Griffith Law Review

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rlaw20

Biodiversity and species extinction: categorisation, calculation, and communication

Esther Turnhout & Andy Purvis

To cite this article: Esther Turnhout & Andy Purvis (2020) Biodiversity and species extinction: categorisation, calculation, and communication, Griffith Law Review, 29:4, 669-685, DOI: 10.1080/10383441.2020.1925204

To link to this article: https://doi.org/10.1080/10383441.2020.1925204

Published online: 17 Jun 2021.

GRIFFITH LAW REVIEW
2020, VOL. 29, NO. 4, 669–685
https://doi.org/10.1080/10383441.2020.1925204

Biodiversity and species extinction: categorisation, calculation, and communication

Esther Turnhout [a] and Andy Purvis [b]

[a]Department of Environmental Sciences, Wageningen University, Wageningen, Netherlands; [b]Department of Life Sciences, Natural History Museum, London, UK

ABSTRACT
After the launch of the Global Assessment of the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) in May 2019, the message that 1 million species are threatened with extinction made headlines in news and social media across the world. These headlines also resulted in critical responses that questioned the credibility of this number and – by extension – the Global Assessment report and the institution of IPBES. In this article, we – as two authors of the Global Assessment – draw lessons from the GA about how to represent biodiversity in assessments and how biodiversity knowledge can inform effective and legitimate actions that contribute to conservation as well as equity, justice, and human well-being. Specifically, we highlight the inherent multiplicity of meanings and definitions of biodiversity to reflect on the limitations of using species richness and extinction as proxies for biodiversity and biodiversity loss. It is crucial to communicate clearly and in a balanced way that biodiversity loss is broader than species extinction, and how this broader loss of biodiversity jeopardises human wellbeing irrespective of whether species die out. Consequently, the post-2020 biodiversity framework will require multiple targets around not only species extinction but also broader biodiversity loss and human well-being.

KEYWORDS
Biodiversity; science-policy interface; extinction; species; indicator; apex target; global environmental governance

Introduction: global environmental knowledge and the science policy interface

The communication of science to policy with the goal to improve decision making and effectiveness has been a prominent theme in conservation, biodiversity and environmental governance at national and global levels. A key example has been set by the Intergovernmental Panel on Climate Change (IPCC) and its efforts to synthesise and assess climate science to enhance awareness and understanding of the causes, extent and impacts of climate change. In 2007, the Panel, together with Al Gore, was awarded the Nobel Peace Prize for its work. This event demonstrated the significance that is attributed

CONTACT Esther Turnhout esther.turnhout@wur.nl Wageningen University, PO Box 47, 6700 AA Wageningen, Netherlands

to science in solving environmental and societal challenges. Following the example of the IPCC, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 after several years of negotiation and calls that the problem of biodiversity loss requires a similar approach as climate change.[1]

The central assumption that underpins these two organisations, is that science provides a common and objective knowledge base to inform decision making. However, in order to improve the functioning of the science-policy interface, it is important that science is appropriately assessed, synthesised, interpreted and presented; and this is where organisations such as the IPCC, IPBES but also other so-called boundary organisations such as planning bureaus and advisory councils, come in. They aim to assess knowledge in a manner that is policy relevant, but not policy prescriptive. This logic, which holds that science – packaged in assessments – provides neutral policy input, is called the linear model of science-policy-society relations. Although this linear model may be attractive and has proven to be persistent, it is also problematic for two reasons.[2] First, in practice science is not separate from policy, and knowledge is the co-produced outcome of policy, societal and scientific concerns and values. Second, organising divisions of labour according to this model has in some cases led to disappointing results where science has failed to contribute to actual concerns and problems.[3] Similar critiques have been directed at global integrated environmental assessments. While undoubtedly these reports and the organisations creating them have contributed to raising understanding and awareness of environmental problems like climate change and biodiversity loss, their effectiveness in terms of policy uptake and implementation has been limited.[4]

Being a new member in a series of global environmental science initiatives, IPBES had a unique opportunity to learn from these lessons.[5] It has taken a number of steps to innovate the biodiversity science-policy interface by actively seeking the participation of diverse experts from not just the natural sciences but also the social science and humanities and promoting the inclusion of different scientific, local and Indigenous knowledge systems and worldviews.[6] The Global Assessment (GA) report[7] that was launched in 2019 was widely heralded for this inclusiveness.[8] Due to the diverse expertise that went into its creation, the GA was able to synthesise and communicate a diversity of key messages that ranged between the identification of the main causes of biodiversity loss, the contribution of Indigenous and traditional practices to biodiversity, and the different policy options that can contribute to conservation and sustainable use.

While the GA's synthesis of the state of nature considered a wide range of facets of biodiversity, the associated key messages – being aimed largely at audiences in policy and society – referred wherever possible to widely familiar concepts. One of these messages, which was also among the headlines of the IPBES press release to announce the launch of the GA, was that one million animal and plant species are threatened with extinction.[9]

[1]Loreau et al (2006).
[2]Turnhout et al (2019).
[3]Sarewitz (2016).
[4]Mitchell et al (2006); Alcamo (2017).
[5]Turnhout et al (2012).
[6]Díaz-Reviriego et al (2019).
[7]IPBES (2019).
[8]McElwee et al (2020).
[9]https://ipbes.net/news/Media-Release-Global-Assessment (accessed 10 March 2021).

This message attracted considerable media attention and was repeated in headlines of major news organisations such as the BBC and CNN, popular science outlets such as National Geographic, and leading science journals including Nature and Science.[10] Within hours, this number of one million also provoked responses in social and traditional media that wanted to know where the number came from and how it could be so much larger than the number of recorded species extinctions over recent decades, or the number of species whose extinction risk status has been assessed. These questions and criticisms resulted in Twitter exchanges summarised in an editorial in Nature Ecology & Evolution.[11] Such questioning also extended to the conclusions of the GA about the problems that loss of species would cause for humanity. As authors of the GA, we received similar questions from journalists who wanted to know how the 1 million number came about and why biodiversity loss is bad.

Critical responses to science are of course not new, and they also form a vital part of how science functions and progresses. Yet, this pattern of immediate pushback also illustrated how global biodiversity science and IPBES have followed climate science and the IPCC. The emergence of extinction denialism can be seen as a somewhat cynical sign that the knowledge presented was apparently considered important enough to be challenged.[12] With this development, IPBES has again the opportunity to learn lessons from the climate domain.

