Conservation Biology

Essay

Transforming conservation science and practice for a postnormal world

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Abstract: *We examine issues to consider when reframing conservation science and practice in the context of global change. New framings of the links between ecosystems and society are emerging that are changing peoples' values and expectations of nature, resulting in plural perspectives on conservation. Reframing conservation for global change can thus be regarded as a stage in the evolving relationship between people and nature rather than some recent trend. New models of how conservation links with transformative adaptation include how decision contexts for conservation can be reframed and integrated with an adaptation pathways approach to create new options for global-change-ready conservation. New relationships for conservation science and governance include coproduction of knowledge that supports social learning. New processes for implementing adaptation for conservation outcomes include deliberate practices used to develop new strategies, shift world views, work with conflict, address power and intergenerational equity in decisions, and build consciousness and creativity that empower agents to act. We argue that reframing conservation for global change requires scientists and practitioners to implement approaches unconstrained by discipline and sectoral boundaries, geopolitical polarities, or technical problematization. We consider a stronger focus on inclusive creation of knowledge and the interaction of this knowledge with societal values and rules is likely to result in conservation science and practice that meets the challenges of a postnormal world.*

Keywords: adaptation pathways, adaptation services, adaptive governance, coproduction, global change, learning, transformation, values-rules-knowledge

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Transformación de la Ciencia y la Práctica de la Conservación para un Mundo Pos-Normal

Resumen: *Examinamos cuestiones para considerar cuándo se deben modificar los marcos de trabajo de la ciencia y la práctica de la conservación en el contexto del cambio global. Nuevos marcos de trabajo sobre las conexiones entre los ecosistemas y la sociedad están emergiendo y están cambiando los valores de las personas y las expectativas de la naturaleza, lo que resulta en perspectivas plurales sobre la conservación. La modificación de los marcos de trabajo de la conservación para el cambio global puede por lo tanto ser considerado como una fase de la relación en evolución entre la gente y la naturaleza, en lugar de una tendencia reciente. Los nuevos modelos sobre sobre la relación de la conservación con la adaptación transformativa incluyen la forma en que los contextos de las decisiones pueden ser re-enmarcados e integrados dentro de una estrategia de vías de adaptación para crear nuevas opciones para la conservación lista para el cambio global. Las nuevas relaciones para la ciencia de la conservación y la gobernanza incluyen la co-producción de conocimiento que apoye el aprendizaje social. Los nuevos procesos para la implementación de la adaptación para resultados de conservación incluyen prácticas deliberadas usadas para desarrollar estrategias nuevas, cambiar las visiones globales, trabajar con el conflicto, dirigirse al poder y a la equidad intergeneracional en las decisiones, y construir conciencia y creatividad que empodere a los agentes para actuar. Argumentamos que la modificación de los marcos de trabajo de la conservación para el cambio global requiere que los científicos y los practicantes implementen estrategias que no estén restringidas por disciplina ni fronteras sectoriales, polaridades geopolíticas, o problemas técnicos. Consideramos que un mayor enfoque en la creación inclusiva del conocimiento y la interacción de este conocimiento con los valores y las reglas sociales probablemente resulten en una ciencia y práctica de la conservación que cumpla con los retos de un mundo pos-normal.*

Palabras Clave: aprendizaje, cambio global, conocimiento-reglas-valores, co-producción, gobernanza adaptativa, servicios de adaptación, transformación, vías de adaptación

Introduction

Conservation science and practice originated in an era when ecological systems were perceived as coherent and predictable and that changed gradually. In such so-called normal times, problems were considered discrete and were addressed using theoretical-analytical foundations in the natural sciences derived through principles of positivism and deduction. Contemporary times are different. The postnormal world of rapid change is characterized by complexity, chaos, and contradictions. In these times, "nothing is definite, truly guaranteed or totally safe," and change is pervasive (Sardar 2010). Knowledge is ambivalent, values and interests are contested, stakes are high, the need for decisions is always urgent, and there is a real danger of highly interdependent global systems running out of control (Helbing 2013).

