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Article *in* Biological Conservation · September 2021

DOI: 10.1016/j.biocon.2021.109322

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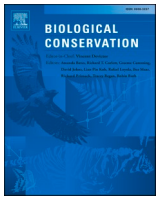

Perspective

The application of reflexivity for conservation science

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ARTICLE INFO

Keywords:
Reflexivity
Conservation
Social science
Research design
Complex adaptive system

ABSTRACT

In recent years, conservationists have been taking an increasingly holistic, interdisciplinary approach to conservation science, utilizing many methodologies and techniques from the social sciences. Reflexivity is one social science technique that holds great potential to aid in the continued advancement of conservation science but is not yet commonly recognized or applied by conservationists. Here we establish a systems-based framework for conservation science and couple it with a discipline-specific definition of reflexivity to enable the integration of reflexivity into future conservation projects. We outline the four major tenets of reflexivity for conservation science, declaring that conservation science *i*) is informed by personal values, *ii*) requires true partnership, *iii*) must contend with its own history, and *iv*) demands progress. We present practical reflexive techniques that conservationists can use to adhere to these tenets and to foster research-informed conservation efforts that are more collaborative, resilient, and diverse.

1. Introduction

Conservation science is in the midst of a paradigm shift, away from purely biodiversity-centered approaches towards a more culturally-conscious, socially-just, 'human heritage-centered' discipline (Huntley, 2014; Vucetich et al., 2018; Montgomery et al., 2020; Wyborn et al., 2021). Although the conservation science community has traditionally leaned heavily on the natural and biological sciences, recent efforts have been made to become more interdisciplinary particularly via an increased use of, and engagement with, the social sciences (Mascia et al., 2003; Newing, 2010; Matulis and Moyer, 2017; Schlüter et al., 2017; Echeverri et al., 2018). Many established frameworks now exist for integrating social science techniques and methodologies into conservation science (Evely et al., 2008; White et al., 2009; Moon and Blackman, 2014; Rust et al., 2017). One concept from the social sciences that has great potential to aid in the continued progression of conservation science, but is yet to be widely utilized, is reflexivity (Moon et al., 2016; Brittain et al., 2020). Recent calls have been made to increase reflexivity in scientific efforts related to community conservation (Koot et al., 2020), land restoration (Swart et al., 2018), conflict management (Arpin, 2019), fossil fuel extraction (Davidson, 2019), environmental governance (Borie et al., 2020), socio-ecological systems modeling (Iwanaga et al., 2021), and conservation volunteerism (Gray et al., 2017), yet specific guiding principles for reflexive practice across conservation fields are lacking (Montana et al., 2020).

Rooted in the disciplines of philosophy, anthropology, and sociology (Mauthner and Doucet, 2003), reflexivity began as a theoretical concept offering scientists various pathways for structured introspection (Schwandt, 2011; Berger, 2015). More recently, reflexivity has been adapted and integrated into the fields of human health and medicine, economics, education, and law, and has made similar inroads across numerous multidisciplinary and interdisciplinary research efforts (Freshwater and Rolfe, 2001; Alvesson et al., 2008; Sandri, 2009). Due to this rapid growth, the definitions of reflexivity and the associated descriptions of reflexive techniques can be ambiguous (Lynch, 2000; Finlay, 2002; Stronach et al., 2007). In tourism research, for example, reflexivity has been described as "an acknowledgement of the agency of researchers, the researched, academic audiences, students, and others.

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https://doi.org/10.1016/j.biocon.2021.109322
Received 18 December 2020; Received in revised form 17 August 2021; Accepted 6 September 2021
Available online 22 September 2021

Being reflexive means… [to] recognize the macro and micro forces which underpin the production of tourism knowledge, and acknowledge our interaction with and responsibilities to the 'researched'" (Ateljevic et al., 2005, p. 10). Conservationists, a term which we use here to be inclusive of the wide range of researchers, practitioners, academics, consultants, technicians, agents of government, and others working to conduct science under the broad umbrella of natural resource conservation, may find that this definition fails to consider at what points reflexivity ought to be used or to what ends reflexive techniques should even be undertaken. The SAGE Dictionary of Qualitative Inquiry explains that reflexivity can "refer to the process of critical self-reflection on one's biases, theoretical predispositions, preferences, and so forth… [and] can point to the fact that the inquirer is part of the setting, context, and social phenomenon he or she seeks to understand. Hence, reflexivity can be a means for critically inspecting the entire research process" (Schwandt, 2011, p. 261). While this definition provides more detail about when and how to use reflexivity, it does not explain in what ways reflexivity could apply to quantitative research projects or how these techniques might improve the production and application of knowledge.

In addition to the potentially confusing definitions of reflexivity, its implementation has also been hindered by its general repudiation across the natural sciences. In these fields, the influence of the researcher has historically been under-recognized or even purposefully avoided in pursuit of scientific objectivity. This omission has recently been labeled a 'reflexive gap' in conservation science (Pooley et al., 2014; Pasgaard et al., 2017), one which could have extensive adverse consequences for the efficacy of conservation practice. For example, research-informed conservation efforts that lack reflexive techniques can inhibit conservationists' capacity to cope with complexities in the field, facilitate institutional change, drive innovation, work effectively in teams, learn from past events, or benefit from the experiences of other scientists (Lawrence and Molteno, 2012; Cooke et al., 2015; Pasgaard et al., 2017). To avoid these pitfalls and further advance new socially-conscious conservation paradigms (see Montgomery et al., 2020), conservationists need a foundational, discipline-specific approach to reflexivity.