In this article, we draw lessons from the IPBES GA about how to represent and govern biodiversity. We foreground the inherent multiplicity of definitions and meanings of biodiversity and use this to critically reflect on the desirability and feasibility of creating a singular metric and apex target for biodiversity. While attempts to emulate climate science and governance are understandable, we argue that for biodiversity this is not a good idea. A narrow focus on biodiversity as species and biodiversity loss as species extinction may be easy to communicate and attractive for policy makers, NGOs or media to signal the urgency of the biodiversity crisis, but it is seriously limited in its ability to reflect diverse values and worldviews and catalyse the effective action that is needed to ensure the wellbeing of people and nature.

Our article draws on the GA with the aim to inform the Convention on Biological Diversity's process for deciding the post-2020 targets and strategy for global biodiversity. Though delayed by Covid-19, the discussions around this new framework are ongoing prior to final negotiation at the Conference of the Parties in Kunming, China, currently scheduled for October 2021. Previous global biodiversity targets have not been met,[13] adding to the pressure of setting targets that will be able to safeguard biodiversity and future wellbeing.[14] Our article contributes directly to these discussions and offers an interdisciplinary perspective on the question of how many and what kinds of targets there should be in the CBD Post-2020 Global Biodiversity Framework. We discuss whether a target for the rate of species extinction might be used as a concise overarching

[10] BBC: https://www.bbc.co.uk/news/science-environment-48169783 (accessed 10 March 2021); CNN: https://edition.cnn.com/2019/05/06/world/one-million-species-threatened-extinction-humans-scn-intl/index.html#:~:text=(CNN)%20One%20million%20of%20the,of%20global%20nature%20loss%20ever (accessed 10 March 2021); National Geographic: https://www.nationalgeographic.co.uk/environment/2019/05/one-million-species-risk-extinction-un-report-warns (accessed 10 March 2021); Nature: Tollefson (2019); Science: Stokstad (2019).

[11] https://www.nature.com/articles/s41559-019-0922-2 (accessed 10 March 2021).

[12] Lees et al (2020).

[13] Butchart et al (2010); Butchart et al (2020).

[14] Mace et al (2018); Díaz et al (2020); Dinerstein et al (2020); Purvis (2020).

goal for the whole post-2020 framework and what role, if any, species extinction should play in that framework.

Biodiversity and the category of species

The concept of biodiversity emerged in the 1980s in response to increasing scientific signs that many of the worlds' species were showing negative trends in abundance and distribution and were even threatened with extinction because population sizes were dropping below the threshold for viability. Biodiversity was meant to serve as a popular shorthand of the then established scientific term biological diversity. The idea was that the term biodiversity could serve as a holistic term to denote the variety of life and that it could replace concepts of nature or wilderness which were thought to be insufficiently effective and appealing for policy and society.[15] The definition of biodiversity that was adopted by the Convention on Biological Diversity reflects this broad approach. Article 2 of the Convention says that 'Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'.[16]

It should be noted though that in several ways, the concept of biodiversity has not achieved these ambitions. While the broad scope of the concept of biodiversity has proven useful in policy, it has had little influence on the practices and priorities of conservation policy and management. It is also generally not well understood by the public. Studies have shown that people generally either do not know what the concept means, and if they are familiar with the term they refer almost exclusively to species of plants and animals.[17] Also in science and conservation, biodiversity is most commonly operationalised by means of the concept of species.

The interpretation of biodiversity as species has resulted in specific forms of research and conservation that aim at the collection of information about how species are doing. The Red Lists developed by the IUCN, which order species in terms of their degree of extinction risk, have become a prominent way in which this information is then made relevant for policy and management, particularly in protected area management and in dedicated species protection plans. The notion of species in these examples is usually considered self-evident in the sense that species are simply assumed to exist. This changes when you take an evolutionary perspective. Darwin, for example, considered 'the term species, as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other'.[18] Indeed, classifications and definitions of what constitutes a species are not static. Taxonomy and systematics are highly dynamic fields and particularly the use of genetic techniques has influenced how and on what basis species are identified; such changes can have a range of impacts on conservation decisions.[19]

While a conception of biodiversity as species is arguably the most dominant one in traditional conservation science and policy, we have in recent years seen a

[15]Takacs (1996).
[16]1760 United Nations Treaty Series 79.
[17]Lindemann-Matthies and Bose (2008); Bermudez and Lindemann-Matthies (2020).
[18]Darwin (1859).
[19]Isaac et al (2004).

diversification of concepts around biodiversity. One of these is the concept of Ecosystem Services that denotes the benefits that people derive from nature and the value they attribute to those benefits. This concept paves the way for policies that promote mutually beneficial relations between nature and those that contribute to the services that nature provides and those that use and depend on those services. One way to do this has been through so-called Payment for Ecosystem Services Programs (PES) which try to match supply and demand by organising schemes and projects in which the users of Ecosystem Services contribute financially to their conservation and sustained delivery.[20] As the idea of PES illustrates, much of the focus in Ecosystems Services science and practice has been on instrumental values and economic benefits, ignoring the multiple ways in which people know, value and live with Biodiversity.[21] To complement this relatively narrow focus, IPBES has delivered another innovation in the biodiversity science-policy interface by introducing the concept of Nature's Contributions to People.[22] This concept resonates better with non-Western and non-scientific worldviews and knowledge systems and emphasises the mutual relations between humans and nature, acknowledging that nature and its values originate from and are embedded in a continuous co-production process in which nature contributes to people, and in which, equally important, people also contribute to nature.[23] In other words, this concept promotes diverse values and relations, beyond those that are normally expressed in science or in economic exchanges. The policy implications of this concept are still to be determined but may include a more explicit recognition of practices and ethics of stewardship, for example by Indigenous Peoples and Local Communities (IPLC).

