CHAPTER 8

What is the evidence for planetary tipping points?

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As living standards, technological capacities, and human welfare have continued to improve, concerns have mounted about possible natural limits to economic and population growth. Climate change, habitat loss, and recent extinctions are examples of impacts on natural systems that have been used as markers of global environmental degradation associated with the expanding influence of humans (Barnosky et al., 2012; McGill et al., 2015). Past civilizations have faced rapid declines and even collapsed in the face of regional environmental degradation, drought, and other environmental challenges (Scheffer, 2016; Butzer and Endfield, 2012). This begs the question of whether long-term societal relationships with the planet's ecology may be approaching a global tipping point as the human population hurtles toward ten billion people. If this is indeed the case, the future of both biodiversity and humanity hangs in the balance. The hypothesis is that without urgent action to prevent reaching a global tipping point, the natural life support systems that sustain humanity may fail abruptly, with drastic consequences.

8.1 Regional tipping points yes—but what about global tipping points?

There is strong evidence for rapid global shifts in the biosphere in the distant past, sometimes taking the form of mass extinction events, which have been linked to biophysical tipping points (Hughes et al., 2013). Tipping points occur when components of a system respond gradually to an external forcing to a point at which the response becomes nonlinear and abrupt. This response is often amplified through positive feedback interactions that induce an eventual state (or regime) shift (Lenton, 2013). Tipping points are well documented in studies of local ecosystems, such as lakes, that undergo regime shifts driven by alterations of energy or nutrient flows when thresholds are crossed and hysteresis prevails (Scheffer et al., 2015). Various tipping elements, some definite and others speculative, have also been noted in the Earth's climate system (Lenton et al., 2008).

Given this context, it would seem logical and indeed intuitive to conclude that the Earth system is susceptible and sensitive to planetary regime shifts caused by human alteration of Earth's ecology. James Lovelock's original Earth-system conception of "Gaia," for instance, focused on interconnections and positive feedbacks between the geosphere and the biosphere, which act to promote stability and resilience (Lovelock and Margulis, 1974). But within this same framework, a temporary global forcing event, invoking disconnections and positive feedbacks, could lead to a rapid transition to an alternative stable state, as has been observed in many local systems (Kefi et al., 2016). This conceptual model invites the question of whether identifiable "boundaries" exist within the interacting components of the Earth system. If they do—and they are transgressed—then the planetary biosphere might be dramatically and permanently altered (Brook et al., 2013).

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8.2 Planetary boundaries as a seductive policy framework

The planetary boundaries concept, coined less than a decade ago (Rockström et al., 2009), represents the idea that contemporary societies have potentially transgressed the historical "natural" conditions—the "safe operating space"—under which human societies have historically thrived. However, to mark the boundaries of a planetary safe "reference state," defined baselines are required. One possibility that has been suggested is the climatic conditions that marked the last 10 000 years of our current warm interglacial period, the Holocene, in which agricultural and urban societies first arose, should be used as a safe space (Steffen et al., 2015). Other safe spaces (or conversely boundaries) might be similarly recognized. In total, nine planetary boundaries have been hypothesized in association with Earth-system processes that, if sufficiently distorted, might potentially cause harmful changes in Earth's functioning as a wholistic system (Table 8.1). This perspective has led some to postulate the potential breaching of critical thresholds, pushing the Earth out of the Holocene and consequently inducing a shift in the stability of the system (Barnosky et al., 2012). To quote: "*Crossing these boundaries could generate abrupt or irreversible environmental changes*." (stockholmresilience.org/research/planetary-boundaries.html).

Table 8.1 Summary of the nine planetary boundaries originally proposed in Rockström et al. (2009; the nitrogen and phosphorus cycles were taken together as flows to the biosphere and oceans). The final two additional boundaries in the list were subsequently suggested in the literature. Shown are the pre-industrial (where estimable) and current status of the process relative to the proposed boundary. The units are highlighted in the descriptions of each parameter. The final column is our assessment of the plausibility of the mechanisms and evidence for a well-defined global boundary and an associated tipping point.