Here, we assert that a conservation-specific definition of reflexivity ought to: *i*) be applicable to all research-informed conservation modalities (i.e., quantitative, qualitative, and mixed methods inquires), *ii*) establish reflexivity as a practice that can be constantly applied and continue to evolve over time, and *iii*) explicitly improve the practice of conservation science and its impacts. Within this context, we define reflexivity for conservation science as a continuous and intentional assessment of a conservationist's influence on the scientific process and the broader socio-ecological system as a means to foster transparency and collaboration, in support of conservation efforts that are ethical, adaptable, and diverse. We expand on this definition by presenting a conceptual framework that positions conservationists as central actors in these complex systems. We describe four essential tenets of reflexivity for conservation science, and explain how conservationists can pragmatically follow each with specific reflexive techniques. Finally, we summarize the important benefits that the implementation of reflexive techniques may bring to conservation science and the conservationists themselves. Although reflexivity is most traditionally applied to projects involving human subjects, the intent of our framework is to illustrate the applicability of reflexivity for all portions of conservation science, regardless of the topic of focus, research methodology, or data collection techniques. Thus, while we take a structured approach to its explanation, reflexivity is personal for each individual who engages in it and will ultimately be expressed differently across contexts. Our hope is that the guidelines we offer here can be used as 'stepping stones' into more habitual, personalized reflexive techniques for all conservationists.

2. Framework for complexity

Conservation scientists have increasingly adopted the concept of complex adaptive systems (CAS), from micro scales (e.g., insect colonies, immune systems) to macro scales (e.g., ecosystems, coupled human and natural systems), with clear benefits for both applied and theoretical research (Levin, 1998; Berkes, 2004; Messier et al., 2015). Complex adaptive systems are comprised of many interconnected actors who learn and adapt over time, nonlinear processes, and multidirectional feedback loops (Holland, 1992, 2006). For example, in coupled human and natural systems, the ecological and socio-cultural elements inherent to this system are intricately linked with one another, and a change in one element of the system can have unexpected impacts on the other (Liu et al., 2007). In a similar way, the scientific and methodological elements of conservation projects cannot be separated from the personal and interpersonal elements of the individuals living and working within the broader system. Thus, each conservation project can be seen as a CAS which includes many distinct actors (e.g., academic, government, and non-governmental organizations, funding sources, local stakeholders) and processes (e.g., ethical procedures, methodological decisions, knowledge generation), all of which interact with one another and with the scientific process itself. Thus, every conservation project can be characterized by its own distinct, ever-evolving CAS (Preiser et al., 2018; de Vos et al., 2019). One basic CAS, for instance, may include a nonlinear scientific process, networks of key actors, and interactions within networks and between actors and the scientific process (Fig. 1). Viewing conservation science as a CAS can help conservationists recognize the critical nature of broader societal contexts and agendas in developing conservation efforts (Cairney, 2019). Adopting a CAS framework can also aid in some of the current shifts already taking place in conservation science, such as the move away from reductionism to a *systems* view of the world (Berkes, 2004; Fabricius et al., 2006; Audouin et al., 2013). Through a systems approach, it also becomes clear that the conservationist is a fundamental component of the CAS (Norberg and Cumming, 2008; Cilliers et al., 2013; Rogers et al., 2013). Therefore, full comprehension of the system requires critical and strategic examination of the role of the conservationist within it. Via reflexive techniques, conservationists can develop their ability to recognize and manage their peculiar role (Finlay, 2002; Berger, 2015).

The definition and tenets we describe here present reflexivity not as an abstract concept of self-awareness but as a practical and powerful tool for conservation scientists. Our four discipline-specific tenets form a framework that can guide conservationists to look *inward* (to their own values, purposes, and influences), *outward* (to their relationships with and understandings of others), *backward* (to lessons from the past), and *forward* (to future impacts). As we discuss below, these tenets are neither mutually exclusive nor exhaustive, but together they provide a broad conceptualization of reflexivity for the field of conservation. Individual conservationists could address a variety of topics through reflexivity, which will vary based on their unique CAS and the actors involved. Therefore, we offer a heuristic tool for each tenet (Supplementary Material 1) to help conservationists gauge and expand their capacity for reflexivity, and to determine topics of significance and areas of their work where reflexivity could be most advantageous. These tools and techniques are not prescriptive but rather provide some key examples and offer individuals an opportunity to practice 'doing' reflexivity on their own terms, in their own time, and with their own teams.

3. The tenets of reflexivity for conservation science

3.1. Looking inward: conservation is informed by personal values

Rooted in the functional and normative postulates of conservation science, conservation research has always been an action-driven, 'mission-oriented' enterprise (Soulé, 1985). Although the guiding principles have shifted over the years (Kareiva and Marvier, 2012), conservation is still fundamentally motivated by certain human values surrounding the desired state of nature and often uniquely personal 'missions' to achieve those desired states (Takacs, 2020). In this way, conservation research is, in theory, a type of action research, which aims