The central point here is that it matters how we conceptualise biodiversity and nature because concepts shape both research agendas and policy responses – we currently see a surge in research effort to assess Nature's Contributions to People and the term is also being picked up in policy documents. In other words, concepts are not neutral units or categories that can be used to 'package' knowledge: they do political work.[24] Going back to the concept of species, it is thus important to consider the political work that this concept does. How is knowledge used to represent species, and render them present,[25] what responses do these representations evoke and make possible, and what political implications do these have? Representing extinction, the loss of species from specific ecosystems or the entire planet, is a powerful way to express biodiversity loss. It appeals to emotional registers and can trigger responses of grief and a sense of irreversible loss.[26] This holds particularly for iconic wildlife species, with the extinct dodo and the highly threatened white rhino as prime examples. For such iconic species, policy responses such as species protection or breeding programs may be possible to prevent extinction. However, as we will show in the next section, this changes when we move from well-known iconic species to assessing extinction in relation to biodiversity as a whole. In so doing, we move from a domain of particular and knowable living creatures

[20]Muradian et al (2013); Schomers and Matzdorf (2013).
[21]Redford and Adams (2009); Turnhout et al (2013).
[22]Díaz et al (2018).
[23]Matuk et al (2020).
[24]Turnhout (2018); Pascual et al (2021).
[25]Hinchliffe (2008).
[26]Yusoff (2012); Ginn et al. (2014).

to one of generalisations, unknowability and diversity.[27] In these representations of biodiversity and its loss, statistical, accounting, archival, and database practices take centre stage.[28]

Calculating biodiversity for policy

The number of species is the statistic most often used to summarise biodiversity[29] and, as we have seen, also approximates public understanding of the term 'biodiversity'. Counts of species also have an advantage not shared with counts of other elements of biodiversity, such as ecosystems, biomes, habitats, ecosystem processes: species can be delimited in relatively easy and repeatable ways, at least in animals and plants.[30] Standardisation and repeatability are considered important criteria when selecting a measure to use in a legal or policy context, with the close scrutiny that is likely to ensue.[31] This may be why, in ways that reflect the linear model of science-policy-society relations, there has been much emphasis on improving this measure as a prerequisite for effective biodiversity conservation. For example, the website of the Convention on Biological Diversity suggests that current deficiencies in taxonomic knowledge impact on 'our ability to conserve, use and share the benefits of our biological diversity'.[32]

Can species richness play a comparable role in biodiversity policy to that of global mean temperature or the partial pressure of Carbon Dioxide (pCO_2) – a measure of the state of the climate system that is linked mechanistically to whether the earth system will change in a way that endangers society[33] – in climate-change policy? Although no single number can ever capture the full hierarchical complexity of the composition, structure and function of biodiversity[34] – or even the biodiversity represented in a single sample[35] – might species richness nonetheless be a sufficiently accurate short-cut to form the basis for policy? There are two main problems. First, it is not practically feasible. Unlike pCO_2, the total number of species on earth is far from being resolved. Recent estimates for global plant diversity are mostly near 450,000 species,[36] but estimates of global animal diversity are not yet strongly converging[37] and few researchers are even willing to guess at numbers of microbial species. Moving scales from global to local, the sheer diversity of life means that producing a complete inventory of a site's species – *all* of its species – cannot practically be done. Surveying everything from microbes to megafauna would require enormous effort and an inhuman breadth of expertise.

Second, whereas pCO_2 plays a central role in determining the global pattern of climate and its trajectory over time, species richness is not so central to biosphere processes. Although local and landscape-scale species richness does influence how ecosystems function and the rates of flow of many ecosystem services, these relationships are typically saturating curves rather than linear, such that successive losses of species have

[27] Yusoff (2012); Rose et al (2017).
[28] Yusoff (2012); Turnhout and Boonman-Berson (2011).
[29] Naeem et al (2016).
[30] Mayden (1997).
[31] Royal Society (2003).
[32] https://www.cbd.int/gti/problem.shtml (accessed 10 March 2021).
[33] Steffen et al (2015).
[34] Noss (1990).
[35] Purvis and Hector (2000).
[36] E.g. Enquist (2019).
[37] Caley et al (2014).

progressively more impact.[38] The relationships can also be highly variable, depending on context and both spatial and temporal scale,[39] and the range and variety of functional traits present in a community can be more important than the number of species.[40] Moreover, species richness is a relatively insensitive measure for detecting biodiversity change.[41] It does not reflect, for instance, how evenly individuals are shared among the species, nor how different the species are from one another[42] and it can be unchanged by changes in species' relative abundances or even by wholesale replacement of one set of species by another. Yet, all these biodiversity changes may affect the functioning of ecosystems and their provision of ecosystem services.

These problems are widely recognised in biodiversity science and a wide variety of practices and methodologies to assess biodiversity have been developed in response. A first pragmatic strategy is to focus on particular taxonomic groups (e.g. birds or flowering plants) and particular sampling methods (e.g. point counts or quadrats), implicitly assuming these can provide a surrogate for biodiversity as a whole. However, different taxonomic groups differ widely in their ecology and evolutionary history, meaning they can show very different geographic patterns of diversity.[43] They also differ widely in their ability to tolerate anthropogenic drivers of change, meaning there is no single group whose responses to drivers can be used reliably to represent biodiversity's response as a whole.[44] There is the risk of mistaking what is easily counted for what counts,[45] and overlooking what is not counted.[46] For example, unless careful steps are taken to avoid it, data biases mean that policies can end up giving undue weight to the taxonomic groups for which the best data are available,[47] even though these may well not be the taxonomic groups that are most important for human wellbeing.[48] A second approach to assess biodiversity and changes in biodiversity is to focus on processes – such as extinction and invasion – that change numbers of species in the study region, since these processes are easier to detect and understand than are biodiversity changes that do not affect species numbers, such as accelerated replacement of species[49] or reduced spatial turnover of which species are present.[50] New technologies have opened new approaches: advances in DNA sequencing and analysis provide a wholly new way to survey whole ecological communities,[51] and remote sensing can provide an unprecedentedly fine-grained view of the structure and functioning of the world's terrestrial ecosystems.[52] Ecosystem functioning can also be tackled, either by linking data on the species composition of ecosystems to data on those species' traits that influence ecosystem processes[53] or through mechanistic global ecosystem models that can report directly on ecosystem functions.[54]

[38]Cardinale et al (2012); Hooper et al (2012).
[39]Isbell et al (2017).
[40]Cadotte et al (2011).
[41]Santini et al (2017).
[42]Purvis and Hector (2000).
[43]E.g. Prendergast et al (1993); Powney et al (2010).
[44]Lawton et al (1998).
[45]Failing and Gregory (2003).
[46]Bowker (2000); Turnhout et al (2014).
[47]One example of a group for which good data is available leading to a bias in policy is birds, see Troudet et al (2017).
[48]Norris (2012).
[49]Also known as temporal turnover, see Dornelas et al (2014).
[50]Known as biotic homogenization, see Li et al (2020).
[51]Deiner et al (2017).
[52]Pettorelli et al (2014).
[53]Díaz et al (2013).
[54]Purves et al (2013).