Earth system process	Scale of process	Parameters	Proposed boundary	Current status	Pre-industrial value	Plausible global-scale threshold?
Land-use change	Local and regional	Global land cover converted to cropland (percentage)	15	11.7	low	No: no obvious mechanism, no evidence for global boundary
Rate of biodiversity loss	Local and regional	Extinction rate (number of species per million species per year)	10	>100	0.1–1	No: no mechanism, limited evidence except at local scales
Nitrogen cycle	Local and regional	Amount of N_2 removed from the atmosphere for human use (millions of tons per year)	35	121	0	No: no mechanism, no evidence, resource not limiting
Phosphorus cycle	Possibly global	Quantity of P flowing into the oceans (millions of tons per year)	11	8.5–9.5	−1	Speculative: possible mechanism, no evidence of boundary
Global freshwater use	Local and regional	Consumption of freshwater by humans (cubic km per year)	4000	2600	415	No: no mechanism or evidence
Ocean acidification	Global	Global mean saturation state of aragonite in surface sea water (product of the concentrations of reacting ions)	2.75	2.9	3.44	Yes: mechanism and evidence demonstrated experimentally
Climate change	Global	(i) Atmospheric carbon dioxide concentration (parts per million by volume) (ii) Change in radiative forcing (watts per meter squared)	3501	3871.5	2800	Yes: multiple mechanisms, supported by evidence of past climatic shifts, and models
Stratospheric ozone depletion	Global	Concentration of ozone (Dobson unit)	276	283	290	Partly: demonstrated mechanism for depletion, evidence for damage
Atmospheric aerosol loading	Regional	Overall particulate concentration in the atmosphere, on a regional basis		To be determined		Speculative: probable climate effects, likely reversibility

(continued)

Table 8.1 (Continued)

Earth system process	Scale of process	Parameters	Proposed boundary	Current status	Pre-industrial value	Plausible global-scale threshold?
Chemical pollution	Local and regional	e.g., amount emitted or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals, and nuclear waste in the global environment		To be determined		No: possible case-specific mechanism, no evidence for boundaries/thresholds
Terrestrial net primary production	Global	Annual net global primary production (NPP) of terrestrial plants co-opted for human use (percentage)	47	38	low	Partly: possible mechanism, remotely-sensed evidence (proposed in Running, 2012)
Biodiversity intactness	Local and regional	Average abundance of native species across a broad range of taxa, relative to abundance in an undisturbed habitat (percentage)	90	84.6	100	No: no mechanism, no evidence (proposed in Newbold et al., 2016)

A hope often expressed is that flagging the crossing of these boundaries as a significant risk will provoke decision makers and the public into taking actions to mitigate harmful global changes (McAlpine et al., 2015). Such a framework, of global tipping points counterbalanced by secure safe spaces within planetary boundaries, is conceptually elegant and politically seductive. Notably, this *implies* two possible conditions—a state in which environmental change is without risk, and another in which risk is clear and action necessary. Such a framework is both constraining and liberating, and clearly defines a safe zone in which human societies may go about their activities without risk. As a consequence, if such clear knowledge on the risks of altering global environmental processes existed, a defined set of boundaries could be extremely useful to decision makers. But is there evidence of global tipping-point dynamics with safe space and global risk clearly demarcated?

8.3 The search for mechanisms and evidence in support of the nine planetary boundaries

Since its original publication, the planetary boundaries framework, including the related concepts of a "safe operating space" and global regime shifts, have become increasingly prevalent in scientific and policy discussions concerned with global change (Corlett, 2015). This work has been heavily cited, updated, and actively promoted as a policy tool. But there has also been a counter-vailing critique that challenges the universality, utility, and even the underlying validity of the planetary boundaries framework (Brook and Blomqvist, 2016; Lenton and Williams, 2013). The underlying bases for this debate stem from disagreements over technical and scientific issues, including questions of scale, scientific underpinning, deterministic "boundary setting," and the generality of mechanisms proposed.

