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Article *in* Trends in Ecology & Evolution · November 2017

DOI: 10.1016/j.tree.2017.10.004

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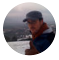

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Planetary Boundaries for Biodiversity: Implausible Science, Pernicious Policies

José M. Montoya,[1,*] Ian Donohue,[2] and Stuart L. Pimm[3]

The notion of a 'safe operating space for biodiversity' is vague and encourages harmful policies. Attempts to fix it strip it of all meaningful content. Ecology is rapidly gaining insights into the connections between biodiversity and ecosystem stability. We have no option but to understand ecological complexity and act accordingly.

How Should We Manage Human Actions That Harm Biodiversity?

Human actions obviously harm the natural world and, as we reduce the populations of species and drive some to extinction, we change ecosystems. How best should environmental science articulate its concerns, set research agendas, and advise policies? One solution embraces the notion of planetary boundaries [1] arguing that global environmental processes very generally have 'tipping points'. These are catastrophes involving thresholds beyond which there will be rapid transitions to new states that are very much less favorable to human existence than current states. The associated notion is that humanity's 'business as usual' can only continue so long as it remains within some 'safe operating space'[i,ii].

The rate of human-caused extinctions – now ∼100–1000-fold the natural background rate [2] – is one of two of the nine global processes deemed to have exceeded a purported tipping point of 10-fold background. Despite widespread criticisms, the tipping-point claim persists, with recent reproduction of the original claim [1] and statements[ii] that the threshold is 'not arbitrary', emerges from 'massive amounts of data' from many fields, and that 'no one is saying that the idea is wrong', despite 'massive breakthroughs in counting extinctions'. As we explain in Box 1, none of these statements are justified.

Drawing attention to global environmental issues is certainly essential, therefore what harm is there in another approach, superficially attractive, even if it has limitations? We show that notions of planetary boundaries add no insight into our understanding of the threats to biodiversity and ecosystem functioning, have no evidence to support them, are too vague for use by those who manage biodiversity, and promote pernicious policies. Attempts to fix these problems strip the original idea of all meaningful content, but still plead for the notion of a safe operating space. Why is this deeply flawed idea so seductive, and what problems arise from its embrace?

To address concerns that extinction rates are an inappropriate metric, the biodiversity boundary is renamed as 'biosphere integrity' [3]. Two static measures of biodiversity replace rates: phylogenetic variability and functional diversity. Problems of definition apart, reliable estimates for anything resembling these are impossible to obtain at regional to global scales.

Confronted with the inappropriateness of their measures, we are urged to keep using 'in the interim' extinction rates – already shown to be flawed – and a 'biodiversity intactness index' [3]. The latter is the average abundance of a broad range of species relative to their abundance in an undisturbed habitat. The boundary is set at >90%, assessed geographically across biomes or other large areas. This proliferation of indices adds no useful insight. Even if we were able to estimate the necessary numbers, their limits are arbitrary.

Finally, the purported threshold occurs for the response variable of 'biosphere functioning'. Neither theory nor empirical data support any threshold of biodiversity below which ecosystem function is

Box 1. Why Tipping Points for Biodiversity Are Fatally Flawed

The critical global extinction rate is operationally undefined: when the heart of the last individual of a species stops beating, global extinction rate spikes momentarily. Why should this lead to planetary collapse? Suppose we define the rate ourselves – for example in terms of extinctions per million species [2] averaged per year or decade. Following the discovery of the Hawaiian Islands by the Polynesians 1500 years ago, they eliminated so many species that even the decadal global extinction rate would have been exceptional. However, why would these extinctions of island endemics cause a collapse that putatively is both global and only now visible? There would certainly be local consequences of species loss, but why a precipitous local collapse in ecosystems and why would it be global in extent? Furthermore, how might the rate of loss (versus its size) be responsible?

Certainly, there are regional physical processes for which empirical data suggests thresholds. Globally their existence is far from certain; they do not exist within the terrestrial biosphere in isolation [12]. Models of single populations and local communities can show thresholds, but these neither deal with extinction rates nor global processes.

Indeed, in publications [3], though not in presentations[ii], planetary boundary arguments have moved away from catastrophes, first to rapid transitions, where small changes lead to large effects, then to more gradual ones. The concession is 'not all Earth system processes included in the planetary boundary have singular thresholds at the global/continental/ocean basin level' [3]. Exactly so. This statement admits their arbitrary nature. If anything can happen, then there is no insight gained: gradual change is embraced by entirely arbitrary and indefinable values where the 'safe operating space' is transgressed.

compromised [4]. Defining a safe operating space for ecosystem function makes even less sense as the spatial scale and the number of functions analyzed increases [5].

If Not Global Processes, Then Local Ones?

'Nevertheless', continue the arguments, 'it is important that boundaries be established for these processes'. Why? Perhaps, although the planetary boundary framework might add no insights into what we know about global human impacts, then its practical utility to environmental managers might justify it. Fatally, the boundaries framework lacks clear definitions, or it has too many conflicting definitions, does not specify units, and fails to define terms operationally, thus prohibiting application by those who set policy or manage natural resources. Moreover, recent reviews indicate that tipping points occur only rarely in natural systems [6], while policies related to boundaries are unlikely to be evidence-based. A need for operational definitions to aid managers is self-evident [7].

At regional and local scales, managers and conservation bodies are starting to abandon the boundaries framework. Many claim that the adoption of boundaries and associated tipping points as a policy goal risks biodiversity conservation. In the case of European forests, it promoted interventions that harmed biodiversity [8]. Planting of 'resilient tree species' – to climate change, pests, and disease – and silviculture practices to promote such resilience – primarily thinning to encourage growth and to increase carbon storage – was recommended to avoid reaching a tipping point in forest service provisioning, primarily timber production. These recommendations run counter to biodiversity conservation guidelines. They endanger old-growth forests, veteran trees, and relatively low-productivity native woody species and the many species that depend on them.