What this section has shown thus far, is that in the absence of a universally agreed operational metric to assess biodiversity, a wide variety of approaches has emerged that measure different components or aspects of biodiversity. This variety increases further if we include the methods and approaches used in the social sciences to analyse biodiversity using sociological, policy science, humanities, environmental law, or anthropological perspectives, as well as in Indigenous and local knowledge systems. This variety poses challenges for the comparability of studies and the interoperability of datasets. Within the realm of the natural sciences, conceptual, technical and infrastructure developments – many prompted and facilitated by science-policy processes – have greatly accelerated efforts to overcome these challenges. A key achievement has been the development of a framework of 'Essential Biodiversity Variables' (EBVs) that rationalises the plethora of statistics that researchers use to quantify biodiversity.[55] The Group on Earth Observations Biodiversity Observing Network (GEO BON), which oversaw the development of the EBVs, is one of many international organisations that are providing the architecture needs to aggregate and synthesise biodiversity data.[56] These efforts have been aided by shifts in science culture towards macroecology (which emphasises the similarities among different sources of data rather than the differences, facilitating synthetic analysis), data-sharing, and data that are 'born digital'.[57]

The IPBES Global Assessment adopted a broad interpretation of biodiversity to allow for the inclusion of this diversity, following the CBD and recognising the value of different worldviews, disciplines, and knowledge systems. Rather than focus on a small set of biodiversity indicators, the GA's review of recent biodiversity trends opted to use nearly 80 global measures of the state of nature, along with nearly 500 local measures developed by IPLC, organised using the six categories of EBV.[58] Species extinction and extinction risk were treated as a subset of the species population category, with a focus on estimating the numbers of vertebrate extinctions since 1500 (syntheses of non-vertebrates were not available, though Humphreys et al have since enumerated plant extinctions since 1500).[59]

Communicating biodiversity loss and extinction

In the Summary for Policy Makers[60] and at the launch of the IPBES GA, the finding that 1 million species are currently threatened with extinction took a central position. It featured prominently in the press release by IPBES and, as we noted before, it attracted considerable attention in news and social media as well. The message proved effective in offering a powerful representation of the severity and urgency of the crisis of biodiversity loss, but it also provoked questions by journalists and critics.

In a striking parallel to journalistic commentaries about climate change, some of the critical comments took the shape of emerging sentiments of extinction denialism.[61] Among others, we saw two well-known figures in climate scepticism and denialism

[55]Pereira et al (2013).
[56]Bingham et al (2017); Purvis et al (2020).
[57]E.g. Purves et al (2013); Sullivan et al (2014); Deiner et al (2017).
[58]Purvis et al (2020).
[59]IPBES (2019).
[60]Humphreys et al (2019). See https://ipbes.net/news/million-threatened-species-thirteen-questions-answers (accessed 10 March 2021), for a step by step explanation of the approach taken by the IPBES GA.
[61]Lees et al (2020).

now turning their attention to the IPBES GA. For example, Patrick Moore stated in his witness statement for a hearing of the US House of Representatives dedicated to the IPBES GA:

> The IUCN estimates that fewer than 28,000 species are threatened with extinction today. The IPBES estimate is one million species. The IUCN estimate is based on real species with Latin names. The IPBES estimate is largely based on unknown species with no names.[62]

Toby Young made a similar comment in The Spectator:

> What about the IPBES's claim that around 25% of species … are threatened? That seems a little pessimistic, given that the number of mammals to have become extinct in the past 500 years or so is around 1.4% and only one bird has met the same fate in Europe since 1852.[63]

Their criticisms of the IPBES GA targeted the gaps between the number of formally described species, the number of these that have been documented as being threatened with extinction or having gone extinct, and the numbers that IPBES has used in the GA. Moore and Young were quick to use this to cast doubt about the IPBES GA and paint it as a political exercise conducted by special-interest groups (scientists and the UN). Of the three main categories of denial in what is termed the 'Scientific Certainty Argumentation Playbook',[64] their statements include both literal denials – assertions that the statement is untrue – and interpretive denials, in which accepted facts are given a different spin. Moore deliberately conflated the IUCN's *documentation* that 28,000 with IPBES's *estimate* of the complete global total, ignoring the fact that IUCN had assessed only 100,000 of the world's estimated 8.1 million animal and plant species. Young cherry-picked seemingly pertinent facts from the GA, but without understanding them, conflating threat with extinction. On Twitter, he proved unable or unwilling to engage with the approach that the IPBES GA had taken that led to the estimate, however simply one of us (@AndyPurvisNHM) broke it down for him.[65] Although responding to such denialists can be stressful – their attacks can rapidly become personal – we would argue that it is necessary to engage in debate and be transparent about methods and data as well as scientific disagreements, limitations and uncertainties.[66] These strategies of science communication will perhaps not succeed in changing the minds of the critics, but they may change other minds that may still be open, and they are vital for the trustworthiness of science. Not responding or responding without offering openness and transparency cedes the narrative to denialism.

Denialists also criticised the GA's statements about why biodiversity loss is a problem. These critics downplayed the consequences of biodiversity loss, or argued that rapid economic growth is a solution to the biodiversity crisis rather than part of the problem – a strategy known as implicatory denial.[67] The GA gave several possible answers to this question which correspond with different interpretations of biodiversity loss and different views of the relationship between people and nature. Under the view that species and

[62]https://docs.house.gov/meetings/II/II13/20190522/109519/HHRG-116-II13-Wstate-MooreP-20190522.pdf (accessed 10 March 2021).
[63]https://www.spectator.co.uk/article/this-extinction-warning-just-doesn-t-add-up (accessed 10 March 2021).
[64]Lees et al (2020).
[65]https://www.nature.com/articles/s41559-019-0922-2 (accessed 10 March 2021).
[66]Lahsen and Turnhout (2021).
[67]Lees et al (2020).

