Environmental Conservation

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Subject Review

Cite this article: Wyborn C et al. (2021) Engaging with the science and politics of biodiversity futures: a literature review. *Environmental Conservation* **48**: 8–15. doi: 10.1017/S037689292000048X

Received: 9 November 2020
Accepted: 11 November 2020
First published online: 25 January 2021

Keywords:
anticipation; Anthropocene; biodiversity futures; futures thinking scenarios; imagination

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Thematic Section: Biodiversity Revisited

Engaging with the science and politics of biodiversity futures: a literature review

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Summary

Future global environmental change will have a significant impact on biodiversity through the intersecting forces of climate change, urbanization, human population growth, overexploitation, and pollution. This presents a fundamental challenge to conservation approaches, which seek to conserve past or current assemblages of species or ecosystems in situ. This review canvases diverse approaches to biodiversity futures, including social science scholarship on the Anthropocene and futures thinking alongside models and scenarios from the biophysical science community. It argues that charting biodiversity futures requires processes that must include broad sections of academia and the conservation community to ask what desirable futures look like, and for whom. These efforts confront political and philosophical questions about levels of acceptable loss, and how trade-offs can be made in ways that address the injustices in the distribution of costs and benefits across and within human and non-human life forms. As such, this review proposes that charting biodiversity futures is inherently normative and political. Drawing on diverse scholarship united under a banner of 'futures thinking' this review presents an array of methods, approaches and concepts that provide a foundation from which to consider research and decision-making that enables action in the context of contested and uncertain biodiversity futures.

Introduction

The Intergovernmental Panel on Biodiversity and Ecosystem Services Global Assessment presents a bleak future for biodiversity; it suggests that without transformative societal change, continued and significant loss of biodiversity will undermine the contribution that nature makes to people and society at large (IPBES 2019). These changes pose fundamental challenges for the conservation community, which now needs to develop methods and approaches to understand ecosystems, the biodiversity they contain, and the services they provide, how these might change in the future (Kim et al. 2018), and how the conservation community, and society as a whole, prioritise actions, and set conservation goals (Prober et al. 2019). Addressing these challenges requires information on possible outcomes of different decisions, and societal input into the nature of a desirable future, which decisions are acceptable, and at what costs.

As such, the methods, approaches and concepts used to understand biodiversity futures must be transdisciplinary, with inputs from the social and biophysical sciences, humanities, law and philosophy (Bai et al. 2016). These disciplines take a spectrum of views towards the knowability and predictability of the future from those that model the future and seek to reduce uncertainties, and those that see the future as inherently uncertain and therefore require methods that embrace uncertainty through creativity and imagination (Guston 2014). From a biophysical science perspective, biodiversity futures are often considered through models that articulate how biodiversity and ecosystems may respond to future environmental change. From the social sciences, 'futures thinking' and 'anticipation' have emerged as fields of inquiry and approaches to help conceptualize the future, facilitate dialogue, and support decision-making that considers how ideas of the future shape present actions, policies, communities, and institutions. Underpinning these models and approaches are concepts that structure how we think about the future, as well as the role of human agency in shaping that future. While the Anthropocene is perhaps the best recognized future-oriented concept, ideas of imagination also feature prominently in futures discourse. It is not enough, however, to simply conceptualize biodiversity futures from within academic domains: decisions about the future are inherently normative, and require societal debate through policy, electoral, or participatory processes (Hagerman & Satterfield 2014, Granjou et al. 2017). New approaches to structuring science-society engagements are needed to enable individuals, communities and institutions to confront the possibility of radically different futures (Bai et al. 2016).

This review responds to calls for new approaches by presenting a selection of literature that can help the conservation community grapple with biodiversity futures. Unlike much scholarship in this field, which is primarily mono-disciplinary, this review provides a novel compilation of literature on biodiversity futures to provide insights into how the future is known and conceptualized. The literature reviewed highlights that thinking about the future involves choices, values and visions of desirable futures, and hence is political. The review begins by articulating the *problematique* of conservation in context of environmental change, which inherently brings up questions of the future. It then moves on to consider a selection of methods, approaches and concepts used to engage with the future. The review concludes with a discussion about the implications of these insights specifically with regard to the politics futuring. It emphasizes that all approaches to charting the future – whether through scientific models or participatory visioning exercises – are inherently political; anticipating and delineating the future necessarily opens some pathways while foreclosing others.