Some authors consider the postnormal concept implies normal science no longer works because the world itself has changed. The world has always been a complex adaptive system: it is how people interpret it that has changed. Thus, in proposing "science for the post-normal age" Funtowicz and Ravetz (1993) emphasized that disciplinary science applied outside a systems framework is of little use for solving problems in social-ecological systems. Given these systems are dynamic and complex, "the science appropriate to this new condition will be based on the assumptions of unpredictability, incomplete control and a plurality of legitimate perspectives" and "requires an 'extended peer community' consisting of all those with a stake in the dialogue on the issue" (Funtowicz & Ravetz 1993:739).

Climate change and other global drivers have major impacts on ecosystems and biodiversity, although future changes for particular locations and ecosystems are unclear. Conserving ecosystems and biodiversity as they are may be credible and legitimate under gradual ecological change but not when change is rapid and widespread (Mori et al. 2013). Understanding the consequences of historical change on social-ecological systems may improve capacity to address current and future change. Ecological change occurs on multiple and large scales and is unpredictable and irreversible. Conservation of biodiversity and ecosystems is moving away from small changes at local scales (Hagerman & Satterfield 2014). Incremental changes to current conservation approaches could prove ineffective; thus, a transformative adaptation approach is likely needed (Stafford Smith et al. 2011; Wise et al. 2014; Colloff et al. 2016*a*, 2017). By *transformative,* we mean "fundamental changes in structural, functional, relational and cognitive aspects of socio-technical-ecological systems that lead to new patterns of interactions and outcomes" (Patterson et al. 2016).

Global-change-ready conservation will accommodate transformation of ecosystems (e.g., from ephemeral wetlands to permanent drylands) occurring in response to shifts in ecosystem drivers (e.g., water, nutrients, and temperature); remain relevant under a range of uncertain trajectories of ecological change; and be inclusive of the multiple dimensions of biodiversity and ecosystems

valued by society (Dunlop et al. 2013; Heller & Hobbs 2014). A transformative approach to addressing climate change has generic value for global-change adaptation.

A global-change-ready approach involves reframing the purpose and objectives of conservation: whom and what conservation is for and what it can achieve (e.g., Cole & Yung 2010; Hagerman et al. 2010). A transformative adaptation approach to conservation under major ecological change acknowledges that some ecosystems are undergoing, or will undergo, permanent climate-change-induced transformation. Transformative shifts in current decision contexts for adaptation and adaptive governance to support transformative adaptation will be required to respond to changes in ecosystems By *decision context,* we mean the cultural-political setting of the decision process, including interconnected systems of values, rules, and knowledge that form how that process is framed (Gorddard et al. 2016). By *adaptive governance,* we mean the structures and processes societies use to deal with change and uncertainty in social-ecological systems that address short-term perturbation and longer term transformation and integrate knowledge systems and learning into inclusive, decentralized decision making and action (Wyborn 2015*a*).

Transformative adaptation differs from adaptive management because it involves fundamental changes to governance to support continuous improvements in decision making and learning (Abson et al. 2017). Although such improvements are components of adaptive management in principle (Roux & Foxcroft 2011), goals are often not achieved because of insufficient monitoring and inadequate stakeholder engagement (Aceves-Bueno et al. 2015). Although adaptive management and adaptive governance are often cited in discussions of climate adaptation, their durability under transformative change has been questioned (Wyborn et al. 2016). Progress requires decision makers to shift their world views from current conservation to global-change-ready conservation and provide new ways to navigate governance, power, and political constraints to change (Hagerman et al. 2010).

We aim to further discussions on reframing of conservation objectives in the context of global change (e.g., Cole & Yung 2010; Stein et al. 2013; Wyborn et al. 2016). Previous authors considered what objectives might look like, but less attention has been paid to processes and structures for reframing them. We present a case for a transformative approach to conservation and a framework that links global-change-ready conservation with transformative adaptation, the TARA approach (Transformative Adaptation Research Alliance [https://research.csiro.au/tara/]). Setting objectives for global-change-ready conservation needs coproduction: engagement between decision makers and "those with a stake in the dialogue" to learn and generate effective, legitimate, ethical solutions (van Kerkhoff & Lebel 2015).