ecosystems have the right to exist, or that humanity has stewardship responsibility of the natural world, biodiversity loss – especially irreversible loss such as species extinction – is an ethical tragedy. More human-centric reasons relate to the value of species and ecosystems to people, whether this value be seen in economic terms, in cultural expression or to inspire or evoke curiosity. Even species with no current use by people may have as-yet-unknown value, whether bio-prospecting value in, for example, the development of medicines, or other option values, which might only be realised in the event of future environmental change.[68]

While these two arguments refer to an interpretation of biodiversity loss as the extinction of species, other powerful arguments in the GA focused on the loss or degradation of nature more broadly through land- and sea-use change or unsustainable management practices. These forms of biodiversity loss involve reductions in natural areas and populations of species, but they do not necessarily involve the extinction of species. Yet, they can have profound implications since they affect access to resources and livelihoods as well as the productivity of land. Making this argument required us to move from the extinction of species to the reduction of ecosystems and populations. For this reason, the scepticism behind the questions we received about whether the loss of species would result in the collapse of humanity was difficult to counter effectively: the knowledge the GA has synthesised about implications for humans did not refer directly to the core message of 1 million species that had attracted so much attention. This was also true for questions about potential solutions and policy options. In explaining these, we needed to shift attention from measures that would prevent species extinction, to measures that reduce or avoid the destruction of natural areas, degradation of managed areas, and the reduction of populations, by land use change, overexploitation of natural resources and wild species, pollution and climate change.

All in all, the focus on species, and particularly the 1 million number, in communication surrounding the GA, has been very successful in attracting attention, but its value in communicating key messages of the GA about consequences and options for action that rely on different interpretations of biodiversity and its loss has proven to be more limited. This limited success spotlights some of the communication challenges that arise from the sheer breadth of the IPBES GA. Its full scope includes three crucial and interconnected questions – (1) What is happening?; (2) What are the consequences?; and (3) What can be done? – each of which requires multiple answers that reflect diverse perspectives, definitions of biodiversity, and forms of knowledge. This inherent multiplicity of biodiversity has important implications not only for assessments and their communication, but also for how biodiversity targets and goals should be chosen.

Biodiversity goals and targets after 2020

2021 could be a pivotal year for global biodiversity. The 15th Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) is scheduled to meet in Kunming to agree the global biodiversity framework of targets and actions that will drive conservation efforts for the next decade and beyond. The precedents, however, are not auspicious. In 2002, at the 6th COP, the world's governments committed to significantly

[68]Mace et al (2014).

reduce the rate of biodiversity loss by 2010.[69] This target was missed.[70] Accepting criticisms that the single target was vague and did not follow naturally from a coherent vision,[71] the 10th COP agreed 20 separate targets for 2020 – the Aichi Targets – designed to help achieve five strategic goals: mainstreaming biodiversity within governments and society, reducing pressures on biodiversity, improving its status, enhancing the level of benefits it confers to people, and improving societal responses to the biodiversity crisis. All 20 targets were missed, as were all 5 strategic goals.[72] To avoid a third decade of underachievement, we must reflect on and learn from the past. We are in a good position to do this and can build on the work done in the IPBES GA, including an improved knowledge base and a broad recognition of the deeply enmeshed interrelationship of people and nature.

There has been a vigorous debate within the research community about the structure and content for the post-2020 framework ranging from general calls to raise the ambition level,[73] suggestions to save wilderness areas,[74] and proposals that call for action on the economic drivers of biodiversity loss.[75] Among the various proposals, Rounsevell et al focus specifically on extinction.[76] They propose that extinction rate should form the basis of a single simple but ambitious biodiversity target analogous to the 2°C climate target. Specifically, they proposed a target of no more than 20 extinctions of known species per year over the next century, across vertebrates, invertebrates, plants and fungi. They argue that such a target is easily communicated and can also be used to drive conservation. However, basing the headline target solely on species extinction is not without problems. Extinction is hard to demonstrate and calls are often incorrect. For example, of a set 187 mammalian species suspected to have been extinct, 67 were subsequently rediscovered.[77] Additionally, lags in reporting mean that extinction rate always appears to have declined over recent years.[78] Since extinction is the end point of an often lengthy downward trajectory in the geographic extent and population size of a species actions will often come too late and the target will not be very responsive to policy interventions.[79] All in all, choosing species extinction rate as the focus for a single biodiversity target therefore seems unwise.

Indeed, we would caution against identifying *any* single quantitative biodiversity metric to serve as *the* main apex target for biodiversity governance.[80] The multiple dimensions of biodiversity are not sufficiently tightly coupled together that any one can be an adequate proxy for the others.[81] For example, targeting all conservation interventions in mostly tropical 'hotspots' of biodiversity – areas combining exceptionally high concentrations of narrowly distributed species and high levels of land-use

[69]Report of the sixth meeting of the Conference of the Parties to the Convention on Biological Diversity, UNEP/CBD/COP/6/20, 27 May 2002, https://www.cbd.int/doc/meetings/cop/cop-06/official/cop-06-20-en.pdf (accessed 10 March 2021).
[70]Butchart et al (2010).
[71]E.g. Mace et al (2010).
[72]Butchart et al (2020).
[73]Mace et al (2018).
[74]Watson et al (2018).
[75]McElwee et al (2020).
[76]Rounsevell et al (2020).
[77]Fisher and Blomberg (2011).
[78]Butchart et al (2018).
[79]Balmford et al (2003).
[80]Purvis (2020).
[81]Díaz et al (2020).

change – may well provide the greatest leverage for slowing the global march of species towards extinction,[82] but it would not conserve the ecosystems of arid, temperate or high-latitude biomes, or maintain the genetic diversity within wide-ranging species that will let them adapt to a changing world. The different dimensions of biodiversity are in tension here. Suggestions that multiple dimensions should be combined into a composite numerical 'apex' target,[83] do not resolve this tension, because meeting any target would not guarantee a desired outcome.