The starting point for this review assumes that grappling with biodiversity futures requires transdisciplinary approaches that embrace diverse ways of knowing and conceptualizing the future. The authors do not seek to take a normative stance on which methods or approaches are best, rather, to suggest that they must be suited to context, and that irrespective of the approach, engagements in biodiversity futures must proceed with an awareness of the politics of futuring practices. Given the breadth of the topic, the review is selective, drawing on aspects of future studies – concepts, methods and approaches – that are most relevant to thinking about biodiversity futures. The literature search included social science scholarship on the Anthropocene and futures thinking, biophysical models and scenarios of biodiversity futures, as well as debates in conservation policy and practice about 'climate ready' goals and strategies. The selection is based on the expertise of the authors as social scientists and modellers who work at the interface of science, policy and practice on biodiversity and futuring. It does not claim to be comprehensive; rather, the selection is intended as a provocation to deepen the conversation between futures studies and biodiversity conservation.

Conservation in the context of environmental change

Traditional conservation policies, goals and strategies that focused on maintaining sites and species in situ have been called into question by climate change (Stein 2013, Dunlop & Brown 2008, Prober et al. 2017). This has spawned a focus on 'climate ready conservation' practices, which generally involve a mix of non-controversial, 'low regrets' approaches, for example, increasing the spatial coverage of protected areas, enhancing connectivity, minimizing non-climate stressors; alongside more interventionist, 'climate targeted' approaches such as assisted migration, and conservation triage (Mawdsley 2011, Hagerman & Satterfield 2014, Prober et al. 2019). Prober et al. (2019), also differentiate between strategies that seek to evade or ameliorate change by directly addressing changing conditions and functions versus enhancing the capacity of species, ecosystems and landscapes to withstand or respond to change (i.e., adaptive capacity).

Existing philosophies, rules and institutions of conservation reinforce preservationist values and strategies that seek to maintain existing species assemblages (Couix & Hazard 2013, Hagerman & Satterfield 2014, Prober et al. 2019). As such, widespread adoption interventionist approaches may require a conceptual shift in how nature is viewed and valued (Dunlop & Brown 2008, Couix & Hazard 2013, Rosa et al. 2017, Prober et al. 2019). Hagerman and Satterfield (2014) identified an emerging shift in norms given stalled global mitigation efforts alongside increased empirical evidence and modelling documenting the severity of current and projected future climate impacts. While there is clear value in low regrets options that address multiple conservation objectives, their dominance raises questions regarding whether this will be sufficient in the context of projected future changes (Hagerman & Satterfield 2014, Prober et al. 2019).

Conservation goals embody the desired condition of a landscape, and thus reflect human values (Stein et al. 2013). As they cannot be set in isolation from context-specific stakeholders, this literature is replete with calls for collaboration among scholars, practitioners and citizens from across scientific, ethical, political and legal aspects of conservation (Staudinger et al. 2013, Hagerman & Satterfield 2014, Wyborn et al. 2016, Prober et al. 2017, Colloff et al. 2017, Kerkhoff et al. 2018). This has catalysed a proliferation of climate informed conservation planning frameworks, most of which entail examining: (1) projected climate change; (2) projected changes to non-climatic stressors; (3) the vulnerability of target species to climate impacts; (4) likely changes to species ranges; and (5) how management strategies are expected to affect outcomes (e.g., Abrahms et al. 2017). Wyborn et al. (2016) critique the overemphasis on the biophysical impacts of climate change on biodiversity in these frameworks, suggesting that planning approaches also consider: whose values are embedded within conservation goals; what types of knowledge are needed to adapt to change; how knowledge of climate impacts (and uncertainty) will be integrated within existing frameworks to support conservation action; and the likely barriers to adaptation.

Some planning frameworks explicitly call for practitioners to reconsider conservation goals in light of projected impacts (e.g., Cross et al. 2012, Stein et al. 2013). This has ignited debates around: the relative focus on managing for change, rather than persistence (Dunlop & Brown 2008, Stein et al. 2013); whether goals should centre on sites and species or ecological function and processes (Prober et al. 2017); or, more controversially, whether resources should be redirected from critically endangered species in order to save others (Wilson & Law 2016). On a philosophical level, goals focused on wildness are inherently incompatible with more interventionist strategies, and may not be appropriate for agencies or organizations guided by a mandate to let natural processes take course. However, as the scope and magnitude of future impacts increases, such mandates may undermine more specific goals related to particular species, ecological communities or ecosystem services. As such, Proper et al. (2019) call for more explicit consideration of what it is about wildness that is valued, and whether these values can be maintained alongside more interventionist strategies. Addressing these questions requires understanding projected future changes to biodiversity and ecosystem services, thus models are critical to discussions of biodiversity futures.

