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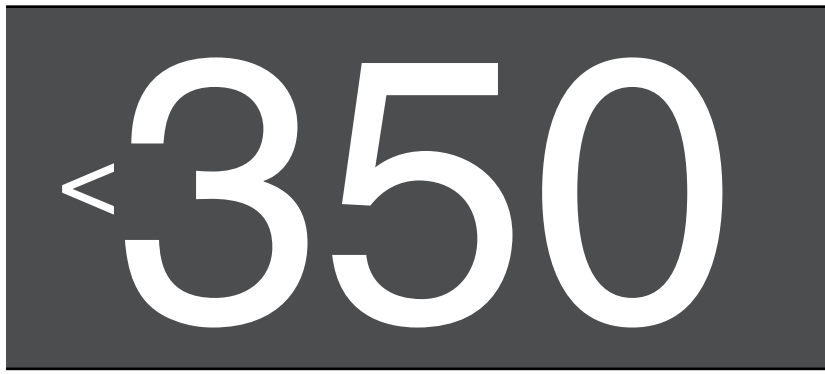
Planetary Boundaries and Big Tent Science

"350. Remember that number for the rest of your life."

So read the headline of a full-page advertisement in the *New York Times*, the *Financial Times*, and the *International Herald Tribune* on June 23, 2008 – twenty years to the day after NASA scientist James Hansen testified before the US Congress on the rising risks of the greenhouse effect and global warming. Undersigned by over 150 well-known scientists, activists, public intellectuals, and political leaders, the advertisement called for reducing the atmospheric concentration of carbon dioxide to below 350 parts per million, the level at the time of the famous June 1988 Hansen hearings. The diverse signatories included Hansen, climate writer Mark Lynas, creator of the Gaia hypothesis James Lovelock, human rights advocate Bianca Jagger, former Swedish prime minister Göran Persson, and Bill McKibben, the environmental activist who employed 350 ppm as the basis for his new climate NGO, 350.org. (Figure 7.1).[1]

One notable name that was not included in the 350 advertisement was that of Bert Bolin, who had passed away in the end of December 2007 – two weeks after Al Gore and the Intergovernmental Panel on Climate Change (IPCC) were presented with the Nobel Peace Prize in Oslo, Norway. Whether Bolin would have signed such a statement even if he were still alive is however uncertain. In an op-ed published posthumously in the Swedish daily *Svenska Dagbladet* several days after

[1] "350. Remember that number for the rest of your life," *New York Times*, *Financial Times*, and *International Herald Tribune*, June 23, 2008.



Remember this number for the rest of your life.

We've been there: atmospheric concentration of carbon dioxide (CO_2) of 350 parts per million (ppm).

On this day twenty years ago, when Dr. James Hansen of NASA's Goddard Institute of Space Studies warned the US Congress of global warming forced by greenhouse gases emitted through human activities, CO_2 stood at 350 ppm.

That was then. Today it is up to 385 ppm. Sixteen years after the UN Convention on Climate Change was agreed upon to stabilize greenhouse gases at a level preventing dangerous human interference with the climate system, global carbon emissions are still increasing – *more rapidly than ever.* We are well on our way to 450 ppm and beyond.

What does the best science tell us?

Until recently, scientific consensus set the safe zone to avoid the worst effects of climate change at 450 ppm. But today the latest science tells us the danger zone may already begin at *350 ppm.* Catastrophic effects cannot be ruled out if *levels above 350 ppm* are maintained for a long time.

What does this mean?

We've gone too far – in a dangerous direction. Now we know enough. To act now. To foresee and forestall any risk of massive and irreversible damage to the earth and all its inhabitants for generations to come, we must reduce atmospheric CO_2 to *levels below 350 ppm.* Scientific insights bring political responsibilities. We need leadership that respects the planetary boundaries of life.