New Framings of the Links Between Ecosystems and Society

Changes in ecosystem structure, function, and uses are generating new relationships between people and the environment via changes in peoples' expectations, values, and perspectives of nature. Authors have stressed the need for an extended peer community to be engaged in collaborative planning (Schultz 2011; Cross et al. 2012) and reframing of conservation in ways that reevaluate naturalness and societal values associated with it (Hobbs et al. 2009; Cole 2012). The postnormal perspective does not imply that conservation science and practice were static during perceived normal times. Mace's (2014) typology of changing ideologies on conservation over the last 50 years identifies 4 approximate eras: "nature for itself" (pre-1970s), "nature despite people" (1970s–late 1990s), "nature for people" (late 1990s–mid 2000s), and "people and nature" (mid 2000s–present day). The short period in which these shifts emerged has resulted in the plurality of perspectives represented in current conservation science and practice. Reframing conservation in the context of global change is thus the next stage in the evolving relationship between people and nature rather than a recent trend.

Many studies project large-scale biodiversity loss under global change (e.g., Dawson et al. 2011; Foden et al. 2013; Urban 2015), but few consider the potential of conservation practices to mitigate impacts. Drivers of change other than climate are likely to be at least as significant as climate drivers, so that regular contingent analysis can ensure the interacting effects of multiple drivers are considered. Conservation strategies that reduce pressures, facilitate species adaptation (Colls et al. 2009), and maintain ecosystem processes are likely to have positive benefits for biodiversity. In a postnormal world, conservation faces unprecedented challenges from the conflict between maintaining ecosystem integrity and increasing demands placed on natural resources by a rising human population. Climate change imposes additional stressors on ecosystems already altered by land-use change and intensification (Oliver & Morecroft 2014).

Ecosystems and biodiversity are threatened by poorly understood interactions between climate change and altered land use that can lead to regime shifts (Leadley et al. 2014). These interacting stressors occur rapidly and are nonlinear and transformational (IPCC 2014). Yet, impacts on biodiversity, and efforts to address them, are inextricably linked with sustainable development challenges "to protect human well-being and life-supporting ecosystems simultaneously and in ways that are socially inclusive and equitable" (ISSC 2013).

Global-change-ready conservation can be enabled by regarding climate change as an amplifying stressor to other drivers likely to cause large-scale, nonlinear, undesirable change and by considering the interaction