Methods to model the future

There is a plethora of approaches to model biodiversity futures; for example, those organized around species, ecological communities, ecosystems or ecosystem services, and several models can exist for any one biodiversity facet. As future states of biodiversity are intrinsically linked to futures of the drivers of biodiversity change, conceptual or quantitative models are used to determine the drivers of biodiversity change and resultant biodiversity responses

(IPBES 2016). All models lie on a continuum reflecting the degree to which they account for systemic processes. While correlative models tend to be simple and easy to apply, they have limitations when applied in novel contexts beyond the data used to parameterize the statistical relationships in the model. Process-based models describe the processes by which the states of biodiversity or ecosystems change as a function of environmental changes. Process-based models can be more generalizable but often require large amounts of data to parameterize the models sufficiently. The emergence of co-existing approaches to model the future reflects different understandings of ecosystem dynamics as well as differing visions of the future (Dolez et al. 2019)

Although there are many modelling approaches, the majority of biodiversity futures are scenario-based projections incorporating alternative decisions about the management of social and ecological systems. Scenarios are commonly used to address uncertainty within projected futures by exploring the implications of different trajectories in key drivers of change. Drivers are commonly categorized as indirect (e.g., economy, population, governance/policy, technology) and direct (e.g., land use, climate change, harvesting of natural resources, pollution) drivers of change. A diversity of qualitative and quantitative approaches is used to model these drivers. Indirect drivers have a substantial influence on the trajectories and spatial patterns of direct drivers of biodiversity and ecosystem service change. In general, the most widely used indirect drivers in scenario studies are economic, demographic and technological, while socio-cultural and governance drivers are relatively less utilized (IPBES 2016). Recently the Intergovernmental Panel on Climate Change (IPCC) developed the Shared Socio-economic Pathways (SSPs) that describe a range of plausible futures for economy (e.g., global and regional GDP, international trade), demographic trends (e.g., population growth rates, urbanization rates), human development (e.g., education, health), lifestyle (e.g., consumption and diet), policies and governance (e.g., environmental policies, international cooperation) and technology (e.g., rate of development, technology transfer rates) (O'Neill et al. 2014). These different indicators are used to develop scenarios for future greenhouse gas concentrations, which are then used in modelling to represent a range of futures.

Illustrations of biodiversity futures

At the global scale, biodiversity modelling has tended to focus on species-level changes (e.g., change in distribution and richness), and ecosystem functioning (e.g., stocks and flows of carbon in vegetation models or fish biomass in ocean ecosystems). The IPBES Expert Group on Scenarios and Models, for example, carried out an inter-comparison of biodiversity and ecosystem services models using a standardized set of land use and climate change projections (BES-SIM, Kim et al. 2018). They examined outcomes for a range of biodiversity and ecosystem service metrics using exploratory scenarios such as 'global sustainability', 'regional competition' and 'economic optimism', finding that biodiversity declined under all scenarios between 2015 and 2050, albeit with smaller declines for the 'global sustainability' scenario. Many ecosystem service variables were also projected to decline (including nitrogen retention and coastal resilience), while ecosystem carbon storage and the production of timber, food and bioenergy were all projected to increase (BES-SIM, Kim et al. 2018). Without substantial socio-economic transformation, similar trajectories of decline were identified in a multi-model ensemble assembled to assess the feasibility of 'bending-the-curve' of biodiversity loss while feeding the global population (Mace et al. 2018).

Recent scenario analysis has taken multiple drivers into account. For example, in the terrestrial realm, the BES-SIM exercise considered the interaction between land use and climate. A recent study predicts increases in potential plant extinction rates of 60% between 1900 and 2015 (Di Marco et al. 2019). Under the effects of land use only, extinction was projected to decline slightly under an optimistic scenario, but to increase substantially under the most pessimistic scenario. However, climate change considerably increased projections of future species extinctions by 3.7–4.5 times depending on the scenario. This finding aligns with Newbold's (2018) prediction that in the coming decades, climate change will be a more important driver of biodiversity change than land use. Little attention has been paid to large-scale projections of genetic diversity despite the impacts that environmental change could have on this biodiversity facet (Pelletier & Coltman 2018). In addition, the interactions between multiple drivers and interactions between species within ecosystems are typically ignored in projections (Shin et al. 2019).

