhoff & Szlezak, 2010). Our results support the findings of Jacobs and colleagues, who found that formalized structures are critical for sustained organizational learning and flexibility (Jacobs, Nicholson, Murry, Maldonado-Román, & Gould, 2016). This is particularly true when social, political, and environmental factors are changing, requiring adaptive approaches (Palmer, 2012). Since boundary organizations occupy a unique position between communities of researchers and practitioners, they are in a unique position to learn from and with other organizations as part of professional networks (Rashman, Withers, & Hartley, 2009). This insight complements the finding, noted above, that actionable science requires the construction and maintenance of relationships.

8.3 | Caveats and areas for further research

Our respondents are predominantly established academics whose perspectives are not necessarily reflective of the emerging generation of researchers or of practitioners. Although this sample does allow us the benefit of drawing from the perspectives of those who are experienced in producing actionable science, it does not allow us to document the challenges that researchers face while trying to gain experience. Expanding our research to include practitioners and early-career scientists would paint a more complete picture of challenges and opportunities in the field.

As our interview pool consisted of professional conservation scientists who had participated in academic fellowship programs, there was broad agreement about what counts as "good" or "legitimate" evidence for decision-making. However, other actors or stakeholders (especially those with different disciplinary or professional backgrounds) could have conflicting views about what knowledge is valid for use in decision-making (Irwin & Wynne, 1996; Suryanarayanan & Kleinman, 2013). Recent work in this area suggests that coming to a consensus around legitimacy of evidence requires sustained interactions and a willingness to learn about the values, rules, and behaviors of other participants (Clark, van Kerkhoff, et al., 2016; Cook et al., 2013; Petty, Gongwer, & Schnabel, 2018). This suggests that the behavioral determinants of actionable science identified in this paper could also lead to stronger consensus around what counts as "good" or "legitimate" evidence—however, given the nature of our interview pool and the content of our interviews, we cannot claim this from our results. Further research, perhaps interviews with other conservation stakeholders, would be needed to explore this hypothesis.

Future research could also explore the relationship between the behaviors of individuals and the type of organization or sector that they work in, as well as the relationships between behaviors, organizational forms, and outcomes.

9 | CONCLUSION

Insights from this research lend empirical support to the growing recognition of the role that scientists play in connecting research to action. The linear or "deficit" model of science communication is ineffective in supporting research-informed decision-making. In contrast, our synthesis of interview data have revealed six "best practice" behaviors that facilitate the production of actionable science in the field of conservation. Although individual researchers can adjust their behaviors to move away from a deficit model of thinking toward more collaborative coproduction approach, these individual efforts are rarely enough. For conservation science generally, and individual researchers in particular, to become agents of change in addressing conservation challenges, the reward model, resource allocation, and culture of scientific organizations will have to shift toward supporting and prioritizing actionable science.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Respondents were interviewed by Samantha H. Cheng, Leah R. Gerber, and Derrick Anderson, with help from Drew Callow, Katje Benoit, and Reyna Olvey. Samantha H. Cheng completed the initial analysis of the data and wrote the first drafts of the paper. Christopher Barton led the re-framing of the paper and wrote later drafts, with help from Leah R. Gerber and Derrick Anderson.

DATA AVAILABILITY STATEMENT

This paper draws on qualitative data from interviews, which will not be shared due to Internal Review Board restrictions and privacy rights of the participants.

ETHICS STATEMENT

This research was approved by Arizona State University's Institutional Review Board (IRB ID: STUDY00005505). All participants gave informed consent prior to participation in this study. Names have been kept anonymous to maintain confidentiality.

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TABLE A1 Research questions and corresponding interview questions

Research questions		
Question 1	What are knowledge outcomes in conservation science and how do they represent, promote or enhance actionable science? How do they fail to represent, promote or enhance actionable science?	
Question 2	What are the individual behaviors of scientists that lead to actionable science outcomes and successful knowledge transfer in conservation biology?	
Question 3	What are the institutional arrangements and practices that lead to actionable science outcomes and successful knowledge transfer in conservation biology?	
Interview questions	**Core question**	**Follow up questions**
Research question 1	Describe your work and goals as a scientist	In the context of conservation, where do your goals and work align?
	What are some of the main questions you are working on?	What approaches do you use?
	What are the products of your work?	Would you consider these products “traditional” for academic researchers? Which are nontraditional?
Research question 2	What do you do (if anything) to make your research more actionable?	Is there a specific example of research that you conducted that was especially actionable? How did you know if was actionable and what did you do to make it such?
	What could you do differently to make your research more actionable?	Is this an objective you have now or see yourself having in the future?
	Have you had any specific experiences or training or mentorships that enhanced your capacity to produce actionable science?	What was it about these experiences that lead to differences in your capacity to produce actionable outcomes?
Research question 3	What does your institution/organization do to help you produce actionable science (if anything)?	Are you rewarded for certain kinds of work? If so, why? Does actionable science play a role in performance evaluations?
	What does your institution/organization do that makes it hard for your research to be actionable?	Are there institutional rules that stand in the way of your efforts to produce actionable science?
	Do you work with other individuals or organizations to make your research more actionable?	How do these partnerships/collaborations make your research more actionable?
Final question	If you had to pick one work product that you have worked on to this point in your career, what would it be?	