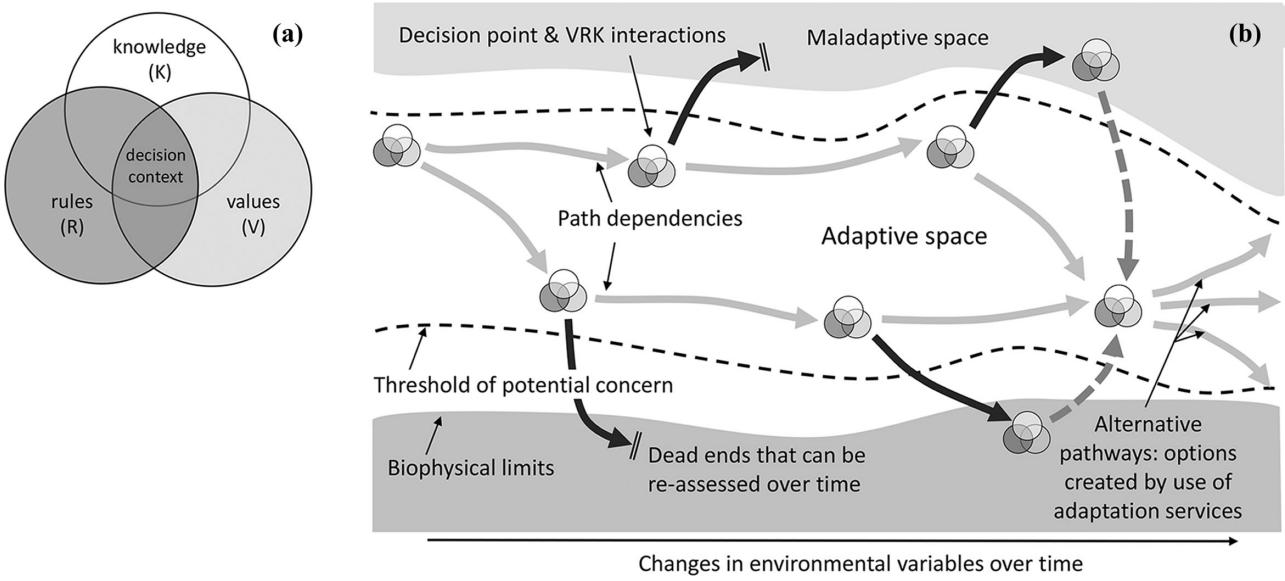

Figure 1. (a) Linkages between the values, knowledge, and rules concept (VRK) and (b) an adaptation pathway incorporating VRK and the use and future-option value of adaptation services.

between what people need from nature and what they might actualize under future constraints on ecosystems. Standard practices such as habitat restoration and protected areas will remain important, but new approaches are needed given the rate and extent of anthropogenic change (Dunlop et al. 2013; Dickinson et al. 2015). The challenge is to factor plausible scenarios of change into conservation and shift from maintaining ecosystems in their current state to managing for dynamic responses to multiple drivers of change. Where these drivers cause transitions to alternative ecosystem states, emphasis will be on facilitating transitions, preserving ecosystem functions, and minimizing species losses.

The choice between incremental and transformative adaptation presents a double bind for decision makers that relates to decision lifetimes (Stafford Smith et al. 2011). Transformative adaptation may be deemed too difficult or unacceptable, so incremental approaches are selected instead. But by the time it becomes clear that incremental adaptation is inadequate to address biophysical change, it may be too late for a transformative approach. This problem is similar to time-inconsistency, whereby a long-term plan is compromised by the incentive of short-term gains (Underdal 2010). For conservation, incremental changes to current strategies may prove inadequate and require subsequent transformative approaches in response to major ecosystem change and biodiversity loss.

Resolving this double bind requires broadening planning and decision making to consider not only longer decision lifetimes (Stafford Smith et al. 2011), but also how short-term gains can be reframed as disincentives because they may limit future options. Adaptive, deliberate sequencing of decisions and actions as part of the adaptation-pathways approach (Wise et al. 2014) addresses time-inconsistency problems. There is no generalized blueprint. Researchers, practitioners, and communities engaged in transformative change have to coproduce approaches relevant to their particular circumstances.

New Models of How Conservation Links with Transformative Adaptation

To diversify options for adaptation, changes are needed to decision making and implementation. The TARA approach can be used to position adaptation in coproduction and learning processes that help diagnose constraints on decision making and develop new approaches to conservation under global change (Colloff et al. 2017). The 3 elements of the TARA approach are the values, rules, and knowledge (VRK) perspective, adaptation pathways, and adaptation services (Fig. 1).

The VRK perspective enables analysis of how decisions are influenced by social-cultural circumstances. It highlights that a mandated decision-making group (e.g., local environmental managers or a national agency) uses systems of values, knowledge, and rules when defining and selecting options for adaptation. Thus, current conservation objectives are underpinned by normative values (held and assigned) (Seymour et al. 2008), knowledge, and rules, but interactions between them tend not to be considered by decision makers. The VRK perspective enables analysis of the particular VRK systems used by the decision-making group and how these systems shape the decision context for adaptation (Gorddard et al. 2016) (Fig. 1a).