The general picture from these examples is that in the absence of substantial changes in the way that society interacts with the natural world, biodiversity will continue to deteriorate. It also shows a range of ways that biodiversity futures can be conceptualized and projected through scientific models, each with different assumptions about current and future trajectories of change (Dolez et al. 2019). The challenge then, is identify approaches that can be used by the conservation community to consider what should be done with this information, and how it can enable anticipatory decision-making that mitigates, or prepares for radically different futures.

Futures thinking

Futures thinking encompasses a diversity of approaches focused on anticipation, foresight, preparation and planning to undertake proactive (as opposed to reactive) actions (Boyd et al. 2015, Bengston 2019). Anticipation is a process of active sense making that considers the implications of the present for challenges of the future (Boyd et al. 2015). Originating in corporate, financial and military strategy, these approaches are now being utilized in sustainable development (e.g., Kelly et al. 2004) and conservation (e.g., Wyborn et al. 2016). Futures thinking aims to address complex and uncertain problems through reflecting on the driving forces, dynamics and assumptions behind a contemporary situation, and subsequently through imagining how those may change into the future; what Sharpe et al. (2016) call 'futures consciousness'. Inayatullah (2008) argues for deep self-reflection that extends beyond technical definitions of problems to question the cultural myths that undergird proposed solutions. He suggests identifying hidden assumptions behind predicted futures, for example, about, gender, nature, technology or culture, and encourages consideration of what changes when assumptions shift.

Futures thinking is often characterized as being normative, exploring desirable futures, or exploratory, adopting an open approach to consider possible futures (Cook et al. 2014, Yung et al. 2019). Cook et al (2014) identify six broad steps in foresight processes: (1) setting the scope; (2) collecting inputs; (3) analysing signals; (4) interpreting information; (5) determining how to act; and (6) implementing the outcomes. Bengston (2019) identifies three continua that shape futures methods: expert-led versus participatory; quantitative versus qualitative; and evidence-based versus imagination. While earlier futuring approaches relied on expert

https://doi.org/10.1017/S037689292000048X Published online by Cambridge University Press

input, participatory methods are growing, attributed to the assumption that complex problems are more effectively addressed by diverse groups (Bengston 2019). There is a range of quantitative and qualitative methodologies used, including the Delphi method (forecasting by expert panels) and back-casting (the envisioning of one future, which is then traced backwards to the present) (Boulding & Boulding 1995). Scenario analysis (see below) is perhaps the dominant futuring methodology deployed (Amer et al. 2013, Bai et al. 2016).

A central insight of futures thinking is that there is no one future – the future is not deterministic, and efforts to predict a singular future will be in vain (Inayatullah 2008). Thus, the goal is not prediction, but rather, to facilitate exercises that consider how present choices relate to multiple possible future trajectories (Inayatullah 1990, Slaughter 2020). Futures thinking also facilitates explicit engagement with uncertainty by considering a range of possible outcomes and drivers of change (Inayatullah 2008). Despite wide agreement that decision-making under uncertainty is inherent to climate adaptation in conservation, lack of information is typically cited as an influential barrier to action (Hagerman & Satterfield 2014). A such, there is potential to use futures thinking to build capacity to make decisions under uncertainty, rather than repressing or minimizing it (Inayatullah 2002, Yung et al. 2019).

The use of futures thinking in conservation

Futures thinking approaches have important insights for conservation. These approaches trigger responses to emerging change processes, catalyse strategic approaches to change, and facilitate acquisition of needed strategic resources. (Rhisiart et al. 2015, Hasegawa et al. 2018). Specifically, they can be used to: (1) monitor existing problems; (2) highlight emerging threats and unforced consequences of policies and actions; (3) identify new opportunities; (4) test the resilience of policies and the assumptions underpinning cause-effect pathways; (5) reduce complexity by drawing together multiple sources of information; (6) synthesize and interpret information and monitoring data for policy, planning and management; and (7) define and set research and policy agendas (Cook et al. 2014, IPBES 2016).