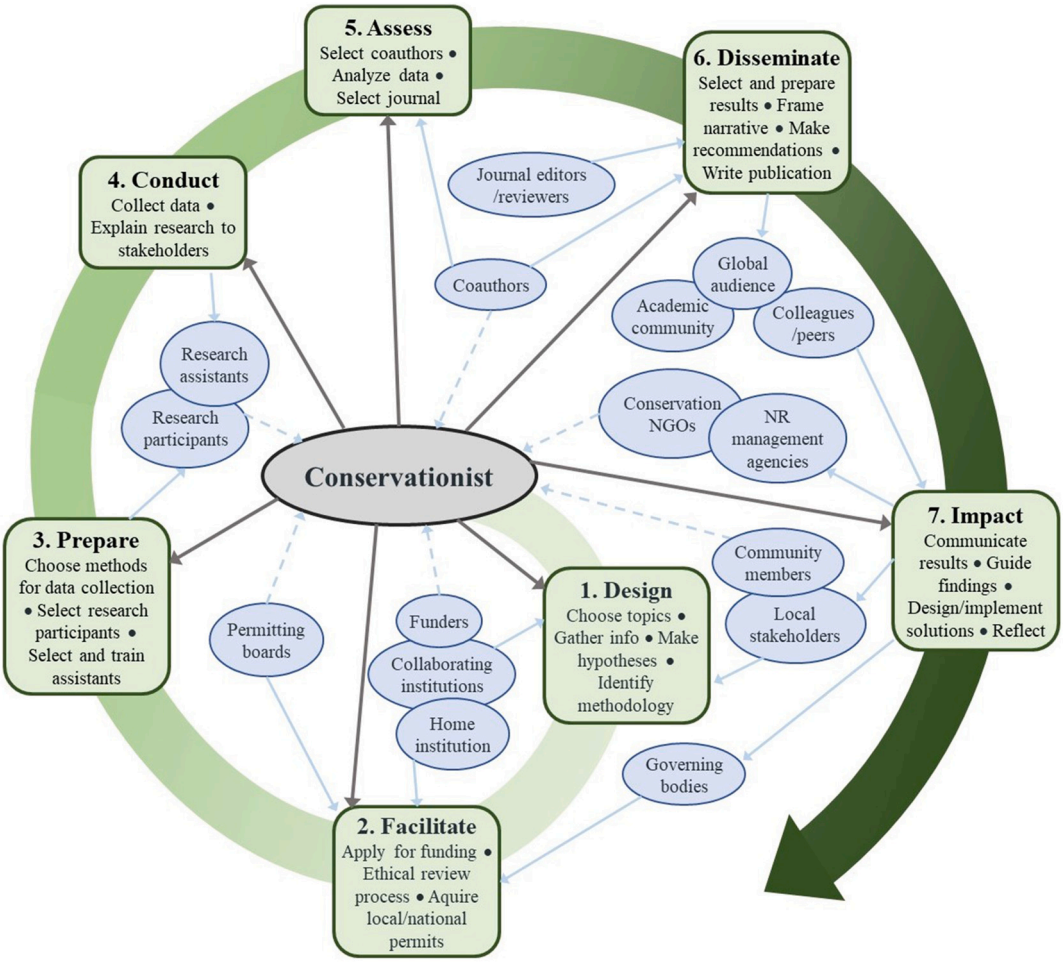

Fig. 1. Conservation science as a complex adaptive system. An example of one potential system, with processes in green, the conservationist (i.e. self) in gray, and other actors in blue. The scientific process is considered nonlinear and actors may stand alone or function as networks. Arrows represent lines of influence between actors and processes, dashed lines represent feedback loops which may cause fundamental changes in the conservationist or their future interactions. Systems will vary across contexts and may change over time. For example, if the scientific process includes a participatory research method, local stakeholders would have additional lines of influence across the system.

to study a system and also to effect change in that system (Greenwood and Levin, 2007). Decades of conservation scientists have now set out not only to study nature and our relationships with it, but *to do* something with the resulting knowledge (e.g., study human behaviors *to* mitigate wildlife conflict, study nutrient cycling *to* improve stream quality). A similar call for actionability has recently been sounded in the social science community (Watts, 2017). Given that these intended actions are grounded in the particular values of the individual scientists, personal objectives and assumptions are a driving force in conservation science (Moon et al., 2018). Therefore, all conservation science mandates some degree of reflexivity to begin to account for the impact of the individual and to ensure that does not overcome effective and ethical science. Reflexive techniques assist conservationists in turning their awareness inward to the many ways they as individuals conceive and shape all aspects of the scientific process.

Philosophers of science have recently focused a great deal of attention on the ways that scientists' values can influence their work (e.g., Longino, 2002; Keeney, 2004; Douglas, 2009; Elliott, 2017; Brown, 2020). They have shown that these values affect a wide array of judgments, including not only topics chosen and questions asked, but also problem-framing, project design, methodological and interpretive choices, evidential requirements, and terminology. In this way, the conservationist's preferences, perspectives, and ways of knowing unavoidably influence the orientation of each project (sensu the observer effect). While value influences are not necessarily a sign of bad science, these effects certainly have the potential to result in biases. Strictly speaking, a value is defined as a quality that is desirable or worthy of pursuit (McMullin, 2000) whereas a bias is a systematic deviation from a standard (Danks and London, 2017). Values can influence science without clearly or explicitly causing research to deviate from an established standard (Guillemin and Gillam, 2004; Elliott and Resnik, 2014). However, personal, cultural, and institutional values can scale up, resulting in biases at macro levels that may skew research to the point at which it no longer accurately represents the system under investigation. For example, preferences to study birds and mammals, particularly those that are charismatic or anthropomorphic, has resulted in research-informed conservation efforts that are inconsistent with the species' prevalence in nature and risk of extinction (Donaldson et al., 2016; Davies et al., 2018). This phenomenon has become widely known as 'taxonomic bias,' and has led to an extremely small proportion of animal species being drastically over-represented in scientific literature and popular writing (Wilson et al., 2007; Rosenthal et al., 2017). Similar issues exist across regions and ecosystems as well, with 'geographic bias' favoring research in forests and terrestrial landscapes in the US, UK, and Australia (Fazey et al., 2005; Di Marco et al., 2017). Such large-scale biases in research can threaten the conservation of lesser-studied species and impede research progress on some of the world's greatest conservation problems, such as climate change and biodiversity loss (Stroud

et al., 2014; Feeley et al., 2017). By employing reflexive techniques, conservationists are encouraged to identify unconscious values that could contribute to such biases and devise more novel and dynamic research goals which have the potential to address serious knowledge gaps.