The influence of VRK systems is rarely explicit and may constrain adaptation options because certain knowledge,

rules, and values are excluded. For example, current conservation paradigms (e.g., reserves and habitat restoration) focus on maintaining or enhancing existing species, habitats, and ecosystems, consistent with perceived cultural values of society (e.g., NRMMC 2010). However, this focus may not be an appropriate values system under climate change and biodiversity decline. Also, a maintain-and-enhance values system may be embedded in rules (e.g., threatened species legislation) and knowledge systems (e.g., methods for prioritizing objectives) of an established decision-making process and is thus difficult to change.

Gorddard et al. (2016) applied the VRK perspective in an 8-step process to change decision contexts for adaptation. The process can be adapted to specific needs of practitioners. By changing the decision context, conservation objectives may shift as new knowledge on ecosystem change emerges: goals may be unattainable for species or ecosystems likely to undergo irreversible loss (Cole & Yung 2010; Hagerman et al. 2010) and positive societal values may be conferred on immigrant species (Hobbs et al. 2009), modified ecosystem remnants (Colloff et al. 2016*b*), or novel ecosystems (Collier 2015). Rules, such as conservation laws and practices, would then need realigning to conform to shifts in values and knowledge.

The adaptation-pathways approach is a process for designing and implementing sequenced adaptation decisions based on uncertain changes over time (Wise et al. 2014). Adaptation-pathways planning involves assessing trade-offs between benefits of preserving flexibilities to respond to future uncertainties against costs of maintaining business as usual. The VRK perspective is used to analyze the decision context and options at each point on the pathway (Fig. 1b). Assessment by decision makers of predicted or actual changes to the social-ecological system determines whether decisions are likely to prove adaptive or maladaptive. For example, a decision to conserve alpine ash (*Eucalyptus delegatensis*) forest in southeastern Australia by reseeding after fire may be adaptive in the short term but maladaptive in the long-term under more frequent, intense wildfires (Colloff et al. 2016*a*; Doherty et al. 2017). Resources to service the increasing area that requires reseeding may become prohibitive: an opportunity cost of other adaptation options forgone. There is also the likelihood that reseeded areas may burn again before trees reach maturity.

An adaptation-pathways approach involves learning and engagement, considers path dependency (i.e., how past decisions constrain future options), time frames over which decisions remain valid, sequencing of decisions to avoid maladaptation, and shifting societal interests and values (Wise et al. 2014). In Australia, adaptation pathways have been used in the Eyre Peninsula (Siebentritt et al. 2014), Southern Slopes region (Bosomworth et al. 2015), and Murray-Darling Basin (Abel et al 2016; Dunlop et al. 2016). Publications on these projects include guidelines for practitioners on setting objectives, scoping futures, developing adaptation pathways, monitoring, evaluating, and learning.

Adaptation services are the set of ecosystem services that provide options for people to adapt to environmental change (Lavorel et al. 2015; Colloff et al. 2016*a*, 2016*b*). The relationship between ecosystem services needed for future livelihoods and well-being and what changing ecosystems can supply determines the adaptation challenge. Biophysical change then becomes a cue for discussions on adaptation options, the future supply of adaptation services, and the governance arrangements regarding their use (Gómez-Baggethun et al. 2013; Collier 2015). The balance of social demands and ecological limits can then form a basis for exploring future options, including trade-offs among ecosystem services (Howe et al. 2014). With the TARA approach, identifying and explicitly managing adaptation services is central to reframing of values, rules, and knowledge systems that underpin conservation and ecosystem management because adaptation services provide future options for adaptation. Options can be actualized by managing for services from those ecosystems that are likely to persist in the future and using new ecosystem services from those ecosystems that transform. As such, the concept of adaptation services is critical for designing adaptation pathways that incorporate social benefits derived from ecosystems. The identification of adaptation services represents new knowledge, but realizing benefits requires shifts in values and rules and trade-offs between distribution of costs and benefits over the short and long term that involve deep engagement with the politics of adaptation (Wyborn et al. 2016).