TABLE A2 Selected quotes from interview data

Outcome being described	Example Statement
Actionable science as marked by the uptake of knowledge being produced	"How I knew that the science had become actionable was when the regional director [of the decision-making organization] went into a staff meeting and told them about my model. I felt like it had a real change on the landscape... The publication isn't even out yet, but we've been showing the model to practitioners and it's being shopped around different agencies in Oregon..."
Successful actionable science as marked by achieving programmatic outcomes	"Maps and reports that identified priority areas for maintaining and restoring habitats, [which] were used by NGOs and decision-makers to figure out what areas to prioritize." "Media attention, coupled with our science, led to changes in legislation and management of live-fish trade and conservation."
Actionable science as sustainable and often-used knowledge	Success is when the "knowledge you create becomes native and others start talking about it without knowing who you are." "What changed it for me was [that]... I started getting invitations to attend workshops and give talks at meetings that involved resource agencies."
Actionable science NOT achieved because of no/weak connection to those who would use the information.	Where "we thought we had a great dataset and great paper, and we tried to get a hold of stakeholders, but we ran into brick walls on every end. We didn't have personal connections with [the] people who needed the information and it was like trying to find a needle in a haystack"
Actionable science NOT achieved because operating environment was resistant to considering the knowledge which is produced.	"I felt that my colleagues were threatened by my work" "The project became too expensive and was eventually abandoned"
Collaboration as important for accessing necessary resources	"Partnerships grant field access to sites and [to] companies with special technologies that assist with the work"
Collaboration as important for creating knowledge that people use often	"Co-producing...outputs [is] important [to create] a product that people can keep using daily" "Rather than thinking about what I want to do, I figure out through an integrative and iterative process with others... how to have an impact on the ground"
The need for collaborators to be empathetic	"People at the table who are open and respectful and willing to listen and consider new perspectives. [They] need good critical thinkers." Scientists must develop a "deep understanding of what stakeholders need help with, [and] see the problem through the eyes of the stakeholder."
The failure of helicopter science	Sustained interaction provided stakeholders "the opportunity to see me frequently and trust me, [and provided me the opportunity to]... remind them of the issue. If you go away and only visit once a year and just highlight certain parts, that doesn't work very well. I recognize that's how a lot of scientists' work, and they want people to be excited about [their work] but that's not how human nature works." For the success of my project "personal facetime was a critical factor... If this had been done over email, it wouldn't have had the same impact, the trust really needs to be built."
Building trust as a core element of what it means to be a scientist	My mission as a scientist is "making sure [scientists] continue to maintain relationships with people outside of academia to brainstorm projects, help frame questions, and understand what is plausible."
The many approaches one can take to science communication	Science communication includes trying "to reduce jargon; sharing access to journals, encouraging people to post data on platforms that are open access; work[ing] with small grassroots organizations and help[ing] them understand what the research means; and train[ing] scientists to communicate better." Science can be communicated many ways, as long as we remain "honest about what the science does or doesn't say... and what we ought to do; and [that] those are all different things and not to muddy them all together."
The importance of ensuring the science communication does not lay blame or disempower any stakeholder groups.	"I always pitch it as an optimistic and positive outcome, so the fishing village [we were working with] isn't viewed as a villain. There's no bad intention, it's just an unavoidable mistake that happens repeatedly, just be careful."

TABLE A2 (Continued)

Outcome being described	Example Statement
Organizations being apathetic to the production of actionable science	My institution has been "not been particularly involved or helpful, not that they've been harmful, everyone's just doing their own thing." "They're permissive and let me alone and don't pester me about what I do. As long as we're producing and pulling in grants, we can do whatever we want. Not a terribly encouraging role but not discouraging, just permissive."
Institutional reward structures as incompatible with actionable science	Engaging in actionable science is an "issue of career progression for junior colleagues, who find it hard to do straddling roles, of [both doing] actionable work" and going up for tenure.
Institutional disregard for actionable science	"Applied work is looked down on and not seen as real science" "Requirements for journal publications are not compatible with professional research outside academia" "Conflicts are set up within the structure of how the university conducts research... the 'privilege of the academic' prevented much collaboration and much useful research. Institutional rules make the process much more burdensome."