Most of the nine processes and systems listed in Table 8.1 lack theoretical mechanisms or evidence for a causal connection from local perturbations to global "boundary crossing" (Brook et al., 2013). The exceptions are the atmospheric and oceanic systems, which seem to most closely fit the characteristics required for a globally "scaled-up" version of the coupled, non-linear dynamics that have been shown to undergo phase shifts. But for others, like global land use or worldwide biodiversity, it is difficult to conceive how aggregated local-to-regional measures are representative of a coherent planetary system that is prone to tipping (Mace et al., 2014). Moreover, anthropogenic pressures vary geographically, and the system responses to stressors can be highly heterogeneous (Reyer et al., 2015). While global tipping points have been hypothesized, their exact "position" has not been determined. If the boundaries did exist at a global level, there is a good chance they could not be known until well after the regime shift or boundary crossing had occurred. This is because of our lack of our understanding of complex systems and the wild fluctuations in state variables that have occurred historically and continue to occur, without any evidence of an irreversible global collapse. Finally, implementing policies that avoid crossing planetary boundaries is a "global commons" problem, and everything we know from climate action indicates that it is difficult to generate agreements that address such risk when there is uncertainty about thresholds (Barrett and Dannenberg, 2012).

8.4 The problem with going from local process to a global tipping point

For at least six of the nine proposed boundaries, the operational scales of these "Earth system processes" are local or regional (Table 8.1), yet the proposed boundaries represent global aggregations (the sum of many component sub-systems). The value assigned to any particular boundary is, in virtually all cases, speculative and represents an arbitrary point along a continuum of possible values, as opposed to a phase shift due to global non-linear dynamics. The most plausible threshold is for ocean acidification, because it is directly related to the calcite and aragonite compensation depth (i.e., something that is inherently quantifiable). The others are purely supported by a statement to the effect that "this stress or change from the baseline is deemed excessive." This lack of scientific underpinning for these boundaries raises significant questions on the biological and physical relevance of such thresholds for the Earth system. What is currently needed are explicit efforts to link long-term monitoring to the choice of these boundary values (Robert et al., 2013). Unquestioning acceptance of these boundaries that in turn guide subsequent global assessment (as in Newbold et al., 2016) will only inhibit our understanding of human impacts.

In addition to masking finer-grained detail, globally averaged or aggregated metrics are also often difficult to link to directed action. For instance, the recent Paris Agreement to limit average global temperature rise to less than 2 °C above pre-industrial levels was ultimately re-framed as a plethora of national goals or aspirations based on carbon-emissions intensity (Rogelj et al., 2016). This is partly because a "global temperature," averaged across all the Earth system, is not a real physical phenomenon or quantity observed in any place. As such, it cannot be used to guide or monitor local system states. What can be monitored and altered are the trajectories of the underlying drivers of system changes (e.g., carbon emissions intensity, in the climate case), and these therefore ought to be the domain of targets.

Even if one can identify and measure a global environmental attribute, it does not automatically follow that it is associated with a real-world threshold that, when crossed, leads to irreversible change. Asserting "safe" global limits on indicators like land-use change (the boundary of a maximum of 15% of land given over to cultivation, see Table 8.1) or decline in the local species abundance of originally present species (e.g., "10% loss relative to undisturbed habitat" as is the case in Newbold et al., 2016) is totally arbitrary. Such thinking ignores inherent complexity and promotes a "one size fits all" mode of thinking for conservation management that elides the very real need for locally appropriate solutions. Trying to avoid crossing a global land-use or biodiversity boundary might also lead to perverse outcomes locally, such as if restoring a "safe level" of biodiversity intactness in the world's most fertile and productive regions (where most food originates) triggers undesirable trade-offs such as the displacement of farming to marginal regions that require more land, greater inputs, and hardship.

