Post-normal conservation science fills the space between research, policy, and implementation

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Abstract
The view that conservation is a linear exchange of knowledge between scientists and practitioners has led to the conceptualization of a “research-implementation gap”. However, conservation is not only about translating science into action but also includes the interplay of values, cultural norms, social interactions, and political consequences. In response, an alternative conceptualization is one where research and implementation exist in a “space”, where conservation partners interact. Here, we argue that post-normal science (PNS) can fill this space. PNS is used when information is incomplete, values are pluralistic, stakes are high, and decisions are urgent. It relies on an extended community of practice that aims to produce knowledge fit for end-users, without the constraints of settled scientific paradigms. We advocate for the wider use of PNS in conservation by showing how aspects of PNS have been useful in mainstreaming conservation planning in South Africa. By following an approach typical of PNS, South Africa has made considerable progress in creating an implementation space for conserving biodiversity despite its limited resources, cultural heterogeneity, and controversial history. We outline the interventions used in South Africa to facilitate PNS and, based on this, propose an operating model that can be applied elsewhere.

KEYWORDS
conservation planning, extended peer community, post-normal science, research-implementation gap, scientific paradigms, South Africa, transdisciplinary

1 INTRODUCTION

Although still a young discipline, conservation science has grown considerably in recent decades. Our understanding of conservation problems expands with every new scientific study, yet, despite this proliferation of scientific research, biodiversity is still declining. This raises concern that current scientific practices are ineffective at combating the loss of nature (Laurence et al., 2012).

The inability to translate conservation research into impact has been conceptualized as the “research-implementation gap” (Hulme, 2014; Knight et al., 2008), which has since inspired efforts to make research more applicable and accessible to practitioners by including them in the research process (Enquist et al., 2017; Hulme, 2014; Laurence et al., 2012). At a fundamental level, the framing of a research-implementation gap implies that solutions to conservation problems exist but are not being applied on the
These solutions are presumed to be based on an objective science, free from bias and doubt (Ravetz, 2006).

This perspective is compatible with “normal” science, which is essentially a puzzle-solving endeavor where the rules are defined by existing paradigms (Kuhn, 1970). Complicated problems can be tackled using normal science, but only when a clear relationship exists between cause and effect and the sources of uncertainty are explicitly known. However, real-world conservation problems arise from unpredictable complex systems, so they are rarely tractable and solvable using technocratic solutions (DeFries & Nagendra, 2017). Such systems blur the boundaries between science and practice and expose the limits of human rationality (Bertuol-Garcia, Morsello, El-Hani, & Pardini, 2018). Furthermore, conservation problems are regularly wrapped in a tangle of nonepistemic value judgments (Baumgaertner & Holthuijzen, 2017), where stakeholders disagree about what ought to be prioritized because of social, political, and pragmatic differences.

In response to this, Toomey, Knight, and Barlow (2017) reframed the research-implementation “gap” as a research-implementation “space”. Their rationale was that translating science into action necessitates the interplay of values, cultural norms, social interactions, and political consequences. Research-implementation spaces better represent the interface where these phenomena can interact.

Reconceptualizing the interplay between research and implementation as a space for multilateral interaction implies that the challenge is not merely about making conventional—or “normal”—science more relevant to practitioners. Instead, the whole scientific process needs to be exposed to the messy interface of values, norms, and politics, which introduces new sources of uncertainty. Post-normal science (PNS, Figure 1) is a way of solving complex problems where facts are uncertain, values are in dispute, stakes are high, and decisions are urgent (Funtowicz & Ravetz, 1993).

PNS developed as a reaction to probabilistic risk assessment in normal science (Funtowicz & Ravetz, 1993; Ravetz, 2006). In normal science, risk is determined by reducing complex issues to tractable subproblems (Colloff et al., 2017; Ravetz, 2006). These subproblems can then be tackled in logical steps using cross-disciplinary evidence and causal chains (Game et al., 2018; Qiu et al., 2018). However, risk is indeterminate for many conservation problems because of emergent uncertainties, incomplete controllability, and multiple legitimate perspectives in socioecological systems (Colloff et al., 2017; Funtowicz & Ravetz, 1993). Reductionist approaches cannot cope with indeterminate risks, so...
PNS was proposed to maintain the integrity of science when facts are not only unknown, but essentially unknowable (Elahi, 2011; Funtowicz & Ravetz, 1993).