When engaging in reflexivity, conservationists identify their own limitations, what they as individuals bring to the table that could substantially impact their work, and how aspects of their own identities uniquely shape the scientific process (Moon and Blackman, 2014). This is a vital component of reflexivity because a conservationist's identity creates the foundation of their scientific perspective and consequently affects the nature and strength of interactions within the CAS. In turn, the research process itself affects the researcher. Reflexivity allows for the examination and explanation of this important feedback loop. For example, Moon et al. (2019) describe their experiences with private land conservation in Australia, highlighting how reflexivity allowed them to acknowledge multiple viewpoints outside their own, shift how they pusued their research questions, and enhance their understanding of the unknown (Moon et al., 2019). The three authors' unique stories demonstrate the value of reflexivity and provide diverse, real-world examples of the critical thinking and personal growth that reflexive techniques can stimulate. As the main author explained, the "processes of reflexivity have provided me with exciting opportunities to develop and evolve" (Moon et al., 2019, p. 430).

One practical technique that conservationists can use to stimulate critical awareness of their values, preferences, motivations, and limitations, is via the practice of writing initial position statements. Kept as personal logs before starting new projects, initial position statements outline critical aspects of the conservationist's experience and the 'fore understandings' with which they approach their work (Andrews et al., 1996; Cutcliffe, 2003). Initial position statements provide an opportunity for conservationists to think about their current influences and any presuppositions they may have regarding a particular project. By doing this, conservationists can become explicitly aware of their motives for pursuing that project and assess their expectations and concerns. Additionally, these statements can act as benchmarks to measure change over time. Looking back over their logs, conservationists can see if their work had the impacts they initially hoped (i.e., if they achieved their conservation missions) or if they experienced any personal changes during the scientific process that may influence future conservation projects. This may be a particularly useful technique for conservationists engaging with the varied, and sometimes conflicting, values represented on multi-disciplinary teams (Pooley et al., 2014) and within the broader socio-ecological systems they study (Jones et al., 2016; Takacs, 2020).

3.2. Looking outward: conservation requires true partnerships

Conservation science has a variety of ecological and social dimensions requiring collaboration across many disciplines (Mascia et al., 2003; Ban et al., 2013; Robinson et al., 2019b). It can be a multidisciplinary, interdisciplinary, or even transdisciplinary endeavor, drawing on theories and methods and collaborating with experts from the fields of ecology, psychology, forestry, sociology, geography, history, political science, and, most recently, fine arts, media, communications, and humanities (Soulé, 1985; Dieleman, 2008; Pooley et al., 2016; Bennett et al., 2017; Brennan, 2018). Nevertheless, discipline-specific science remains the norm (Fox et al., 2006; Brook and McLachlan, 2008; Pooley et al., 2014; Montgomery et al., 2018a), and conservation science should continue to become more holistic and inclusive not only disciplinarily, but demographically, institutionally, philosophically, and epistemologically. In recent years, calls have been made to diversify the conservation science community (Tallis and Lubchenco, 2014; Green et al., 2015) and to embrace varied, if even conflicting, viewpoints (Matulis and Moyer, 2017). To make this ambition a reality, conservationists should put in the hard work to establish, strengthen, and maintain partnerships with those unlike themselves both professionally and personally. Consequently, the second tenet of reflexivity for conservation science encourages conservationists to look outwards, towards their interactions and relationships with all actors in the CAS, and to work to appreciate the many unique perspectives and worldviews.

Collaborative partnerships are imperative to effective conservation outcomes. Many conservation problems today are known to be 'wicked,' in that they are extremely uncertain and complex, difficult to manage, have no single solution, and frequently involve a variety of stakeholders with often conflicting views of the situation (Game et al., 2014). One of the most reliable and effective methods to confront wicked problems is through the coproduction of knowledge, whereby scientists work together with non-scientist stakeholders and decision-makers before, during, and after the scientific process to create knowledge and solutions applicable to their unique situations (Cash et al., 2003; Nel et al., 2016; Beier et al., 2017). Coproducing knowledge requires that conservationists hone their ability to understand and engage with diverse stakeholders, including community members, natural resource managers, government agencies, and nongovernmental organizations, and to establish partnerships that are immersive and rooted in mutual trust and respect (Young et al., 2016; Domínguez and Luoma, 2020). 'Fly-by' research in foreign nations (i.e. that without coproduction or other lasting in-country collaborations; known as parachute science) puts trust-building at risk and can lead to many lasting negative outcomes such as reduced research capacity and dependency on external funding (Barber et al., 2014; Woodall et al., 2021). Parachute science has recently been detected in research on socio-ecological systems (de Vos et al., 2019), marine systems (Stefanoudis et al., 2021), wildlife conservation (Bauer et al., 2019), geoscience (North et al., 2020), plant sciences (Culley et al., 2021), and other environmental fields (Roldan-Hernandez et al., 2020). Conservationists from any area of expertise can learn to avoid these practices through reflexivity that enhances their empathy and collaborative skills.

Authentic, reflexive partnerships also increase the likelihood that conservationists will achieve their project goals and produce information relevant to solving wicked conservation problems (Balmford and Cowling, 2006; Gray et al., 2019). Taking the time to understand other actors' distinct missions, values, philosophies, expectations, and assumptions through reflexive techniques prepares conservationists to build more trusting, effective, fruitful, and equitable partnerships. For example, Coreau (2016) describes how ecological researchers and environmental NGOs collaborating on Mediterranean biodiversity conservation implemented a unique 'reflexive strategic action' framework (including a combination of techniques such as stakeholder interviews, document analysis, and collaborative workshops) to ease tensions and operational difficulties among partners (Coreau, 2016). Through the use of reflexive techniques, the diverse actors were able to establish a shared vocabulary, engage in open discussions about research methods and future opportunities, and to identify the potential risks that could threaten the partnership. This led to mutual understandings between organizations, the lack of which had previously hindered their ability to successfully achieve their joint conservation objectives (Coreau, 2016).