We, the signatories of this message from all continents, call upon all nations in the ongoing climate negotiations to adopt 350 as the target to be reached peacefully and deliberately, *with all possible speed.*

350 is one of our planet's boundary conditions. It should not have been transgressed. We must go back for a future:

<350

essential to maintain human and planetary well-being

Poonam Ahluwalia, President, Youth Employment Systems
Pindarous W.T. Allison West Africa Coordinator, Youth Employment Systems (YES)
Dennis Altman, Professor
Peter Anderberg
Ray C. Anderson, Interface
Thomas Andersson, President, Jönköping University
Gunilla Arhen, Ruter Dam
W. Brian Arthur, Economist, Santa Fe Institute
Alan AlKlason, President, The AlKlason Group
Brian Bacon, Founder & President, Oxford Leadership Academy
Graham Barnes, Ph.D., psychotherapist, author
Steve Bass
Héctor Castillo Berthier
Göran Bexell, Vice-Chancellor, Lund University
Mihir R. Bhatt, Director, All India Disaster Mitigation Institute
Peter Blom, CEO, Triodos Investment
David Blood, Generation Investment Management
Nicole-Anne Boyer, Managing Director, Adaptive Edge
Derek Brown, Peace Appeal Foundation
Kann Bruce
Dan Brändström
Göran Carstedt
Per Carstedt
Robert Charpentier, CEO, Kaupthing Bank Sverige AB
Nayan Chanda
David Chaytor, MP Bury North
Göran Collert
Napier Collyns
Audrey Codera, Youth Works Inc.
Robert Corell
Hilary Cottam, Participle
Alexander Crawford
Tom Cummings, Chairman, Executive Learning Partnership
Bei Dao, Poet, Professor of Humanities, Chinese University of Hong Kong
Avril Doyle, MEP
Gwynne Dyer
Bo Ekman
Göran Ekman
Sara Ekman
Kristin Engvig, Founder, Women's International Networking
Profs Alice and Bob Evans, Plowshares Institute
Tim Flannery

José María Figueres Olsen, Ex-President of Costa Rica
Ulla-Britt Fräjdin-Hellqvist
M.Shafik Gabr, Chairman & Managing Director, ARTOC Group for Investment & Development
Yubaraj Ghimire, Editor, Samaj/Newsfront Kathmandu
Marilou van Golstein Brouwers, Managing Director, Triodos Investment Management
Lennart Grebelius
Hal Hamilton, Sustainability Institute
KG Hammar
Dongfang Han
James Hansen
Molly Harriss Olson CEO, President Clinton's Council on Sustainable Development
Satu Hassi, Member of the European Parliament
Martin Hedberg, Swedish Weather & Climate Centre
Pär Holmgren, Meteorologist
Thomas Homer-Dixon, Professor, University of Toronto
Will Hutton
Ross Jackson, Gaia Trust, Denmark
Bianca Jagger, Chair, World Future Council
Oliver James, Psychologist, author of Affluenza
Colin Vivian Jones
Bill Joy, Partner, KPCB
Koosum Kalyan
Madhu Kishwar
Niclas Kjellström-Matseke, CEO, The Swedish Post Code Lottery
Igor Kluin, Founder Qurrent
Shulamith Koenig, Founding President- PDHRE, People's Movement for Human Rights Learning
Jules Kortenhorst
Anna Langenius
Charles Larroche, Larroche Conseil
Alejandro Litovsky, Volans Ventures
Christine Loh, CEO, Civic Exchange, Hong Kong
Prof. Jack Lohman, Director, The Museum of London
Augusto Lopez-Claros, Ph.D. Director, EFD - Global Consulting Network
James Lovelock
Caroline Lucas, Member of European Parliament, Green Party
Mark Lynas
Dirk Messner, Director, German Development Institute
Fred Matser, Founder/Chairman Fred Foundation
Anand Mahindra