In the context of food production, Running (2012) recently argued that at most an additional 10% of harvestable annual net global primary production (NPP) of terrestrial plants could be co-opted for future human use without crossing out of the planetary safe space. The implications of this assertion are draconian. Global NPP has been essentially steady, even with the massive agricultural expansion that has occurred over the last century. Thus, because the allocation of NPP is essentially a zero-sum activity, asserting that humans can only get at most an additional 10% of that NPP implies future shortages of food, fiber, fodder, and fuel for people (Erb et al., 2012; Lewis, 2012). Policy based on this boundary would be fraught with human suffering, while the boundary itself has little mechanistic support or clear evidence of existence. In a similar vein, seeking to achieve uniform limits on practices such as nitrogen or phosphorus fertilizer use would inevitably lead to winners and losers at local scales (de Vries et al., 2013), because of differences in soil fertility and the legacies of historical farming practices (Erb et al., 2012; Carpenter and Bennett, 2011). For instance, while nitrogen fertilizer has been over-used in many developed countries, increases are urgently needed in sub-Saharan Africa to close the yield gap (Mueller et al., 2014). Given the consistent need for regionally appropriate limits, what practical use is a globally defined boundary?

8.5 Finding the research questions in an arena that is rife with competing visions of desirable futures

Planetary boundaries are typically based on biogeochemical and ecological principles. Their frame is simple: if we pass threshold "*X*," then the following ecological degradation or regime shift will occur. What this framing neglects is that there are inevitable trade-offs between human development goals and environmental protection/risk. Policy based on any assumed boundary will substantially impact development options. For the most part, truly natural areas are not the main "life support systems" for humanity; instead, people rely on those ecosystems that have been modified or engineered (Ellis et al., 2013). If it comes down to a choice between improved human development and the potential risk of transgressing an uncertain (and data poor) planetary boundary, it may be that society is willing to accept that risk. Science has a vital role in guiding environmental management. Ultimately, however, science must intersect with human decisions: physical laws are not negotiable, but our response to them is (Larsen et al., 2015). Global change is not a societal construct, so we must avoid the temptation to couch scientific models as policy directives. Value judgements do (and must) play a key role in determining how people respond to global environmental challenges and the possibility of inflexible planetary boundaries.

What has become starkly apparent from the debate on planetary tipping points and possible global regime changes is the need for a concerted research agenda aimed at the potential links between biophysical and social systems to determine possible boundary "positions." This research could come in the form of:

(1) empirical examinations of regime shifts (or not) under gradual degradation;
(2) models that explicitly link ecosystem changes and hypothesized boundaries to specific upheavals; and
(3) explorations of how the framing of a boundary influences decision makers.

For instance, our approach to Earth-system simulations is sophisticated for climatic components but lacks the resolution and mechanisms needed to test ideas on the planetary interconnectedness of nutrient and energy flows, or feedbacks across global biomes (Harfoot et al., 2014). The Madingley model of ecosystem dynamics (https://madingley.github.io/about) offers one promising example of an innovative attempt in this direction, because its design goals are to explicitly capture the scaling of processes that affect biodiversity from local to global scales (Purves et al., 2013). We can also seek a better understanding of the mechanistic underpinnings of the drivers of changes in global systems, such as land-use change and agricultural intensification. This could generate empirically based "bottom-up" forecasts of trajectories, which, when linked to multi-ecosystem models, should improve our forecasts of the risks of planetary state shifts (Brook and Blomqvist, 2016).

One of the appeals of planetary boundaries is the hypothesis that it resonates as a narrative for environmental action. The question is: how do decision-makers respond to these boundary arguments? Some research suggests that thresholds inhibit collective actions against tragedies of the commons (Barrett and Dannenberg, 2012). This is a field ripe for theoretical and empirical study. We also need to ask the hard questions about whether conceptual models like planetary boundaries are the most effective strategy and engagement tool for conservation and mitigation. The difficulty in getting international agreement on climate targets (e.g., the 2 °C "guardrail") is an obvious case in point (Symons and Karlsson, 2015). Perhaps focusing on planetary opportunities: leverage points for guiding global change in better directions (e.g., carbon-neutral energy systems) is potentially a more effective focus of scientific attention (DeFries et al., 2012). By focusing on something to be averted as opposed to an outcome to be achieved, we risk breeding complacency on one side of a boundary, and hopelessness on the other.