These tensions become even clearer if we take a broader perspective on biodiversity and human-nature relations. Too narrow a focus on preventing species extinction could result in imposing one value system on a diverse world, thereby exacerbating inequity and injustice;[84] and it may contribute little to reversing the destruction of nature or the reductions of populations – forms of biodiversity loss with major implications for human well-being and quality of life. Human wellbeing requires ecosystems to continue to function worldwide, not just in biodiversity hotspots: trying to use a single target to safeguard both species and nature's contributions to people risks losing both.[85]

Considering the current draft of the Post-2020 Global Biodiversity Framework,[86] we see a mixed picture emerging. The framework has recognised the need to have a goal that focuses on traditional notions of biodiversity and another goal relates to nature's contributions to people. Also, the framework includes multiple components for each goal: the goal relating to traditional views of biodiversity, for example, has components relating to ecosystems, population sizes, threatened species and genetic diversity. Ignoring any of these facets of biodiversity is likely to preclude the CBD's 2050 vision of 'living in harmony with nature';[87] species extinction is therefore recognised as one – but not the only – key element of biodiversity loss in the framework. However, our discussion of the interrelationships among the facets of biodiversity, their linkages to nature's contributions to people, and the diverse perspectives on biodiversity and human-nature relations highlights the potential benefits of expanding the scope of actions in the Post-2020 Global Biodiversity Framework beyond these two goals of nature or species and nature's contributions to people. To adequately account for diverse worldviews and value systems about biodiversity, about what constitutes a good quality of life, and about the role of nature therein, will require a holistic and integrated perspective that considers conservation as part of a flourishing and vibrant world. Such a paradigm shift resonates with the call of the IPBES GA for transformative change. Based on such a perspective, priority actions are first of all those that deliver synergistic benefits towards multiple goals or milestones. For example, restoring high-carbon ecosystems such as forests and wetlands makes progress towards both goals; and if those ecosystems are also rich in endemic species, it makes progress towards all the components of the

[82]Myers et al (2000).
[83]See for example the recent speech by Inger Anderson at the Open Ended Working Group on the Post-2020 Global Biodiversity Framework, https://www.unenvironment.org/news-and-stories/speech/speech-open-ended-working-group-post-2020-biodiversity-framework (accessed 10 March 2021).
[84]See the recent critical comment addressed to the so-called 30 × 30 proposal promoted by among others The Campaign for Nature: https://openlettertowaldronetal.wordpress.com/ (accessed 10 March 2021).
[85]Purvis (2020).
[86]Zero draft of the Post-2020 Global Biodiversity Framework, dated 17 August 2020, https://www.cbd.int/doc/c/3064/749a/0f65ac7f9def86707f4eaefa/post2020-prep-02-01-en.pdf (accessed 10 March 2021).
[87]Díaz et al (2020).

biodiversity-focused goal.[88] But priority actions should also include those that advance equity and justice, for example by securing tenure and access rights to IPLC. The EU parliament has debated making at least some aspects of the post-2020 targets legally binding.[89] It is surely time to take seriously how the causes of biodiversity destruction are also the causes of growing global inequality, and the implication that direct action against global inequality, for example addressing excessive wealth, overproduction and overconsumption, is itself a conservation action and a possible focus for legislation.

Conclusion: biodiversity requires diversity

The concept of biodiversity was always intended to be broad and multi-faceted. This breadth probably contributed to the rapid acceptance of the term, and has enabled its scope to broaden even further to accommodate a wider diversity of knowledge systems – biodiversity really does not mean the same thing to everybody. But the same breadth now also contributes to very real challenges in communicating science to policy. The desire to capture biodiversity in single metrics – especially metrics focusing on species and extinction – is understandable because such metrics can be used in simple messages which are considered attractive, as with the Paris Agreement's 1.5°C target. We have also seen this trend within the GA. But we have also experienced the risks that messages based on simple metrics can provoke distracting critical scrutiny, and can even overshadow other, arguably more important messages for policy and action.

What this means is that biodiversity requires diversity;[90] what is needed is a diversity of metrics and definitions that reflect diverse worldviews and values systems, and that translate into targets and options for action that are legitimate and actionable for diverse actors in policy, businesses, and society. Species are without doubt an indispensable aspect of biodiversity that appeals to science, policy and society, and the extinction of species raises important ethical questions that must be addressed in conservation policy. However, a narrow focus on species and extinction as a proxy to represent biodiversity and a focus for biodiversity targets is bound to fail for reasons of legitimacy as well as effectiveness. The challenge for the post-2020 CBD framework is to propose an integrated road map for action that embraces this diversity and communicates it in a sufficiently compelling way. This road map will have to include a mix of short-term actions and long-term strategies to change structures and paradigms, working together to catalyse the transformative change that is needed to ensure human and ecological well-being.

Acknowledgements

Working on the IPBES Global Assessment changed how we think about many of the issues discussed in this paper, and we are grateful to everyone involved for their collaboration and for broadening our knowledge and perspectives. We are also grateful to Afshin Akhtar-Khavari, Katie Woolaston and Michelle Lim for organising the workshop 'Environmental Law's Extinction Problem' (3–4 December 2020, Faculty of Law, Queensland University of Technology and

[88] Díaz et al (2020).
[89] See https://www.europarl.europa.eu/news/en/press-room/20191203IPR67906/biodiversity-meps-call-for-legally-binding-targets-as-for-climate-change (accessed 10 March 2021) and https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/ENVI/RE/2019/12-02/1189143EN.pdf (accessed 10 March 2021).
[90] Turnhout et al (2013); Turnhout et al (2014).

Macquarie Law School) where a first draft of this paper was presented and for editing the special issue of which this paper is part.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

AP received support from the Prince Albert II of Monaco Foundation (Plants Under Pressure 2) and the Natural Environment Research Council (award number NE/M014533/1).

Notes on contributors

Esther Turnhout (PhD) is a professor and an interdisciplinary social scientist and holds a personal chair in 'The politics of environmental knowledge' at Wageningen University. Her research and teaching focuses on biodiversity governance and the conservation and sustainable use of nature at global to local scales and on the relation between science, other knowledge systems, and environmental policy and management practices. She has published numerous articles on the biodiversity science-policy interface and other topics in high impact journals and she is also the first author of the book *Environmental Expertise: Connecting Science, Policy and Society* with Cambridge University Press. She has played active roles in the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) and was an author of the IPBES Global Assessment of biodiversity and ecosystem services.

Andy Purvis (PhD) is a Research Leader and Individual Merit Researcher at the Natural History Museum in London, and was previously Professor of Biodiversity at Imperial College London. His research largely involves statistical modelling of specially compiled large data sets to answer a wide range of questions in biodiversity science, from macroevolution to conservation. He heads the PREDICTS project (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems), which aims to model globally how local terrestrial biodiversity responds to human pressures and to use these models to project potential biodiversity futures under alternative scenarios of socioeconomic development. He was a Coordinating Lead Author on the first IPBES Global Assessment of biodiversity and ecosystem services.