PNS differs qualitatively from normal science because the integrity of scientists is not determined by how impartial they are, but rather by their behavior beyond a closed circle of expertise (Ravetz, 2006). Thus, PNS makes the dichotomy between scientists and practitioners redundant because it is typified by an extended peer community (Figure 1). This community is a hive of interaction between participants with a wide assortment of backgrounds and affiliations (Funtowicz & Ravetz, 1993). These interactions blur the boundary between facts and values because values form a key ingredient of “extended facts”, which combine explicit scientific observations with tacit knowledge obtained through individual experiences (Francis & Goodman, 2010; Healy, 2011). Applying extended facts to conservation problems shifts the focus away from the “predict and determine” model that typified early wildlife management, toward the model of “assessing and consulting” needed for modern conservation problems (Healy, 2011).

Related decision-support frameworks—for example, “structure decision-making” (Gregory et al., 2012)—have also been put forward to deal with intractable environmental problems (Schwartz et al., 2018). Many of these frameworks overlap with PNS in that they consider both facts, which are used to link actions to outcomes; and values, which determine the acceptability of different outcomes (Gregory et al., 2012). Thus, many such frameworks already apply a philosophy compatible with PNS (Rose, 2018). A subtle difference is that extended facts derived from PNS blend facts and values in a way that reflects the relational values people have for nature (i.e., the philosophical view that nature derives value from people’s relationships and responsibilities toward it: Chan et al., 2016). Therefore, extended facts should be viewed as evidence with varying degrees of support, rather than unquestionable truths (Ravetz, 2006). The benefit of combining personal experiences with scientific data is that policy decisions embody an appreciation of what is politically and administratively feasible, especially in atypical social contexts (Evans, Davila, Toomey, & Wyborn, 2017; Hulme, 2014).

In this article, we present PNS as a way to occupy the research-implementation space. This assertion is based on spatial conservation planning in South Africa, which has transitioned from a science-focused to implementation-focused planning (Botts et al., 2019) through a model that can be defined as PNS. The South African example is distinct because of intentional efforts to cultivate an extended peer community and embrace extended facts. We propose that these efforts have made South African conservation research, policy, and implementation more effective, despite obvious obstacles in terms of limited resources, cultural heterogeneity and historical inequality. In the following sections, we describe how a PNS approach was cultivated in South Africa and generalize this approach so that that could be applied elsewhere.

2 | POST-NORMAL SPATIAL CONSERVATION PLANNING IN SOUTH AFRICA

Systematic conservation planning is a modern subdiscipline of conservation science and South Africa has been at its forefront for decades (Balmford, 2003; Knight et al., 2006). Conservation prioritizations have most frequently been developed by four countries: United States, Australia, South Africa, and Canada (Sinclair et al., 2018). Notably, South Africa is the only of these countries not categorized as a high-income country.

Conservation planning in South Africa is even more noteworthy considering the country's substantial biodiversity (including three different global biodiversity hotspots), which means that complete ecological data are often uncertain or unavailable. Moreover, South Africa faces excessive economic inequality, and its Gini coefficient (0.70) ranks among the highest worldwide (Hvistendahl, 2014), so limited available resources are generally prioritized for urgent economic development and poverty alleviation. This interplay between conservation, economic, and social goals has created a multifaceted political climate, where environmental values held by government officials tend to vary along professional and cultural lines (Wilhelm-Rechmann, Cowling, & Difford, 2014). Biodiversity conservation in South Africa bears the hallmarks of an intractable problem, where facts are uncertain, stakes are high, decisions are urgent, and values are in dispute. Given this broader context, the space between biodiversity research, policy, and implementation was particularly suited to PNS.

Although success in conservation planning is difficult to quantify, South Africa is recognized internationally as a leader in using multi-stakeholder engagement to develop conservation plans suited for implementation on the ground (Balmford, 2003; Knight et al., 2006; Smith, Veríssimo, Leader-Williams, Cowling, & Knight, 2009). A key ingredient of this success was the willingness of planners to work beyond their familiar scientific paradigms (e.g., life sciences, earth sciences, or social sciences) by focusing on decision-making, behavioral change and policy implementation (Botts et al., 2019; Reyers et al., 2010). Pragmatic decisions could be made based on combinations of the best available scientific data and the practical experience of practitioners (Botts et al., 2019. Through engagement with a broader community of stakeholders (i.e., the extended peer community of researchers, policy-makers, practitioners, and government
officials), the values of those outside of traditional science informed the motives for conservation planning (Nel et al., 2016). Combining explicit and tacit knowledge was particularly useful for informing what was technically feasible, practically implementable and politically palatable.