Partnerships can be strengthened using techniques for collaborative reflexivity. Conservationists should take responsibility for generating open discussions within their teams and with other actors across the CAS. Many tools and frameworks exist for helping to facilitate these sometimes difficult discussions (see O'Rourke and Crowley, 2013; Cheruvelil et al., 2014). Conservationists can also use the tools provided here (Supplementary Material 1) within a group setting to spark collaborative brainstorming sessions. Collaborative reflexive techniques can solidify team comprehension not only of personal values, ethical standings, and research philosophies, but also important concepts in the scientific process such as interpersonal expectations, communication norms, and academic vocabulary (Eigenbrode et al., 2007). This, in turn, allows the team to establish a common vision of success, minimize potential conflicts, and mutually learn from any trials they experience (Norris et al., 2016). Using techniques like these to foster a positive team

climate has been shown to promote greater satisfaction among the members of environmental science teams (Settles et al., 2019). Another technique that conservationists can use to stimulate reflexivity is to create a visual representation of their own scientific CAS (see Fig. 1). Determining the major stages of their unique scientific process and identifying specific actors involved can help conservationists think strategically about their relationship with and impact on each. Taking the time to depict the CAS may also offer clarity about where and when they should plan to use other reflexive techniques in their conservation efforts.

3.3. Looking back: conservation must contend with its own history

History and context play critical roles in the functioning of every CAS (Holland, 1992). Conservation science has a long and complex history which varies across countries and regions, but which often stems from colonial occupation and the theft and capitalization of land and natural resources (MacKenzie, 1988, Singh and Van Houtum 2002, Barrett et al., 2013, Ross, 2017a, Domínguez and Luoma, 2020). Because of this, conservation policies and public attitudes towards protected areas and biodiversity are often implicitly rooted in histories of violence, extraction, and the exclusion of local communities from their native lands (West et al., 2006; Randeria, 2007; Mkumbukwa, 2008; Dowie, 2011). Relationships between conservationists and other actors in the CAS also exist within these historical and political contexts. Conservationists should think critically about how the histories of these actors may influence current collaborations or research expectations. For example, many large environmental organizations that fund conservation research have also normalized and institutionalized unjust practices such as fortress conservation and green militarization (Duffy et al., 2019; Montgomery et al., 2020). Past events and the treatment, governance, and cultural perspectives of local community members cannot be separated from the influences conservationists hope to have with their work. Reflexivity can assist conservationists in recognizing and attempting to rectify historical inequities and power imbalances (Pasgaard et al., 2017; Trisos et al., 2021) and to ultimately devise more humane and socially-just conservation practices and research protocols. Reflexive techniques help conservationists to look backwards in time, towards the histories of the field and the hard truths of the past, in order to learn lessons needed to conduct high-quality, impactful science with honesty and humility.

Conservation science is often conducted by foreign research institutions (Wilson et al., 2016, Montgomery et al., 2018a, Gray et al., 2019, also see *parachute science*, above, in Tenet 2). Therefore, conservationists may frequently be considered 'outsiders' in the communities where they work, not only in terms of race and nationality, but also religion, culture, and language. By being reflexive about important differences between themselves and other critical actors in the CAS, conservationists not only acknowledge that differences exist but also that those differences can have direct effects on their work. For example, a 'Western' scientific perspective may differ greatly from a diverse range of Indigenous perspectives in regards to values of nature and how human-environment relationships should be maintained (Peterson et al., 2010; Lynch et al., 2016; Milstein et al., 2019). Relationships between conservationists and community members can be challenging to navigate but inattention to the importance of these dialogues creates barriers to success and research implementation. Negative interactions may lead to research fatigue, feelings of abuse or exploitation (Tapela et al., 2007; Cochran et al., 2008), or even physical or economic harm (Clark, 2008). The results of such interactions may subsequently devalue the potential impact of conservation science and adversely affect conservation efforts far into the future (Lynch, 2017). This is particularly important when conservation projects involve human subjects (Brittain et al., 2020). By applying the tenets of reflexivity, conservationists recognize the impacts of institutional imbalances, become aware of the power dynamics between themselves and others, and rectify these power differences whenever possible (Drury et al., 2011; Muhammad et al., 2015; Trisos et al., 2021). When reflexive conservationists share the lessons they've learned over time, they can help to guide others through these sometimes tricky scenarios. For example, Mishra et al. (2017) provide a reflexive account of 20 years of community conservation experience with suggestions for improved practice (Mishra et al., 2017).

Conservationists who practice reflexivity take steps to learn about and incorporate aspects of history and culture into their work. For many, this requires engagement with decolonial practices that holistically center the needs and desires of local communities in conservation efforts (see Rodríguez and Inturias, 2018; Gould et al., 2019; Larocco et al., 2019). Coloniality refers to enduring patterns of inequity "that emerged as a result of colonialism, but that define culture, labor, intersubjective relations, and knowledge production well beyond the strict limits of colonial administrations… [which] is maintained alive in books, [and] in the criteria for academic performance" (Maldonado-Torres, 2007, p. 243). Decolonial practice can be an 'unsettling process' in which individuals work to consciously disrupt the patterns of coloniality found in modern, apolitical, and ahistorical research paradigms (Adams et al., 2018; Singh et al., 2018), and to expose and eliminate enduring colonial mindsets and white supremacy (Garland, 2008; Chaudhury and Colla, 2021). Ross (2017b) provides an example of a decolonial conservation narrative in their analysis of the wilderness ideology perpetuated by conservationists in modern Tasmania. The author explains that incorporating reflexive techniques in their writing, "let me express my own humanity… and ultimately allowed me take a stance against the racism and oppression I encountered in Tasmania" (Ross, 2017b, p. 8).