Horizon scanning and scenario analysis are the two most common approaches used in environmental management (Cook et al. 2014, Hasegawa et al. 2018, Bengston 2019). Horizon scanning is used to organise diverse information streams about current trends and conditions to identify emerging issues and connections. Sutherland et al. (2020) conduct an annual horizon scanning exercise to identify emerging threats to global biodiversity. This process uses an expert workshop modelled on a Delphi process to identify the most significant 15–20 threats through an iterative, confidential scoring process. The 2020 scan was the 11th conducted, identifying 15 emerging priority topics for biodiversity futures (Sutherland et al. 2020).

Similarly, scenario analyses assess uncertain, future pathways to support strategic decision-making that anticipates, adapts to and mitigates impacts of change. In their most basic conception, scenarios are depictions of alternative futures. However, scenarios, and the processes used to develop them, are highly diverse, ranging from expert-led computational models of climate and ecosystem change discussed above to participatory processes that use artistic methods to develop collective visions of the future (e.g., Pereira et al. 2018) and everything in between. A common categorization of scenarios distinguishes between: (1) exploratory scenarios to support agenda setting; (2) target-seeking scenarios to support policy design; (3) policy-screening scenarios to support implementation; and (4) scenarios for retrospective policy evaluation (also known as ex post evaluation) to support policy review (IPBES 2016).

There are a number of barriers to using futures thinking approaches in policy and practice. This includes lack of capacity for developing and using outputs from scenarios and models, and the limited availability of scenario tools for decision-makers (IPBES 2016). Others have identified more substantive barriers inherent to the methods themselves, particularly those involving more creative, or unconventional thinking, which run counter to the quantitative training of natural resource professionals (Bengston 2019). There are also substantial institutional barriers to adopting methods that inherently embrace, rather than seek to reduce, uncertainty in decision-making (Serrao-Neumann et al. 2013, Bengston 2019, Pereira et al. 2019). There is often greater desire for certainty in highly politicized decision-making contexts than are afforded by futures thinking methods (Serrao-Neumann et al. 2013). Moreover, participatory methods are resource intensive and can be difficult for problems that transcend geographies or scales. As such, Pereira et al. (2019) identify a 'chicken and egg' problem in that policymakers need to see the value of these approaches to invest in them, but the processes need to be utilized to develop the proof of concept.

Pereria et al. (2019) find that most approaches to explore biodiversity futures are grounded in natural sciences and argue for a greater role for participatory and/or arts-based processes. They put forward several arguments for doing so: to engage stakeholders and rights holders in decision-making; to include different worldviews and knowledge systems; to produce more robust knowledge of complex and uncertain systems; to legitimise decisions taken; and to reinforce processes of social learning and change. Others have argued that quantitative, predictive forecasting methods are of limited utility in complex social-ecological systems with multi-scalar, diffuse, and uncertain drivers of change (Bengston 2019). When the future is predicted from the probable, desirable and knowable, it will be derived from assumptions about past or present trends, and unable to account for non-linear feedback dynamics and uncertainties that are inherent to social-ecological systems (Pereira et al. 2019, Miller 2007). Moreover, such approaches often present apolitical visions of the future that do not engage with the politics of futuring, and the role of science in co-creating these futures (see Pereria et al. 2019, and below).

Such critiques have spawned calls for mixed-methods approaches that are inclusive of new, and unconventional ways of thinking (Bai et al. 2016, Rosa et al. 2017, Pereira et al. 2019, Yung et al. 2019, Hamann et al. 2020, Allain et al. 2020). This often involves using quantitative and semi-quantitative methods to model or project drivers of change and qualitative methods to gain an understanding of broader decision-making context, or to integrate modelling into participatory processes (Yung et al. 2019). For example, Rosa et al. (2017) propose a 'visioning future natures process' that would combine an iterative participatory process to identify 'desirable nature futures' with quantitative and qualitative methods to identify possible pathways to realise those futures. Creative and imaginative approaches can be used to combine qualitative and quantitative such as visioning or storytelling methods.