Peer networks will not have an impact unless they are supported by organizations with institutional and legislative authority (Amel, Manning, Scott, & Koger, 2017). This is where the South African National Biodiversity Institute (SANBI) plays an important role. SANBI was established under the National Environmental Management Biodiversity Act (Act 10 of 2004) and has the responsibility of supplying evidence-based policy support to government departments on issues related to biodiversity. Thus, SANBI is an important conduit for knowledge flows and serves as a recognized bridging agent to facilitate interactions both within the conservation sector and beyond (Roux, Nel, Cundill, O’Farrell, & Fabricus, 2017). SANBI’s institutional authority added structure to the extended peer community in a way that facilitates PNS (Table 1).

In addition to providing institutional authority, SANBI, as a public entity under the National Department of Environmental Affairs, sets the agenda for conservation planning at the purposive level, which is the highest level of national values that are supposed to reflect the core values of the country’s populace (Reyers et al., 2010; Roux et al., 2017). Clarity at the purposive level avoids unnecessary duplication or counter-productive competition by promoting national coherence and integrating biodiversity in multisector governance (Table 1). The purposive level directs the extended peer community toward a common goal, while remaining versatile enough to allow behavioral adjustments based on changing knowledge, rules, and values (e.g., Colloff et al., 2017).

Although SANBI has a central role at institutional and purposive levels of the PNS process (Table 1), they acknowledged that they cannot meet their core mandate without external contributions from other stakeholders. Therefore, they endeavored to nurture an extended peer community with the autonomy to self-mobilize (Botts et al., 2019). SANBI expends both funding and institutional resources to coordinate conservation planning in South Africa, but wider collaboration throughout the extended peer community makes it possible to leverage serendipitous external opportunities. The ability to self-organize positions participants as colleagues, rather than contractors, and can lead to deeper levels of engagement

| Actions | Outputs (some examples)* | Outcomes | Impacts |
|---------|--------------------------|----------|---------|
| **Institutional level** | | | |
| Create a legislative framework that defines the organizational mandate | Section 10 of the National Environmental Management Biodiversity Act 10 of 2004 | Clear roles, responsibilities and accountability for institutional authority | Effective pathway between science, policy and implementation |
| **Purposive level** | | | |
| Establish conservation goals that define the adaptive space within which the extended peer community operates | National Biodiversity Strategy and Action Plan; National Biodiversity Framework | Conservation interventions are aligned to national and international conservation priorities | Coherent and adaptive multi-stakeholder biodiversity conservation and management |
| Expand goals beyond narrow conservation themes | Mining and Biodiversity Guidelines, Mainstreaming Biodiversity: Key Principles from the Grasslands Program | Biodiversity conservation is mainstreamed and integrated with development planning and decision-making | Biodiversity is embedded in multi-sector planning |
| **Intervention level** | | | |
| Provide a platform for shared learning | The biodiversity planning forum | Inclusive and accessible multi-stakeholder engagement | Diverse knowledge, values and rules are integrated into conservation planning |
| Promote a common vocabulary | Lexicon of biodiversity planning | Reduce ambiguity and encourage exchange of information | Consistent and unambiguous flow of knowledge |
| Support access to data and information | Biodiversity advisor; BGIS | Transparent and equitable access to information | Planning grounded in the most recently available scientific information |
| Create pathways for synthesis | Technical guidelines for CBA maps | Products aggregated to become more than the sum of their parts | Incremental actions are leveraged into step-changes in progress |

Text in italics refers to information products.

*Complete citations to these documents are provided in Appendix S1.
This mutually beneficial and nonhierarchical organization is arguably the best way to tap into a broader pool of expertise on biodiversity issues (Turnhout, Bloomfield, Hulme, Vogel, & Wynne, 2012). Pooling resources and expertise in this way ensures that (a) return on investment is higher because outputs are shared across organizations and (b) financial sources are diversified and less vulnerable to funding trends. An obvious downside is the lack of financial security needed to meet long-term objectives.