Manfred A. Max-Neef, Professor of Ecological Economics, Universidad Austral de Chile.
Jacqueline McGlade, Professor
Bill McKibben
John Morelli, McCarthy Chair, Rochester Institute of Technology
Ieva Morica
Carl Mossfeldt
Herman Mulder
Geoff Mulgan
Robert Myall, Chairman, Namyuki River Water Association
Carlos Nobre
Cecilia and Lars Nordstrom
Karl-Erik Norrman, Sec-Gen, European Cultural Parliament
Harald Norvik
Paul O'Hara
Rebecca Oliver
Hans-Olov Olsson
Marcello Palazzi
Anthony Patt, International Institute for Applied Systems Analysis
Göran Persson, former Prime Minister of Sweden
Iqbal Z. Quadir, Founder, MIT Legatum Center
Sigrid Rausing
Ralph Rayner, London School of Economics
Pierre Rehnlund, Vice President, Swedbank AB
Howard Rheingold
Mike Robinson, Chair of Stop Climate Chaos Scotland
Johan Rockström
Yasuhiro Sakakibara
Mohammad Sammak
Peter Schwartz
Michael Schragger, The Forum For Design & Sustainable Enterprise
Dr. Ismail Serageldin
Clare Short, MP
Anthony Simon
Jens Martin Skibsted, Creative Director of Skibsted Ideation/Biomega
Youba Sokona
Paolo Soleri, Arcosanti
Hans Sollerman CEO, e-man AB
Jaap Spier, Prof. Dr, Netherlands Supreme Court
Ingrid Sinrath, CIVICUS
Grace K and John R. Stanek, Stanwood Associates

Caroline Stiernstedt Sahlbom
Alan Stoga, Zero Communications
Ira Sundberg, Sustainable Sweden Association
Uno Svedin
Sverker Sörlin, Professor of Environmental History, author
Pedro Tarak, Fundacion Avina, Panama
Camilla Toulmin
Domien Van Gool, Founder, Leader Academy
Sasa Vucinic
Denny Vågerö, Professor, Centre for Health Equity Studies
Dr. Marc A. Weiss, Chairman and CEO, Global Urban Development, Washington, DC
Anders Wijkman
Lawrence Wilkinson, Chairman, Heminge & Condell
James and Eva Wine
The Wirth Family
Frank Wisner, Vice Chairman, External Affairs, American International Group
Xu Sitao, Chief Representative, China The Economist Group
Oran Young, Bren School, UC Santa Barbara
Niklas Zennström, Co-founder Atomico, Joost, Skype
Zou Xinqing, Professor
American Indian Institute
China Labour Bulletin
Ejendals AB
e-man
The Foresight Group AB
Generation Investment Management LLP
Good Energies
H & M Hennes & Mauritz AB
The Lemelson Foundation
Living Partnership, International NGO (Belarus)
Mahindra & Mahindra Limited
NTR plc
Schweisfurth Foundation, Munich
Sundaram Tagore Galleries
The Swedish Post Code Lottery
The David Suzuki Foundation
Triodos Bank N.V.
Vsemirnyi Fond Prirody
350.org
European Environment Agency
Stockholm Environment Institute
Tällberg Foundation

Individual signatures represent the personal and professional perspectives of the signatories, not necessarily the opinion of the institution associated with their names. Institutional signatories represent solely themselves.

We invite you to watch the live webcasts from the Tällberg Forum June 26-29 from the village of Tällberg in Sweden. Information and the schedule can be found online at www.tallbergfoundation.org. The opening session includes a panel on "Defining planetary boundaries and tipping points" presented in partnership with the Stockholm Environment Institute, featuring James Hansen, Diana Liverman, Johan Rockström, Will Steffen. For more information on the global movement, please visit www.350.org.

TÄLLBERG FOUNDATION
How on Earth can we live together?
Tällberg, Sweden

FIGURE 7.1 The 350 advertisement. *New York Times*, June 23, 2008. Courtesy of the Tällberg Foundation.