To summarize the above: the biosphere, and much of the geosphere, responds to external pressures in many and varied ways. The global human enterprise is driving large-scale changes in most components of the Earth system, but in a haphazard fashion, with responses often being weakly connected or transmitted slowly at a cross-continental scale. What we observe, for the global processes compiled in Table 8.1, is largely just the sum of all those changes. Acknowledging this reality should not be taken as diminishing the seriousness of these impacts or denying that major changes are occurring to the biosphere, atmosphere, and hydrosphere due to human activity. But it does make it implausible that the planet, or indeed most of its component systems, are primed to tip irreversibly to a radically different state that is inhospitable. Although the goal of sustainable stewardship of our planet is a laudable and an achievable one, the mechanisms and opportunities to conserve biodiversity and ecosystems lie mostly in targeted, localized actions (Jonas et al., 2014).

References

Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., Getz, W. M., Harte, J., Hastings, A., Marquet, P. A., et al. (2012). Approaching a state shift in Earth's biosphere. *Nature* 486, 52–8.

Barrett, S. and Dannenberg, A. (2012). Climate negotiations under scientific uncertainty. *Proceedings of the National Academy of Sciences of the United States of America* 109, 17372–6.

Brook, B. W. and Blomqvist, L. (2016). Innovations and limits in methods of forecasting global environmental change. *Basic and Applied Ecology* 17, 565–75.

Brook, B. W., Ellis, E. C., Perring, M. P., Mackay, A. W., and Blomqvist, L. (2013). Does the terrestrial biosphere have planetary tipping points? *Trends in Ecology & Evolution* 28, 396–401.

Butzer, K. W. and Endfield, G. H. (2012). Critical perspectives on historical collapse. *Proceedings of the National Academy of Sciences of the United States of America* 109, 3628–31.

Carpenter, S. R. and Bennett, E. M. (2011). Reconsideration of the planetary boundary for phosphorus. *Environmental Research Letters* 6, 014009.

Corlett, R. T. (2015). The Anthropocene concept in ecology and conservation. *Trends in Ecology & Evolution* 30, 36–41.

DeFries, R. S., Ellis, E. C., Chapin, F. S., Matson, P. A., Turner, B. L., Agrawal, A., Crutzen, P. J., Field, C., Gleick, P., Kareiva, P. M., et al. (2012). Planetary Opportunities: a social contract for global change science to contribute to a sustainable future. *Bioscience* 62, 603–6.

de Vries, W., Kros, J., Kroeze, C., and Seitzinger, S. P. (2013). Assessing planetary and regional nitrogen boundaries related to food security and adverse environmental impacts. *Current Opinion in Environmental Sustainability* 5, 392–402.

Ellis, E. C., Kaplan, J. O., Fuller, D. Q., Vavrus, S., Goldewijk, K. K., and Verburg, P. H. (2013). Used planet: a global history. *Proceedings of the National Academy of Sciences of the United States of America* 110, 7978–85.

Erb, K. H., Haberl, H., Defries, R., Ellis, E. C., Krausmann, F., and Verburg, P. H. (2012). Pushing the planetary boundaries. *Science* 338, 1419–20.

Harfoot, M., Tittensor, D. P., Newbold, T., McInerny, G., Smith, M. J., and Scharlemann, J. P. W. (2014). Integrated assessment models for ecologists: the present and the future. *Global Ecology and Biogeography* 23, 124–43.

Hughes, T. P., Carpenter, S., Rockstrom, J., Scheffer, M., and Walker, B. (2013). Multiscale regime shifts and planetary boundaries. *Trends in Ecology & Evolution* 28, 389–95.

Jonas, M., Ometto, J. P., Batistella, M., Franklin, O., Hall, M., Lapola, D. M., Moran, E. F., Tramberend, S., Queiroz, B. L., Schaffartzik, A., et al. (2014). Sustaining ecosystem services: overcoming the dilemma posed by local actions and planetary boundaries. *Earth's Future* 2, 407–20.