3 | THE EXTENDED PEER COMMUNITY OF SOUTH AFRICAN BIODIVERSITY PLANNERS

When conservation policy interacts with science, it is usually not technical nuances that are at stake, but rather how the scientific information relates to the real world (Ravetz, 2006). This relationship between scientific information and the real world is woven into PNS from the outset through the extended peer community because participants bring their own expertise, experience, values, and judgments. Although identifying key stakeholders is an important first step toward conservation action (Hulme, 2014), the extended peer community of South African biodiversity planners is not just a set of stakeholders that need to be consulted (Rose, 2018). Instead, it is a dynamic aggregation of government officials; private consultants; and government—, NGO—and university scientists who interact to form something larger than the sum of its parts (Figure 2).

As the authors of this study, we consider ourselves to be active participants in the extended peer community. However, we are only a small part of a much broader community of more than 1,000 individuals who have been involved over the last 15 years (Figure 2). These individuals participate in the extended peer community either through self-selection or deployment by their various employers and they reflect the wide network of participants, including novices and experts across various disciplines, needed to produce fit-for-purpose knowledge (Roux et al., 2017). We assumed that members who had been part of the extended peer community for more than five years made up the small core contingency (6.23%), while the rest of the participants made up the considerably larger transient group (93.77%) (Figure 2a). Both these groups are made up of members from several different sectors in relatively consistent proportions (Figure 2b,c), which
is noteworthy considering that this pattern emerged spontaneously through voluntary participation.

The core members of the extended peer community provide the critical social memory that ensures continuity of ideas and experiences, which is essential for the sustainability of the PNS process. However, the importance of core members does not detract from the contributions of transient members. As long as there is deep engagement, even short-term interactions by transient members can contribute to meaningful learning (Evely et al., 2011). The transient group also buffers the extended peer community against the pitfalls of biased participant self-selection, where educated and affluent individuals are more likely to participate in the learning process (Roux et al., 2017).

4 | INTERVENTIONS THAT CREATE SYNERGY WITHIN THE EXTENDED PEER COMMUNITY

Although a diverse group of participants emerged spontaneously, SANBI carried out interventions specifically intended to create synergies in the extended peer community (Table 1). A first step to cultivating PNS was creating a platform where the extended peer community could interact. To this end, the National Biodiversity Planning Forum is hosted by SANBI as an annual event where stakeholders exchange ideas, knowledge, and experiences (i.e., the “third place”: Roux et al., 2017). This forum is akin to the “transdisciplinary social-learning institution” recommended to improve conservation effectiveness (Knight et al., 2008; Smith et al., 2009).

The Biodiversity Planning Forum provides a neutral ground where participants can engage professionally and socially. Meetings are held at a different accessible venue each year to encourage broad participation. These venues are away from urban centers, encouraging immersive engagement. This immersion is critical for the functioning of PNS because it builds the trust that underlies quality assurance of extended facts (Ravetz, 2006). Because extended facts are subject to debate, it is crucial that these debates are negotiated in good faith. Trust protects these debates from devolving into displays of scientific power-politics where one form of information is considered superior to another (Ravetz, 2006, 2011; Roux et al., 2017). The biodiversity planning forum cultivates the collaboration, deep engagement and long-term trust necessary for effective conservation implementation (Enquist et al., 2017).

Growing trust and spreading information through the diverse group of participants also depends on a common vocabulary and clear communication (Enquist et al., 2017; Fox et al., 2006). Without a shared set of definitions, participants risk talking past each other and becoming lost among a tide of acronyms. To overcome this, SANBI developed a lexicon of terms commonly used in conservation planning (Table 1). The lexicon codifies important definitions and reduces ambiguity because it ensures consistency across different reports and provides novices a convenient point of reference.

Even when outputs use a common vocabulary, PNS will be unable to function without convenient and equitable access to information (Francis & Goodman, 2010). To address this, SANBI hosts a dedicated website, the Biodiversity Advisor (http://biodiversityadvisor.sanbi.org/), which provides free access to SANBI’s publications, proceedings of the Biodiversity Planning Forum, and any other relevant open access literature. Since conservation planning has a strong spatial component, a similar system—the Biodiversity Geographic Information System (http://bgis.sanbi.org/)—has been set up to serve open access spatial data products, which are essential for efficient conservation (Turner et al., 2015). These products are accompanied by dedicated interpretive information focused on assisting end-users (Knight et al., 2006).