Conservationists can begin to engage with Tenet 4, and the broader notion of decoloniality, by identifying their own research philosophies and the research paradigms to which they subscribe. One practical technique to do this is the creation of positionality statements that clearly explain how personal aspects of the individual's education, background, and identity may have impacted the scientific process and the resulting data (Milner, 2007; Syracuse, 2016; Larocco et al., 2019). Positionality statements should be included in academic publications and conservation journals should encourage these statements or offer space for them as supplemental documents (for the authors' own example, see Supplementary Material 2). Land acknowledgement statements should also be considered when appropriate, with the proper time and respect to ensure such acknowledgements are not performative (Robinson et al., 2019a; Wark, 2021). Finally, conservationists should read the works of scholars from different backgrounds and with varying worldviews than themselves, and encourage their students to do the same. These include the works of Indigenous, feminist, neocolonial, participatory action, and critical research scholars both within and outside of the field of conservation. Reading diverse work can aid conservationists in seeing different histories through multiple cultural lenses and more effectively collaborate with scholars and professionals with varying histories. These types of collaborations can even enhance individual success, as scientists who train under mentors with disparate expertise achieve more successful academic careers than those whose work closely aligns with that of their mentors (Liénard et al., 2018).

3.4. Looking forward: conservation demands progress

Conservation science has been criticized for failing to directly contribute to applied outcomes where they are needed and for using valuable resources for study rather than direct action (Knight et al., 2008; Laurance et al., 2012). This issue is prevalent and is often referred to as the 'knowing-doing gap,' or the 'research-implementation gap' (Knight et al., 2008; Gossa et al., 2015; Toomey et al., 2017; Gray et al., 2019). Conservation researchers, for example, may be wary of becoming advocates for a particular cause out of fear of biasing the research effort (Horton et al., 2016; Gray et al., 2019). In an evaluation of conservation biology however, Noss (1999) explains, "whenever one recommends, however cautiously or conservatively, one advocates" (Noss, 1999, p.

117). Thus, conservationists are inherently advocates within the context of policymaking and management, even if they do not seek out or fully accept their role as brokers of information (Pielke Jr., 2007). This can lead to disconnects between conservationists and practitioners and a lack of research-informed conservation action on the ground (Arlettaz et al., 2010). Reflexive techniques help conservationists to consider the implications and feasibility of the messages they send and the recommendations they make, and are thus useful in attempts to reduce the research-implementation gap. Reflexivity is not simply a retrospective assessment of past choices and circumstances, but also an opportunity to think critically about how current choices and circumstances bring about future ones. Practicing reflexivity encourages conservationists to look forward towards the positive impacts they wish to have and take the appropriate actions to explicitly link those impacts with the scientific process.

Improving the impact of conservation science may require some shifts in the way conservationists view data analysis, the knowledge they generate from those analytics, and the way they share the resultant information. First, conservationists should keep in mind that the outcomes of their conservation efforts are directly influenced by ontological and epistemological assumptions rooted in the particular methods of analysis they choose to use (Mauthner and Doucet, 2003; Moon et al., 2018). Additionally, because conservation is a policy-relevant field, conservationists cannot avoid making choices that affect whether their results are more favorable to some social or political priorities as opposed to others. For example, methods of modeling animal observational data at an aggregate level might encourage different conservation or management decisions than if the data were assessed at an individual animal level (Montgomery et al., 2018b). It is important to make these decisions thoughtfully, to be transparent about them, and to gather input about them from other scientists and potentially affected communities (Elliott, 2017). Finally, conservationists have a responsibility to appropriately guide their findings, including critically assessing the ways in which they frame their research, present their results, and to whom they make findings available (Guillemin and Gillam, 2004; Audouin et al., 2013).

As illustrated in Fig. 1, conservationists disseminate their results to various actors, which may include academic peers, professionals from other fields, practitioners within conservation NGOs, or even a broader global audience and it is important for conservationists to consider the identities of these various actors. For example, many individuals may find academic jargon difficult to interpret and put into action (Pullin et al., 2004), potentially engendering distrust in or disengagement with academic institutions. Conservationists can use reflexivity to gain a deeper awareness of personal aspects of their audiences, such as native language, formal education, ontology, and professional standing. By taking these factors into consideration when writing up and presenting their results, conservationists show empathy and effort, which can increase the likelihood that their recommendations are implemented by policy makers (Reed et al., 2014). Continuing to engaging in reflexivity following knowledge dissemination is also important. An excellent example of reflecting on the results and success of a collaborative conservation planning project can be found via a study of regional and national South African freshwater ecosystems. In this study, Nel et al. (2016) were able to identify and present a critical missing link. As the authors explained, “in hindsight, the project would have benefited from explicit representation of local government… from the outset” (Nel et al., 2016, p. 185). Rather than simply recommending in their publication that future conservation initiatives include local representation, the team took responsibility for the unforeseen exclusion of local stakeholders, a decision which subsequently stimulated enhanced cooperation. This application of reflexivity also increased the usability of their data, built capacity for multi-scale implementation beyond the initial project boundaries, and provided practical guidance for other conservationists seeking to increase the uptake of their own science (Nel et al., 2016).