Imagining the future

The concept of imagination is prominent across diverse futures literature. Imagination is a social process, shaped by situated

https://doi.org/10.1017/S037689292000048X Published online by Cambridge University Press

practices (Pereira et al. 2019) and politics (Jasanoff & Kim 2009), that infuses the cognitive, emotive and normative to generate new ideas or practices (adapted from Jensen 2014, Mikoreit 2016, cited in Pereira et al. 2019). Lehoux et al. (2020) explicitly engage with the normative aspects of imagination, positing a definition of 'moral imagination' whereby individuals connect past, present and future ethical dilemmas creatively and selectively. These ideas underpin efforts to engage the imagination to facilitate action and change. Bai et al. (2016) see imagination as a means to foster creativity and innovation and engage with uncertainty, while Pereira et al. (2019) claim that imagination enables people to envision radically different futures, and to step out of existing structures, practices and institutions. In both these examples, imagination is invoked to overcome the 'weaknesses' in dominant modes of doing science, and its interface with policy. Pereira et al. (2019) and Bai et al. (2016) cite issues of fragmentation within science, policy and their interactions, alongside reductionist tendencies in science and a focus on reducing uncertainty. They call for new processes to facilitate engagement with multiple knowledges and alternative frameworks for thinking about and mobilizing expertise to support decision-making. These authors, however, differ in their assumptions about what type of knowledge and expertise should be mobilized, and through what processes. Bai et al. (2016) promote the use of big data at global to regional scales, through modelling processes and multi-stakeholder dialogues. In contrast, Pereira et al. (2019) focus on arts-based practices (literary, performative and visual) to facilitate participatory processes and practices. Imagination, they argue, mobilises emotions in participatory processes in ways that transcend cognitive awareness to create an embodied understanding of uncertainty and surprise in ways that can motivate change.

In contrast, others examine how the 'environmental imaginaries' found within scientific and natural resource programmes reflect specific ideas about a future environment (Hirsch 2019). Scholarship within environmental politics, anthropology, and science and technology studies (STS) build on Anderson's concept of 'imagined communities' to examine relationships between the state and citizens, science and society (Jasanoff & Kim 2009). Within STS, the concept of socio-technicial imaginaries examines how promises, visions and expectations for the future are embedded within social organizations and practices (Jasanoff & Kim 2009). Socio-technical imaginaries are 'collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology' (Jasanoff 2015, p. 4). These imaginaries can influence policy through delineating the boundaries of how an issue and its possible solutions are framed, and invoke images of how the world 'ought to be'. For Hirsch (2019), environmental and socio-technical imaginaries are intimately connected: science created to support decision-making about future environmental management reflects societal ideas about what the future should be.

Productive engagement across literature on imagination can enhance efforts to develop ethically grounded and effective modes of engaging with, and making decisions for the future. An analysis of normative visions of the future can illustrate which interests are scaled up and which voices are privileged or silenced in deliberative processes, as well as how these processes unfold. STS scholarship has shown how socio-technical imaginaries gain traction when they are complemented by, or embedded within, efforts to support particular societal or technological innovations, and used to guide, coordinate, and justify investments in science, technology and policy (Jasanoff 2015). Pereira et al. (2019) find that imaginative processes can: (1) foster translation and understanding of complexity, systemic interactions and uncertainty; (2) promote integration of emotions, feelings and judgements into understanding of and development of solutions for sustainability challenges; (3) 'mobilize and weave' different knowledges into action-oriented dialogues for change. Analysis of socio-technical imaginaries can provide insights into the ways in which participatory efforts to develop imagined futures align with (or not) broader societal and cultural norms shaping decisions about biodiversity futures.

The Anthropocene

The Anthropocene is a central concept for imagining a deeply altered planet and linking current actions to future conditions. In its most common invocation, the term refers to a new planetary condition marked by unprecedented ecological transformation and biodiversity loss, where humans are the driving force of change (Crutzen 2002). From post-apocalyptic, sci-fi work such as Cormac McCarthy's *The Road* and Jan Zalasiewicz's *The Earth After Us*, to geo-engineering proposals, the Anthropocene emphasizes a new and unknown geological era shaped by human action that may create dramatically different future conditions from those of the past (Castree 2014, Lorimer 2017). The concept obliges society to consider how current actions impact biological, climactic and geologic systems across spatial and temporal scales in more dramatic ways than terms like 'sustainability' (Castree 2014).