Lavorel et al. (2015) described a 4-step process for incorporating adaptation services into adaptation pathways planning based on characterizing current ecosystems drivers and ecosystem services; predicting effects of climate change on ecosystems and services; identifying adaptation services related to ecosystem persistence or transformation; and scoping management options for adaptation services.

New Relationships for Conservation Science and Governance

Conservation agencies have begun to recognize the need for conservation science, policy, and practice to be coproduced (Schuttenberg & Guth 2015; Wyborn 2015*a*, 2015*b*). This new approach involves reconsideration of major science questions in order to shift knowledge generation away from a knowledge-deficit model, whereby "a linear, unidirectional flow of knowledge from experts to users" is assumed (Young et al. 2014; Fernández 2016).

Coproduction of knowledge between researchers, practitioners, and citizens then "supports collective action and reflection directed towards improving the management of human and environmental interrelations," which represents the social-learning approach (Keen et al. 2005). Social learning provides an ethical basis for supporting new forms of knowledge for adaptation (Collins & Ison 2009; ISSC 2013). Integrating coproduction with nature-based solutions (use of ecosystems and their processes to improve human well-being) is becoming a priority under climate change via ecosystem-based adaptation (Vignola et al. 2009).

Coproduction processes can be applied to diverse and difficult situations. One example is the World Wildlife Fund (WWF) REDD+ participatory scenarios of land-cover change in Tanzania (Capitani 2015). Implementing forest conservation for carbon stocks and creating monetary value for them provided incentives to reduce emissions from forested land and to invest in low-carbon pathways for sustainability and poverty alleviation. In another example, collaboration between WWF Colombia and the Luc Hoffmann Institute is building capacity of protected-area managers to conceptualize transformational change and incorporate responses into management frameworks (Wyborn et al. 2016). This effort includes a learning framework on how coproduction processes can shift behaviors and capacities of all project partners, scientists, and practitioners alike.

Using the VRK perspective to focus on social, political, and cultural dynamics of the decision context can highlight opportunities for, and constraints on, coproduction. This focus enables targeted activities that build on existing strengths, such as good relationships between researchers and decision makers, or alerts project designers to social-political power dynamics that affect the scale at which research can make the greatest contribution (van Kerkhoff & Lebel 2015). For example, Wyborn (2015*b*) showed how histories of trust between conservation agencies and landowners strongly shape the possibilities for coproduction. The dialogue critical to coproduction can identify where capacity development can best support collaboration between practitioners and researchers in ways that reframe power relations so that activities are not dominated by scientists, who instead of assuming control become important but equal participants (van Kerkhoff & Lebel 2015).

However difficult and time-consuming, coproduction is happening; tacit knowledge held by stakeholders engaged in adaptation is increasingly being recognized and is conferring legitimacy to scientific processes (Fernández 2016). Coproduction is not straightforward, partly because it is caught in a bind between the driver of urgency (i.e., facilitation of stronger relationships between researchers and practitioners to speed up action and change) and the driver of deliberation (i.e., need for such collaborations to learn and evolve, where learning takes time). Both drivers emphasize the need for skills and opportunities that can drive stronger engagement between science and governance (Diaz et al. 2015; van Kerkhoff & Lebel 2015).

New Processes for Implementing Adaptation for Conservation

A rapidly changing world requires greater emphasis on understanding and implementing the practice of intentional responses to change. Research on conservation and adaptation has rarely addressed how capacities for change can be implemented. Knowledge that is abstract or teachable tends to dominate, rather than practical knowledge for implementation. Practical knowledge is typically developed experientially, is implicit, and quite different from research-based knowledge (Boiral 2002; Fazey et al. 2005). We argue that scientific research needs to be complimented by experiential knowledge to implement transformative adaptation for conservation.