ORCID

Esther Turnhout http://orcid.org/0000-0002-2190-2076
Andy Purvis http://orcid.org/0000-0002-8609-6204

References

Joseph Alcamo (2017) 'Evaluating the Impacts of Global Environmental Assessments' 77 *Environmental Science and Policy* 268.

Andrew Balmford et al (2003) 'Measuring the Changing State of Nature' 18 *Trends in Ecology & Evolution* 326.

Gonzalo MA Bermudez and Petra Lindemann-Matthies (2020) '"What Matters Is Species Richness"—High School Students' Understanding of the Components of Biodiversity' 50 *Research in Science Education* 2159.

Heather C Bingham et al (2017) 'The Biodiversity Informatics Landscape: Elements, Connections and Opportunities' 3 *Research Ideas and Outcomes* e14059.

Geoffrey C Bowker (2000) 'Biodiversity Datadiversity' 30 *Social Studies of Science* 643.

Stuart HM Butchart et al (2018) 'Which Bird Species have gone Extinct? A Novel Quantitative Classification Approach' 227 *Biological Conservation* 9.

Stuart HM Butchart et al (2020) *Assessing Progress Towards Meeting Major International Objectives Related to Nature and Nature's Contributions to People, Chapter 3 of the IPBES Global Assessment of Biodiversity and Ecosystem Services*, Intergovernmental Platform on Ecosystem Services, IPBES.

Stuart HM Butchart et al (2010) 'Global Biodiversity: Indicators of Recent Declines' 328 *Science* 1164.

Marc W Cadotte, Kelly Carscadden and Nicholas Mirotchnick (2011) 'Beyond Species: Functional Diversity and the Maintenance of Ecological Processes and Services' 48 *Journal of Applied Ecology* 1079.

M Julian Caley, Rebecca Fisher and Kerrie Mengersen (2014) 'Global Species Richness Estimates Have Not Converged' 29 *Trends in Ecology & Evolution* 187.

Bradley J Cardinale et al (2012) 'Biodiversity Loss and Its Impact on Humanity' 486 *Nature* 59.

Charles Darwin (1859) *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, John Murray.

Kristy Deiner et al (2017) 'Environmental DNA Metabarcoding: Transforming How We Survey Animal and Plant Communities' 26 *Molecular Ecology* 5872.

Isabel Díaz-Reviriego, Esther Turnhout and Silke Beck (2019) 'Participation and Inclusiveness in the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services' 2 *Nature Sustainability* 457.

Sandra Díaz et al (2013) 'Functional Traits, the Phylogeny of Function, and Ecosystem Service Vulnerability' 3 *Ecology and Evolution* 2958.

Sandra Díaz et al (2018) 'Assessing Nature's Contributions to People' 359 *Science* 270.

Sandra Díaz et al (2020) 'Set Ambitious Goals for Biodiversity and Sustainability' 370 *Science* 411.

Eric Dinerstein et al (2020) 'A "Global Safety Net" to Reverse Biodiversity Loss and Stabilize Earth's Climate' 6 *Science Advances* eabb2824.

Maria Dornelas et al (2014) 'Assemblage Time Series Reveal Biodiversity Change but Not Systematic Loss' 344 *Science* 296.

Brian J Enquist (2019) 'The Commonness of Rarity: Global and Future Distribution of Rarity Across Land Plants' 5 *Science Advances* eaaz0414.

Lee Failing and Robin Gregory (2003) 'Ten Common Mistakes in Designing Biodiversity Indicators for Forest Policy' 68 *Journal of Environmental Management* 121.

Diana O Fisher and Simon P Blomberg (2011) 'Correlates of Rediscovery and the Detectability of Extinction in Mammals' 278 *Proceedings of the Royal Society B: Biological Sciences* 1090.

Franklin Ginn, Uli Beisel and Maan Barua (2014) 'Flourishing with Awkward Creatures: Togetherness, Vulnerability, Killing' 4 *Environmental Humanities* 113.

Steve Hinchliffe (2008) 'Reconstituting Nature Conservation: Towards a Careful Political Ecology' 39 *Geoforum* 88.

David U Hooper et al (2012) 'A Global Synthesis Reveals Biodiversity Loss as a Major Driver of Ecosystem Change' 486 *Nature* 105.

Aelys M Humphreys et al (2019) 'Global Dataset Shows Geography and Life Form Predict Modern Plant Extinction and Rediscovery' 3 *Nature Ecology & Evolution* 1043.

IPBES (2019) *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services*, Intergovernmental Panel on Biodiversity and Ecosystem Services.

Nick JB Isaac, James Mallet and Georgina M Mace (2004) 'Taxonomic Inflation: Its Influence on Macroecology and Conservation' 19 *Trends in Ecology & Evolution* 464.

Forest Isbell et al (2017) 'Linking the Influence and Dependence of People on Biodiversity Across Scales' 546 *Nature* 65.

Myanna Lahsen and Esther Turnhout (2021) 'How Norms, Needs, and Power in Science Obstruct Transformations Towards Sustainability' 16 *Environmental Research Letters* 025008.

John H Lawton et al (1998) 'Biodiversity Inventories, Indicator Taxa and Effects of Habitat Modification in Tropical Forest' 391 *Nature* 72.

Alexander C Lees et al (2020) 'Biodiversity Scientists Must Fight the Creeping Rise of Extinction Denial' 4 *Nature Ecology & Evolution* 1440.