The concept provokes far-reaching questions that are simultaneously scientific, practical, ethical, philosophical and existential. The basic yet profound assertion is that the Anthropocene signals the 'end of nature', unmarked by human activities (Wapner 2014). This idea elicits polarized responses: on one hand, scholars shudder at the political implications (if there's no nature, on what grounds can we combat the complete destruction of Earth by extraction and development?). From this perspective there is plenty of relatively intact nature worth fighting for. Yet others argue for explicitly acknowledging humanity's role in creating desirable forms of nature (Robbins & Moore 2013). For example, eco-modernist thinkers suggest that humans may serve as benevolent engineers or managers, actively partaking in things like rewilding, translocation and de-extinction (Lorimer 2017). Anthropocene debates feature a spectrum of arguments ranging from those who celebrate self-willed nature to those where humanity is seen as managers, gardeners or architects of the Earth (Holmes 2015).

The Anthropocene has confusing implications for biodiversity futures. Taking it seriously casts doubt on founding assumptions of conservation that there is an external nature, best left untouched by humans, and that the species and ecosystem assemblages of the past can be maintained into the future. Holmes (2015, p. 93) suggests the concept requires the practical, ethical, political and normative underpinnings of issues such as invasive species, extinction and habitat to be questioned. For this reason, he suggests that there has been limited engagement with the concept in the conservation community beyond using the term as a catch-all, attention-grabbing phrase rather than as an analytical concept. Yet in practice, the Anthropocene concept is sparking debate about things like rewilding, where species are translocated, substituted or hybridized to facilitate biodiversity (Lorimer et al. 2015) or conservation of anthromes – anthropogenic areas co-produced by human, biotic and abiotic forces (Holmes 2015). While Bai et al.

(2016) suggest that the concept provides an opportunity to explore different futures and the role of science in shaping them, they argue that the societal significance of the idea lies in the extent to which it can be used to generate shifts in attitudes, choices and actions.

Implications: politics of biodiversity futures

The literature reviewed thus far has pointed to profound challenges for biodiversity futures, both concerning the fate of species and ecosystems themselves, and emerging from the complex and uncertain information and ideas that shape how decisions about the future are made. Tying this all together, this final section argues that charting biodiversity futures is inherently political, and irrespective of the method or approach adopted, explicit engagement with this politics is required.

It is widely accepted within social science scholarship that the practices of calculating, imagining, modelling and performing futures is inherently political (Hulme 2010, Jasanoff 2015, Mathews & Barnes 2016, Granjou et al. 2017, Beck & Mahony 2017, Duncan 2017, Esguerra 2019). To anticipate is to chart the future realms of possibility, thus what is in and out of that frame shapes which 'processes' and what 'practices' are seen to be problematic (Anderson 2010, in Granjou et al. 2017, Esguerra 2019). The assumptions embedded into such models and practices have implications for what decisions are made, and therefore, how costs and benefits are distributed and which injustices are addressed or exacerbated (Dooley & Gupta 2017, Allain et al. 2020). Modelling practices, participatory or otherwise, play out on an existing socio-political landscape when they are mobilized to inform decisions. Different practices imply distinct politics (Esguerra 2019): how a process is designed and whose knowledge is present and legitimized will either exacerbate or confront existing distributions of power, opportunity and injustice.

Processes can be designed in ways that will 'open up' or 'close down' debate about alternative pathways to action (Stirling 2008). Moreover, the practices themselves create artefacts – maps, projections, scenarios, narratives, etc. – that are often used in other contexts, thus solidifying the imaginaries that are embedded in those artefacts. Maps and models can be used to discuss the underlying assumptions about the world, including the social, ecological, political and biogeochemical drivers of change. However, these assumptions have implications for the legitimacy of representations of the future and their utility within decision-making. It matters what and whose knowledge is represented because the socio-political implications of maps and models are in part a product of the assumptions upon which they were founded (Dooley & Gupta 2017). This performative nature has meant that futuring practices themselves have become the focus of political and academic debate and contestation (Esguerra 2019).