Kefi, S., Holmgren, M., and Scheffer, M. (2016). When can positive interactions cause alternative stable states in ecosystems? *Functional Ecology* 30, 88–97.

Larsen, F. W., Turner, W. R., and Mittermeier, R. A. (2015). Will protection of 17% of land by 2020 be enough to safeguard biodiversity and critical ecosystem services? *Oryx* 49, 74–9.

Lenton, T. M. (2013). Environmental tipping points. *Annual Review of Environment and Resources* 38, 1–29.

Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., and Schellnhuber, H. J. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences of the United States of America* 105, 1786–93.

Lenton, T. M. and Williams, H. T. P. (2013). On the origin of planetary-scale tipping points. *Trends in Ecology & Evolution* 28, 380–2.

Lewis, S. L. (2012). We must set planetary boundaries wisely. *Nature* 485, 417.

Lovelock, J. E. and Margulis, L. (1974). Atmospheric homeostasis by and for the biosphere: the Gaia hypothesis. *Tellus* 26, 2–10.

Mace, G. M., Reyers, B., Alkemade, R., Biggs, R., Chapin, F. S., Cornell, S. E., Diaz, S., Jennings, S., Leadley, P., Mumby, P. J., et al. (2014). Approaches to defining a planetary boundary for biodiversity. *Global Environmental Change–Human and Policy Dimensions* 28, 289–97.

McAlpine, C. A., Seabrook, L. M., Ryan, J. G., Feeney, B. J., Ripple, W. J., Ehrlich, A. H., and Ehrlich, P. R. (2015). Transformational change: creating a safe operating space for humanity. *Ecology and Society* 20, 56.

McGill, B. J., Dornelas, M., Gotelli, N. J., and Magurran, A. E. (2015). Fifteen forms of biodiversity trend in the Anthropocene. *Trends in Ecology & Evolution* 30, 104–13.

Mueller, N. D., West, P. C., Gerber, J. S., MacDonald, G. K., Polasky, S., and Foley, J. A. (2014). A tradeoff frontier for global nitrogen use and cereal production. *Environmental Research Letters* 9, 054002.

Newbold, T., Hudson, L. N., Arnell, A. P., Contu, S., De Palma, A., Ferrier, S., Hill, S. L. L., Hoskins, A. J., Lysenko, I., Phillips, H. R. P., et al. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science* 353, 288–91.

Purves, D., Scharlemann, J. P., Harfoot, M., Newbold, T., Tittensor, D. P., Hutton, J., and Emmott, S. (2013). Ecosystems: time to model all life on earth. *Nature* 493, 295–7.

Reyer, C. P. O., Brouwers, N., Rammig, A., Brook, B. W., Epila, J., Grant, R. F., Holmgren, M., Langerwisch, F., Leuzinger, S., Lucht, W., et al. (2015). Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. *Journal of Ecology* 103, 5–15.

Robert, K. H., Broman, G. I., and Basile, G. (2013). Analyzing the concept of planetary boundaries from a strategic sustainability perspective: how does humanity avoid tipping the planet? *Ecology and Society* 18, 5.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., et al. (2009). A safe operating space for humanity. *Nature* 461, 472–5.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K., and Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature* 534, 631–9.

Running, S. W. (2012). A measurable planetary boundary for the biosphere. *Science* 337, 1458–9.

Scheffer, M. (2016). Anticipating societal collapse; hints from the stone age. *Proceedings of the National Academy of Sciences of the United States of America* 113, 10733–5.

Scheffer, M., Barrett, S., Carpenter, S. R., Folke, C., Green, A. J., Holmgren, M., Hughes, T. P., Kosten, S., van de Leemput, I. A., Nepstad, D. C., et al. (2015). Creating a safe operating space for iconic ecosystems. *Science* 347, 1317–9.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., et al. (2015). Planetary boundaries: guiding human development on a changing planet. *Science* 347, 1259855.

Symons, J. and Karlsson, R. (2015). Green political theory in a climate-changed world: between innovation and restraint. *Environmental Politics* 24, 173–92.