Since members of the extended peer community work independently, it is important that their separate efforts can be synthesized (Botts et al., 2019). This was especially true for the national map of critical biodiversity areas in South Africa, which is a composite of prioritizations from different ecological realms (terrestrial, freshwater, estuarine, coastal and marine) and provincial jurisdictions. Synthesis was facilitated after producing technical guidelines for producing maps of biodiversity priorities (Table 1), which encouraged consistent legend categories and color palettes as well as ways of edge-matching adjacent planning regions. The benefits of this decentralized approach are fourfold:
(a) it prevents national plans from being limited by the data availability or planning capacity of the weakest sub-region;
(b) it allows the incremental updating of sub-national plans, without the delays and logistical difficulties of national-level prioritizations;
(c) it encourages local implementing agencies to develop plans tailored to their own needs; and
d) it enables planning at spatial resolutions appropriate for local land-use decision-making, without encountering computational limitations.

While these interventions were undoubtedly costly to SANBI, they created considerably more value by equipping the extended peer community with the tools needed to produce new knowledge with eventual implementation in mind. The level of engagement in these products went well beyond the traditional “public participation” processes (Rose, 2018). By contrast, many of the products of the extended peer community were true examples of co-produced knowledge (Nel et al., 2016), where the people who are responsible for implementing spatial biodiversity plans (e.g., maps of...
critical biodiversity areas) were integral in the formulation of those plans.

5 THE FUTURE OF POST-NORMAL CONSERVATION SCIENCE

PNS is not without its flaws. Merging research with implementation means that both systems may need to reorganize how they evaluate effectiveness. There are concerns that PNS becomes a diluted pool of extended facts, where the lack of academic rigor can be hidden behind a veneer of pragmatism (Sutherland & Wordley, 2017). Although the research-implementation space should theoretically mean that scientific information is more closely considered during implementation, it could arguably create a situation where scientific data are overlooked in favor of other factors, such as social trends and power politics (Ravetz, 2011; Sutherland & Wordley, 2017). Moreover, because PNS transcends traditional scientific paradigms, individual members of the extended peer group are unlikely to understand every aspect of the broader process, possibly leading to the “diffusion of responsibility” (a psychological effect where individuals are less likely to take responsibility when in a group because they assume someone else will). These issues can be overcome by applying new frameworks for evaluating knowledge that combine scientific criteria, such as the variety and consistency of evidence; with more implementation-oriented criteria, like the credibility of sources and the applicability of information (Game et al., 2018).

South African conservation planning is still dealing with these and other challenges, but it is worth remembering that present day achievements are the result of a gradual progression over the last three decades from theory to practical implementation (Botts et al., 2019). By allowing an approach grounded in PNS, conservation planning in South Africa has become increasingly integrated into government policy and more widely used in decision-making.

It remains to be seen how the same operating model could be generalized to other countries. We anticipate that the wholesale adoption of PNS in other countries is conditional on local context of history, politics, and existing capacity for conservation (Magliocca et al., 2018). For developed countries, the primary challenge lies in overcoming the existing status quo, which may be limited by traditions, cognitive biases, and fear of change (Toomey et al., 2017). In these instances, formal institutions would be more important for mobilizing collective effort toward shared goals (Amel et al., 2017) because the capacity for an extended peer community already exists. By contrast, in developing countries the more urgent issue is probably lack of capacity in the extended peer community, which could be addressed by formal scientific training as well as opportunities for knowledge exchange and shared learning (O’Connell et al., 2019).

At a philosophical level, PNS is free of pre-existing paradigms, so it follows that its adoption would not follow a rigid recipe. Many nations already have the ingredients for an effective extended peer community and likely already operate in ways consistent with PNS (Rose, 2018). However, their success depends on an improvised dialogue between professionals from several different sectors and the acceptance that policymakers rely on sources of information beyond formal scientific evidence (Evans et al., 2017). Although extended facts may leave many conservation scientists feeling uneasy, the PNS paradigm provides an overarching framework applicable in many contexts. This framework acknowledges the usefulness of tacit knowledge and the strength of the extended peer community. Instead, embracing different forms of knowledge and the complexity of the broader socio-political landscape can make conservation more relevant by integrating scientific information into the decision-making process.

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CONFLICT OF INTEREST

The authors disclose that E.A.B. was contracted to the South African National Biodiversity Institute as a freelance scientific writer during the preparation of this manuscript. However, this manuscript was unrelated to those contracts.

AUTHOR CONTRIBUTIONS

F.T.B. wrote the first draft after discussions with E.A.B. and S.P.S, who both revised subsequent drafts.

DATA ACCESSIBILITY STATEMENT

The R-scripts and data to recreate Figure 2 are available on Figshare (https://doi.org/10.6084/m9.figshare.8188154.v1).

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**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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