Daijiang Li et al (2020) 'Changes in Taxonomic and Phylogenetic Diversity in the Anthropocene' 287 *Proceedings of the Royal Society B: Biological Sciences* 20200777.
Petra Lindemann-Matthies and Elisabeth Bose (2008) 'How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland' 36 *Human Ecology* 731.
Michel Loreau et al (2006) 'Diversity Without Representation' 442 *Nature* 245.
Georgina M Mace et al (2018) 'Aiming Higher to Bend the Curve of Biodiversity lOss' 1 *Nature Sustainability* 448.
Georgina M Mace et al (2010) 'Biodiversity Targets After 2010' 2 *Current Opinion in Environmental Sustainability* 3.
Georgina M Mace et al (2014) 'Approaches to Defining a Planetary Boundary for Biodiversity' 28 *Global Environmental Change* 289.
Fernanda Ayavira Matuk et al (2020) 'Including Diverse Knowledges and Worldviews in Environmental Assessment and Planning: The Brazilian Amazon Kaxinawá Nova Olinda Indigenous Land Case' 16 *Ecosystems and People* 95.
Richard L Mayden (1997) 'A Hierarchy of Species Concepts: The Denouement in the Saga of the Species Problem' in MF Claridge, HA Dawah and MR Wilson (eds) *Species: The Units of Diversity*, Chapman & Hall.
Pamela McElwee et al (2020) 'Ensuring a Post-COVID Economic Agenda Tackles Global Biodiversity Loss' 3 *One Earth* 448.
Ronald B Mitchell, William C Clark, David W Cash and Nancy M Dickson (2006) *Global Environmental Assessments: Information and Influence*, MIT Press.
Roldan Muradian et al (2013) 'Payments for Ecosystem Services and the Fatal Attraction of Win-Win Solutions' 6 *Conservation Letters* 274.
Norman Myers et al (2000) 'Biodiversity Hotspots for Conservation Priorities' 403 *Nature* 853.
Shahid Naeem et al (2016) 'Biodiversity as a Multidimensional Construct: A Review, Framework and Case Study of Herbivory's Impact on Plant Biodiversity' 283 *Proceedings of the Royal Society B: Biological Sciences* 20153005.
Ken Norris (2012) 'Biodiversity in the Context of Ecosystem Services: The Applied Need for Systems Approaches' 367 *Philosophical Transactions of the Royal Society B: Biological Sciences* 191.
Reed F Noss (1990) 'Indicators for Monitoring Biodiversity: A Hierarchical Approach' 4 *Conservation Biology* 355.
Unai Pascual et al (2021) 'Biodiversity and the Challenge of Pluralism' *Nature Sustainability* doi:10.1038/s41893-021-00694-7.
HM Pereira et al (2013) 'Essential Biodiversity Variables' 339 *Science* 277.
Nathalie Pettorelli, Kamran Safi and Woody Turner (2014) 'Satellite Remote Sensing, Biodiversity Research and Conservation of the Future' 369 *Philosophical Transactions of the Royal Society B: Biological Sciences* 20130190.
Gary D Powney et al (2010) 'Hot, Dry and Different: Australian Lizard Richness Is Unlike That of Mammals, Amphibians and Birds' 19 *Global Ecology and Biogeography* 386.
JR Prendergast et al (1993) 'Rare Species, the Coincidence of Diversity Hotspots and Conservation Strategies' 365 *Nature* 335.
Drew Purves et al (2013) 'Time to Model All Life on Earth' 493 *Nature* 295.
Andy Purvis et al (2020) *Status & Trends – Nature, Chapter 2.2 of the IPBES Global Assessment of Biodiversity and Ecosystem Services*, Intergovernmental Panel on Biodiversity and Ecosystem Services, IPBES.
Andy Purvis (2020) 'A Single Apex Target for Biodiversity Would Be Bad News for Both Nature and People' 4 *Nature Ecology & Evolution* 768.
Andy Purvis and Andy Hector (2000) 'Getting the Measure of Biodiversity' 405 *Nature* 212.
Kent H Redford and William M Adams (2009) 'Payment for Ecosystem Services and the Challenge of Saving Nature' 23 *Conservation Biology* 785.
Deborah Bird Rose, Thom van Dooren and Matthew Chrulew (2017) 'Introduction: Telling Extinction Stories' in DB Rose, T van Dooren and M Chrulew (eds) *Extinction Studies: Stories of Time, Death and Generations*, Columbia University Press.

Mark DA Rounsevell et al (2020) 'A Biodiversity Target based on Species Extinction' 368 *Science* 1193.

Royal Society (2003) *Measuring Biodiversity for Conservation*, The Royal Society, Policy Document 11/03, ISBN 0 85403 593 1.

Luca Santini et al (2017) 'Assessing the Suitability of Diversity Metrics to Detect Biodiversity Change' 213 *Biological Conservation* 341.

Daniel Sarewitz (2016) 'Saving Science' 49 *The New Atlantis, Spring* 4.

Sarah Schomers and Bettina Matzdorf (2013) 'Payments for Ecosystem Services: A Review and Comparison of Developing and Industrialized Countries' 6 *Ecosystem Services* 16.

Will Steffen et al (2015) 'Planetary Boundaries: Guiding Human Development on a Changing Planet' 347 *Science* 1259855.

Erik Stokstad (2019) 'Landmark Analysis Documents the Alarming Global Decline of Nature' 371 *Science* doi:10.1126/science.aax9287.

Brian L Sullivan et al (2014) 'The eBird Enterprise: An Integrated Approach to Development and Application of Citizen Science' 169 *Biological Conservation* 31.

David Takacs (1996) *The Idea of Biodiversity, Philosophies of Paradise*, The Johns Hopkins University Press.

Jeff Tollefson (2019) 'Humans Are Driving One Million Species to Extinction' 569 *Nature* 171.

Julien Troudet et al (2017) 'Taxonomic Bias in Biodiversity Data and Societal Preferences' 7 *Scientific Reports* 9132.

Esther Turnhout (2018) 'The Politics of Environmental Knowledge' 16 *Conservation and Society* 363.

Esther Turnhout et al (2012) 'Conservation Policy: Listen to the Voices of Experience' 488 *Nature* 454.

Esther Turnhout and Susan Boonman-Berson (2011) 'Databases, Scaling Practices, and the Globalization of Biodiversity' 16 *Ecology and Society* 35.

Esther Turnhout, Katja Neves and Elisa De Lijster (2014) '"Measurementality" in Biodiversity Governance: Knowledge, Transparency, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)' 46 *Environment and Planning A* 581.

Esther Turnhout, Willemijn Tuinstra and Willem Halffman (2019) *Environmental Expertise: Connecting Science, Policy and Society*, Cambridge University Press.

Esther Turnhout et al (2013) 'Rethinking Biodiversity: From Goods and Services to "Living With."' 6 *Conservation Letters* 154.

James EM Watson et al (2018) 'Protect the Last of The wild' 563 *Nature* 27.

Kathryn Yusoff (2012) 'Aesthetics of Loss: Biodiversity, Banal Violence and Biotic Subjects' 37 *Transactions of the Institute of British Geographers* 578.