One specific technique that conservationists can use to help increase the impact of their work is reflexive journaling. This technique consists of daily or weekly notes about project management, methodological decisions and rationale, and personal contemplation. It provides a place for conservationists to engage actively and personally in self-monitoring, to articulate in their own words how they interact with the data and the scientific process. This practice can improve decision making and may help conservationists to understand and interpret results by adding context to the findings, in both quantitative and qualitative projects (Finlay, 1998; Haas and Hoebbel, 2018). A reflexive journal can even become data of its own (Schwandt, 2011), providing conservationists with valuable new insights that have unique academic and practical value from which others may benefit. Additionally, making the data collection and analysis processes more transparent and accessible may open up opportunities to strategically scrutinize and improve these processes and may reveal new uncertainties and knowledge gaps. This could illuminate productive paths for future research-informed conservation work and potentially increase the actionability of that work (Ban et al., 2013; Pasgaard et al., 2017). Conservationists can also become more reflexive about the potential outcomes of their conservation efforts through experiences working with those who apply research findings. For example, the American Association for the Advancement of Science (AAAS) offers Science and Technology Policy Fellowships which provide opportunities to collaborate with lawmakers, federal agencies, and environmental NGOs to see how, when, and why policy makers draw on scientific information (Jenkins et al., 2012). For those unable to pursue such intensive experiences, training programs and workshops may also be helpful. For example, the European Union offers a virtual workshop series aimed at creating links between scientists and policy makers at international scales (Commission 2020).

4. Integrating reflexivity into conservation practice

Solving conservation problems requires integrated and innovative approaches because of the complex interconnectedness of the socio-ecological systems in which these problems persist. Consequently, conservationists need tools to holistically understand and evaluate complex systems (Berkes and Turner, 2006). The CAS framework paired with reflexivity for conservation science, as defined and outlined above, fill this need by offering a structured approach for addressing critical issues relating to: *i*) conservationists' value judgments and positionality, *ii*) partnerships and trust building, *iii*) history and culture, and *iv*) decisions that lead to conservation impacts. The four tenets of reflexivity and their accompanying techniques are neither exhaustive nor discrete, and considering where their major themes intersect in practical settings can be a valuable reflexive technique of its own (see Fig. 2). Importantly, by linking and integrating the CAS framework and the four tenets of reflexivity for conservation science into their work, conservationists can practice in more ethical, adaptable, and diverse ways. We now describe how conservationists can productively blend and apply the four tenets in support of these aims and why this type of work is necessary for the betterment of conservation practice.

First, two major types of ethics in conservation science are procedural ethics and ‘ethics in practice.’ The former involves acquiring approval from relevant ethics committees and clearly stating how the research-informed conservation efforts intend to be conducted ethically. Conservation science has, at times, been unsuccessful in establishing or adhering to appropriate procedural ethics (Law et al., 2017). For example, nearly half of all conservation studies that involve human subjects do not include necessary ethics information regarding the treatment of those subjects (Ibbett and Brittain, 2019). The second main type of ethics, refers to ‘everyday ethical issues’ that arise while in the field (Guillemin and Gillam, 2004) which involve certain responsibilities on the part of the scientist, to act humanely, and to not exploit other actors in the CAS. While these types of ethics are challenging to quantify, there is evidence that conservation science may be among the fields guilty of harmful, invasive, and exploitive projects in the past

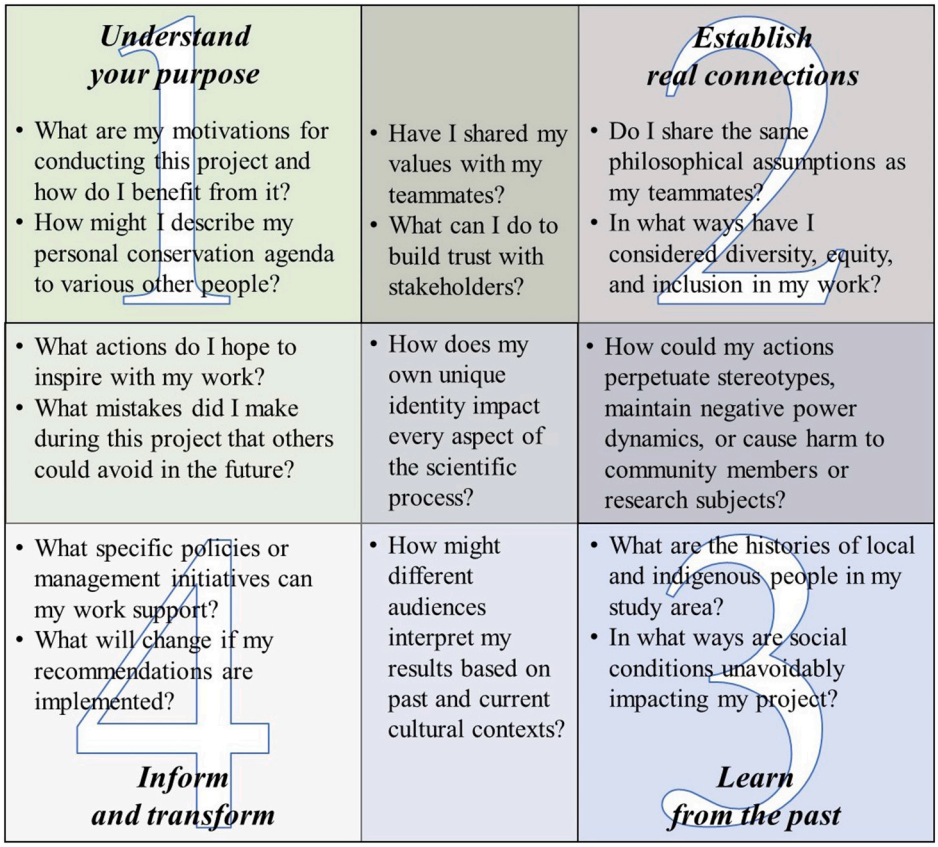

Fig. 2. Representation of the overlapping nature of the four tenets of reflexivity for conservation science, with example prompts to encourage reflexivity. Additional prompts can be found in Supplementary Materials 1.