Intentional change includes learning from deliberate practices used to develop new strategies, shift world views, work with conflict, consider power and intergenerational equity in decisions, and build consciousness and creativity that empower agents to act (Page et al. 2016). For example, the Three Horizons practice facilitates dialogue on moving from what is known to new ways of thinking and acting (Fig. 2). This practice can be used to implement the TARA approach, whereby Horizon 1 represents current modes of conservation, including norms, framings, and practices. Horizon 3 represents new ways of operating, and Horizon 2 represents the intermediate steps that facilitate emergence of new approaches. The Three Horizons practice involves working with groups of agents to shape transitions toward transformation and can be used in situations of high contestability and diverse world views by empowering participants to plan for change together (Sharpe et al. 2016).

Deliberate methods are emerging in conservation to facilitate dialogue between researchers and decision makers, build capacity, and support learning (Zachrisson 2010; Lundmark & Matti 2015). Certain practices may be more effective than others in creating conditions for change, depending on context and end-users (Newell 2012). Some processes are complex, involving sophisticated modeling, which can inhibit transparency and exclude certain forms of knowledge. The notion of a deliberate practice emphasizes the need to deal with complex issues in ways appropriate to the skills, knowledge, and tools available to users, and simple approaches may generate greater agency than complex ones. Requisite simplicity applies here (Stirzaker et al. 2010), whereby some detail can be discarded, but conceptual clarity and scientific rigor are retained so that users benefit from new knowledge.

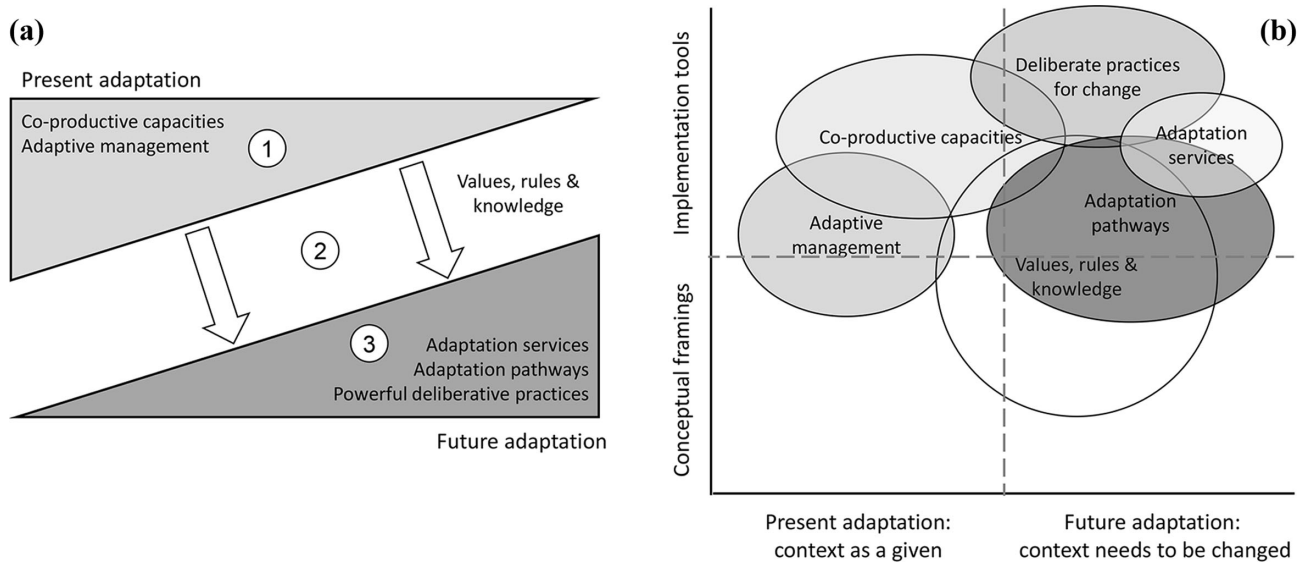

Figure 2. Two representations of the relationships between the concepts and tools for conservation and adaptation to global change: (a) Three Horizons framing (1, what is happening now in conservation; 2, changes needed to achieve adaptation; 3, successful conservation in the future through adaptation to global change) and (b) application of the concepts and tools outlined in this paper as conceptual framings or implementation tools and their uses in understanding how the past has shaped present adaptation-decision contexts or how decision contexts can be shaped in the future. Positions on the quadrat indicate how concepts and tools are intended to be applied and are used currently. Over time, positions may change and some concepts and tools merge.