Irrespective of spatial scale, the boundaries framework is ill-founded, inoperable, and can have unexpected detrimental effects on ecosystems.

The Dangers of a Flawed Worldview

In an informative example, Rockström[i] reinforces his initial claims arguing that the collapse of the Newfoundland cod fishery in 1989 represents 'a very precise tipping point' of human actions transgressing global planetary boundaries. Human actions were apparently within bounds before 1989. The year 1989 was apparently 'the boundary between the Holocene and Anthropocene' – a notion we find particularly specious. The facts are entirely prosaic: cod landings averaged about 300 000 tons from the late 1880s until the late 1950s, spiked at over threefold higher in the 1960s, and the stock declined precipitously thereafter [9].

First, there is an acute moral hazard. Because there is no operational definition of 'safe operating space', this not only encourages arguments that 'growth within limits'[i] is acceptable but also the belief that human actions were once environmentally either benign or allowed recovery. Worse still, if the planet is not obviously collapsing around us, then surely we can continue to deplete it.

Second, if we suggest that a catastrophe has taken place and the consequences are not evident, then how will managers and policy makers trust the science we do? When bad science informs policies, its future credibility is compromised.

Third, the planetary boundary framework suggests that we can view nature and its complex ecological processes as a type of black box – if we do not poke it too hard, we will not need to understand its details. We need not define measures, terms, processes, responses in operational ways. In short, ecological ignorance is bliss, if human actions remain within limits.

Reality is different. Nothing changed globally in 1989, and this local experience has many precedents elsewhere, before and after. This cod collapse was unfortunate, but overfishing is global, as appreciated since the 18th century, and the term was first used (for cod) in 1855. Humans overfished, overharvested, overgrazed, deforested, polluted, and caused many other environmental ills long before 1989 and in many other places. They have exterminated substantial numbers of species globally, and especially top predators, across vast swaths of land and sea, and have done so for tens of thousands of years.

Ways Forward

How then can environmental science sensibly inform those who manage and set policies for the complexity that is nature? Elsewhere, we review 42 large organizations devoted to global environment management and their various aspirational targets [7]. We applaud the Convention on Biological Diversity (CBD) and others when they define rigorous and operational targets. Good examples are 17% of land area and 10% of the ocean protected (CBD Aichi target 11), with the areas being 'ecologically representative and well-connected', 'avoiding overfishing' (target 6), and preventing 'the extinction of known threatened species' (target 12). Environmental scientists must seek ways to engage policymakers to frame all their other aspirations similarly, because some are not so clearly defined.

At the heart of the problem are terms such as 'planetary boundaries', but also 'sustainability', 'health', 'harmony', and others, that are emotionally appealing but rarely, if ever, defined. They all speak to the urgent need to understand how human impacts change ecosystems, when at best we aspire to protect only half of it. We must set policies and establish management for the vast tracts of land and sea that we do not protect. Fatally, those who do so often use language that does not borrow from the existing knowledge about ecosystem processes, nor readily translates its aspirations to those who study them [7].

Fortunately, mounting evidence demonstrates the patterns and mechanisms by which biodiversity loss alters the provision of functions and the stability of ecosystems. We can now assess and monitor how losses in biodiversity affect different ecosystems. This in turn allows the effectiveness of a given environmental policy to be determined. The focus must be on appropriate scales and variables that we can measure operationally. It must recognize and define the multiplicity of human actions and their consequences. We must create mutual translations of the terms used by empirical ecologists, theoreticians, policymakers, and managers to describe them [7]. This way forward is shared by researchers within different disciplines: from those interested in the dynamics of socioecological systems [10] to those centered on biodiversity conservation [8].

We know many useful things about these issues, and theory and empirical studies mutually reinforce each other. We suggest a way forward: to address how biodiversity loss affects the different facets of ecosystem change [7] – resilience (how fast systems recover), resistance (how much they change), variability (how much they fluctuate over time), and persistence (how long they persist). These measures of change are well-defined, have units, can be monitored over time, and can inform management. They tie to pressing practical problems.

We provide some examples where ecosystem change is gradual but is inextricably tied to biodiversity loss. First, what pollinators can we not afford to lose? Regional declines in native wild pollinators compromise the quality and quantity of food crops that depend on pollination. Second, how well do species abundances resist harvesting or removal of top-predators – as we have done over much of the land and the oceans? How can we ensure that fisheries and other exploited resources provide reliable yields against a natural background of year-to-year variability, given economic drivers that require a minimum annual return and discount the future value of the stock? Third, how can the functioning of ecosystems and their associated services to humans persist in the face of climate change, particularly when local extinctions reduce the resistance of ecosystem productivity to climate extremes [11]?

Good policy means we have no option but to understand the necessary complexity of nature in the environments we are starting to unravel. However, acknowledging such complexities is not enough. We need the particulars – the aspects of ecosystem change that we aim to minimize. Which species are vital to which processes, and how these connect to human social and economic systems. We must understand how economic losses depend on the species involved and the ecological communities in which they are embedded. We must also understand that the loss of any species is a loss of cultural values and poses significant moral issues.

There are limits to growth. When we harm nature, environmental changes sometimes kick in immediately and in inevitably complex ways that deny the simple and seductive notion that, within some limited space, whatever the stresses we inflict on nature it will be OK. We have no option but to understand that complexity, make it operational, and act accordingly.

Acknowledgments

J.M.M. was supported by the French Laboratory of Excellence Project 'TULIP' (ANR-10-LABX-41; ANR-11-IDEX-002-02).

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https://doi.org/10.1016/j.tree.2017.10.004

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