(Schroeder et al., 2018). Recently, the establishment of new procedures to prevent unethical research have become more prevalent (see for example, the South African San Institute's Code of Ethics for researchers (Schroeder et al., 2019) and the Climate and Traditional Knowledges Workgroup's guidelines for scientists and policy makers (Climate and Traditional Knowledges Workgroup, 2014)). However, such procedures for ethics in practice are still relatively rare and conservationists should encourage community stakeholders to develop their own ethics codes or work to devise these codes collaboratively. Ultimately, the success of conservation efforts results from inclusion, equity, and the long-term development of trust with various stakeholders (Peterson et al., 2010; Young et al., 2016). Engaging with tenet 3 can help conservationists more fully understand and address issues relating to the treatment of community stakeholders and integrating tenets 2 and 4 can offer guidance for conservationists to build the type of fair and trusting relationships that enhance the credibility of their work. As the trustworthiness of science is increasingly being questioned, conservationists should operate under a high standard of ethical conduct to sustain the integrity of the conservation field into the future (Horton et al., 2016; Hopf et al., 2019).

Second, change is ever-present in the socio-ecological systems where conservation science is applied, as well as in each unique scientific CAS. To contend with uncertainty and change in the field, conservationists are increasingly utilizing collaborative learning-based methods, such as coproduction (described in tenet 2), co-management, adaptive management, and participatory action research (Olsson et al., 2004; Bacon et al., 2005; Knight et al., 2019). These approaches are seen as long-term, iterative, and circuitous processes rather than linear progressions of cause and effect (Redpath et al., 2013). And while they may hold a lot of promise, adaptive methods can be extremely difficult to implement in practice (Game et al., 2014). Additionally, to successfully participate in adaptive research and decision making, a thorough and accurate understanding of stakeholder values is required, an ability that conservationists may not traditionally be trained to develop (Robinson et al., 2019b). Conceptualizing the scientific process as a CAS and adhering to the tenets of reflexivity for conservation science can foster the critical thinking, experiential learning, and social awareness needed to participate successfully in adaptive conservation efforts. It can also assist conservationists in managing uncertainty within their own systems (Quarshie et al., 2019), supporting the continued functioning and reorganization of the CAS during times of change (e.g., loss of funding, data collection failures, communication issues, new stakeholders). Specifically, tenet 4 can assist conservationists in explicitly addressing both success and failures and learning how to change course when necessary to achieve their goals. Blending tenets 1 and 2 in practice can support conservationists in recognizing their own values and those of others, and to hone important social skills that are often overlooked in natural science trainings. As conservationists increase their ability to anticipate changes and become more resilient to stressors, they also increase the potential for multifaceted, adaptive conservation strategies to be successful.

Finally, across various fields of science, teams are becoming larger and more diverse (Wuchty et al., 2007, National Science Foundation, 2019). Some forms of diversity on teams can promote positive team climates and enable team members to solve complex problems more successfully (Whitfield, 2008; Woolley et al., 2010). Engaging with diverse team members can also help conservationists recognize their own values and become more thoughtful about their choices (Longino, 2002; Schuurbiers and Fisher, 2009). However, a lack of understanding between diverse team members is a major challenge for interdisciplinary teams (Lélé and Norgaard, 2005; Miller et al., 2008) and individuals who contribute disciplinary and demographic diversity to teams may

have more negative experiences than their peers (Settles et al., 2019). Additionally, while interdisciplinarity in natural and social sciences has been encouraged for decades (MacMynowski, 2007), methods and concepts from the social sciences are still not being as productively integrated into conservation science as they might be (Bennett et al., 2016). Reflexive techniques can be combined with all other research methods and may offer conservationists accessible approaches to assess the functioning of their teams and to alleviate some of the challenges of working in disciplinarily- and demographically-diverse groups. For example, adhering to tenet 2 can help conservationists to establish deeper epistemological awareness and bolster communication between scientists from dissimilar backgrounds while the integration of tenets 1 and 3 may provide much-needed structure to understand themselves through the eyes of others. Ultimately, fostering an inclusive and diverse community will help conservationists to increase their collaborative impact and devise conservation efforts that are themselves more diverse, with the novelty and innovation needed to solve today's wicked environmental problems (Game et al., 2014; Green et al., 2015).

To achieve future conservation outcomes that are ethical, adaptable, and diverse, instruction in reflexive techniques should be added to course curricula at the graduate and undergraduate level of higher education institutions providing instruction in conservation science. The tenets and guidelines presented here can be adapted for use as training materials in conservation methods or environmental ethics workshops for both students and professionals. By learning to be reflexive throughout the scientific process, conservationists at all career levels can begin a continuous cycle of self-reflection, assessment, and improvement. Some of the major challenges to the implementation of reflexivity include the adherence to reductionist thinking (Rogers et al., 2013; Knight et al., 2019), enduring coloniality (Kearney, 2019; Chaudhury and Colla, 2021), and a lack of practical examples necessary to appreciate the influence of these techniques (Chua et al., 2020). Our hope is that continued progress will be made in conservation science to confront these issues and push the boundaries of prevailing practice to embrace new, socially-just, and reflexive conservation paradigms. It is the responsibility of the conservationist to decide when to utilize reflexive techniques and how much of the resulting information to share with others. However, increased transparency and collaborative reflexivity will increase the conservation community's ability to solve the complex problems that blight the field, while also promoting personal and professional development in the broader conservation community. Recognizing the tenets of reflexivity will encourage conservation science that is socially and ethically responsible, inclusive of diverse ways of knowing, and attentive to the inherent complexities of social-ecological systems.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2021.109322.

Declaration of competing interest

All authors hereby declare no direct or indirect conflicts of interest including financial, personal, or organizational, in regards to the manuscript, “The Application of Reflexivity for Conservation Science.”

Acknowledgments

We would like to thank C. F. Hoffmann for comments on an earlier draft of this manuscript. This work was supported by the National Science Foundation Graduate Research Fellowship Program and Michigan State University. All authors hereby declare no direct or indirect conflicts of interest.

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