A Synthesis of Concepts, Tools, and Approaches

The concepts and tools of adaptive management, adaptation pathways, VRK, adaptation services, coproduction, and deliberate practices for change are related via a temporal perspective and their value as a basis for adapting conservation to global change (Fig. 2). Some concepts and tools inform understanding of how past changes and adaptations have shaped the present (adaptive management, coproduction, and VRK in part). Others shape contexts into the future (VRK in part and adaptation pathways and services). An understanding of how present adaptation-decision contexts have emerged informs what needs to change in the future.

Adapting to global change requires new ways of learning and thinking. Humanity has not had to address such pressing challenges before and is yet to realize what these new ways might be. The VRK perspective provides a bridge between current and future conservation concepts and practice (Fig. 2a). Ways forward can emerge from deliberate practices based on interactions of evolving knowledge, rules, and values. Thus, new knowledge focuses on the nature and extent of global change and ways for conservation to adapt. Emerging values reflect preferences for different conservation outcomes based on evolving interests and world views. Changes in rules involve new governance arrangements, consistent with new knowledge and values, which can facilitate agreement on preferred conservation outcomes.

Contestation is inevitable among stakeholders because of uncertainties about biophysical change and resistance to the need for transformative adaptation. Such conflicts cannot be reconciled with a set of guidelines. We therefore provide pointers to transformative conservation approaches based on coproduction and deliberate practices. The emphasis is on experimentation, learning, and discovery. Abel et al. (2016) detailed processes for transformative adaptation that could be "inserted into stakeholders' long-held and strongly established environmental discourses, each one representing the continuing values, understanding, and aspirations of a particular group. The processes are intended to develop and expand debates and negotiations among those groups and lead toward transformations."

Society may not yet know how to learn and adapt to global change but can start by deliberating on likely consequences of various adaptation approaches, avoiding maladaptation, and identifying future options via the VRK perspective, adaptation pathways, and adaptation services. Although trade-offs cannot be avoided, success is likely if adaptation is framed as a social-learning challenge rather than as an attempt to resolve contestation. For conservation science to remain relevant to the rapidly changing nature of conservation practice, reflexive approaches to research are required. The knowledge gaps for conservation identified by Velasco et al. (2015) focus on people and nature and involve transdisciplinary research collaboration, inclusion of indigenous and local

ecological knowledge, and engagement in knowledge coproduction. Similar calls have been made for more reflexive approaches to climate adaptation research (Fazey et al. 2010; Preston et al. 2015).

By reframing adaptation to change in social-ecological systems from reformist to transformative approaches (Bassett & Fogelman 2013), conservation no longer needs be constrained by discipline and sectoral boundaries or geopolitical polarity or haunted by the ghost of technical problematization, whereby every issue is a dilemma to be solved using specialist scientific content knowledge (Funtowicz & Ravetz 1993). Science that can exorcise the spectre of technical specialization will be based on ethical virtues of humility and accountability (Jasanoff 2003). Processes of coproduction involve reframing the relationship between science and society as one of coevolution and deliberate engagement with the normative elements that shape decisions about what actors do and how they do it (Jasanoff 2004). In postnormal times, accountability and responsibility are needed for the production and use of scientific knowledge. Humility is needed to acknowledge the limits of understanding and capacity for prediction, control, and management of the environment (Clark et al. 2016).

To be effective and relevant into the future, conservation needs to change. This does not mean that conservation professionals need to become experts in integration and transdisciplinarity. Rather, they may benefit from engaging with the changing environmental, political, and social circumstances in which they operate in order for their research to find effective application. The map they may choose to follow is still being drawn and is subject to continual revision. Processes that bring together and value diverse knowledge and perspectives of conservation biologists, social scientists, transdisciplinary scientists, communities, policy makers, and practitioners may enable the conservation community to collectively determine the pathways.

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