Engaging with the concept of the Anthropocene not just as a descriptive term for a novel geologic epoch, but as a heuristic for understanding the challenges of conserving biodiversity into the future, is essential. Critical scholars of the Anthropocene suggest that the concept marks an exciting opportunity for increased disciplinary and epistemological diversity. By acknowledging the power of humanity to shape the earth, the concept could increase the role of social sciences, and social and cultural theory to enhance understandings of earth systems (Malm & Hornborg 2014). Similarly, in raising questions about society-nature dualism at the core of modern environmentalism (Lorimer 2012, Wapner 2014), many critical scholars of the Anthropocene argue that the mainstream acknowledgement of nature as a socio-cultural construct could be key to imagining transformed futures. The idea challenges the notion that natural science speaks for a stable and objectively knowable nature, and thus could allow for more critical analysis of the social and cultural dynamics behind environmental crises. A radical interpretation of the concept 'opens up a plurality of nature framings, knowledges, and cosmologies' (Lövbrand et al. 2015, p. 213). Engaging critically with the Anthropocene concept may serve to bring a broader set of knowledge systems and communities into conversations about the future of biodiversity, including new combinations of the methods, concepts and approaches reviewed here.

To project the future is an engagement in the politics of the future: that needs to be explicit when futuring approaches are developed and deployed. However, discussions of the future within much of the biodiversity, conservation and ecosystem services literature from the biophysical and positivist sciences does not acknowledge this politics. There may be passing references to 'multiple worldviews', or 'societal values' and methodological pluralism, however trade-offs, conflicts, power and justice tend to be absent from scientific conceptualizations of the future, and the role of science in co-producing (sensu Jasanoff 2004) that future. Put simply, who gets to imagine and model the future matters, and how it is imagined is political. If projections of the future (be they models, scenarios, narratives, myths or artefacts of new media) both represent and create futures, there is a critical need to recognise the responsibilities of researchers engaged in these endeavours (be they from the social or biophysical sciences, humanities, or the arts).

Conclusion

This review outlined a broad body of scholarship that engages with, or can contribute to, grappling with biodiversity futures. In isolation, these literatures present an incomplete picture, in combination they offer a set of methods, approaches and concepts that can be harnessed to ask what futures society may confront and how to anticipate and prepare for them. Engaging with these questions now, rather than reactively as changes unfold is critical, as there will be winners and losers across social and ecological communities. The distribution of the costs and benefits of these change processes will play out on an existing politics and as such, needs to attend to questions of power, politics and inequality. Ultimately, there is no right answer, or simple solution; what is desirable or appropriate is subjective, and situated within a given place, organization or community.

Advances in the biophysical modelling of biodiversity futures is key, as insights into the potential nature of change, and the implications of different decision pathways are critical to making informed choices. However, to be effective they require a robust understanding of the politics that shapes discussions of biodiversity futures, including how models are developed, used and adopted within decision-making processes. The models themselves have implications for communities, policies and management because they contain assumptions about the relationship between socio-cultural and institutional drivers of change that have implications for how decisions are made, and also for the credibility of the models themselves as means to support decision-makers. As such, futures thinking approaches present both opportunities and challenges for engaging with complex and uncertain change processes that underpin biodiversity futures, and efforts to address them.

Charting the future is an inherently political practice. To anticipate is to delineate the future realms of possibility by bringing certain futures to the fore, thereby marginalizing other pathways or trajectories. As such, futuring practices require careful consideration of whose knowledge and values are embedded within efforts to calculate, imagine and perform different futures. We must ask: what is a desirable biodiversity future and for who? Recent literature suggests that these philosophical questions are central to the more practical agenda of determining what policies or actions are implemented, where and when. To this end, research and practitioners could usefully pilot novel processes that enable diverse stakeholders to engage with scientific projections of future change while deliberating on more political questions about the nature of a desirable futures. There is also a need to address the philosophical and institutional barriers to adopting novel or interventionist approaches in order to mitigate the negative impacts of more transformative climate and ecological changes. This includes considering how to confront the trade-offs and inequitable distribution of costs and benefits across and within human and non-human communities now and into the future.

Acknowledgements. This paper was produced as part of the Biodiversity Revisited Initiative, which was coordinated by the Luc Hoffmann Institute, in collaboration with WWF, Future Earth, ETH Zürich Department of Environmental Systems Science, University of Cambridge Conservation Research Institute and the Centre for Biodiversity and Environment Research at University College London, and supported by funding from the MAVA Foundation, the NOMIS Foundation, WWF, The Rockefeller Foundation Bellagio Center and the Foundation for Environmental Conservation.

Financial support. Financial support for this review was provided by the NOMIS Foundation, via a grant from the Luc Hoffmann Institute and the Biodiversity Revisited Initiative.

Conflict of interest. None.

Ethical standards. None.

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