FIGURE 7.2 Senior Swedish science diplomats meeting in the 1990s. Ambassador Bo Kjellén (left), head of the Swedish Kyoto delegation, and Bert Bolin (right), founding Chairman of the United Nations Intergovernmental Panel on Climate Change (IPCC). Photo: Jessica Gow/Scanpix.

his death, Bolin and the article's co-author Ambassador Bo Kjellén – Sweden's former chief climate negotiator who had played an instrumental role in establishing the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol as well as the UN Convention to Combat Desertification – argued that it was scientifically impossible to identify an exact point beyond which humanity would not be able to manage climate change. Bolin and Kjellén (Figure 7.2), citing IPCC science, also took exception to the more alarmist statements of Al Gore and others on the melting of Arctic sea ice and Greenland's glaciers and emphasized the uncertainties surrounding weather-related catastrophes such as Hurricane Katrina that many had linked to climate change.[2]

As implied by the editorial's title, "Serious – but not Hopeless," Bolin and Kjellén – who had worked closely with one another on climate science and diplomacy throughout the 1990s – strongly preferred the

[2] Bert Bolin & Bo Kjellén, "Allvarligt – men inte hopplöst," *Svenska Dagbladet*, January 4, 2008, www.svd.se/a/3b8b9e79-74bb-30bc-a745-e41abdc6c7b5/allvarligt-men-inte-hopplost.

deliberate, scientifically informed diplomatic process that was moving toward an inflection point over what they saw as the counterproductive discourse of the climate crisis, based on fear, that had become prominent in 2007. The editorial was written in the wake of the December 2007 UNFCCC meeting in Bali, where the Bali Road Map was adopted to guide international climate negotiations over the next two years. With the Kyoto Protocol's first commitment period expiring in 2012, climate diplomats' sights were set on the COP15 meeting in Copenhagen at the end of 2009, where they hoped to reach a legally binding agreement that would extend and enhance commitments by signatory nations to limit greenhouse gas emissions.

Following the 2007 breakthrough of climate change in terms of public awareness – epitomized by Nobel Peace Prizes and Oscar awards, for Al Gore's movie *An Inconvenient Truth*, as well as landmark scientific reports – the interim years between Bali and Copenhagen would be animated by an almost overwhelming sense of urgency, opportunity, and excitement. It was shared among scientists, activists, and diplomats who had devoted much of their careers to the climate issue. It was in the context of this decisive moment of climate governance that a large gathering of global elites took place in a scenic Swedish village, and a new framework for reconceiving humanity's relationship with the Earth System emerged.

TÄLLBERG 2008 – FRAMING A FRAMEWORK

On the same day as its publication in the three major international broadsheets, the 350 advert also appeared in a fourth newspaper, the *Falu-Kuriren*, a local daily covering the largely rural province of Dalarna in Sweden. It was there, in the hillside village of Tällberg, overlooking Lake Siljan, that many of the signatories and hundreds of other experts, industry leaders, and international elites, including UN Secretary General Kofi Annan, would gather later that week to discuss issues related to sustainable development and global interdependence. The event was the fourth installment of the Tällberg Forum (Figures 7.3 and 7.4), a major annual gathering convened by the Stockholm-based Tällberg Foundation. Founded by former Volvo executive Bo Ekman, the Tällberg Foundation has since 1981 been arranging, at first small informal workshops and, after the turn of the Millennium, larger events, in Tällberg and other locations in Sweden and around the world. The meetings were dedicated to promoting globalism and intellectual

FIGURE 7.3 Tällberg, a small village in the province of Dalecarlia, Sweden, was the place of several years of Midsummer conferences where Earth System scientists and other scholars engaged and networked with politicians, activists, artists, businessmen, trade unions, sponsors, media, royalty, and members of the general public. Workshops took place in nineteenth-century cottages, talks were held, and music was played for hundreds of people in big tents. Collective nature walks took place in the surrounding landscape in an old Swedish out of doors tradition. Photo: Courtesy of the Tällberg Foundation.

exchange under the banner "How on Earth can we live together?." In a village of small wooden houses, Tällberg Forum sessions took place inside large circus-style tents that could be seen as symbolizing the "big tent" approach to global problems that the Tällberg Foundation had fostered for forty years.

The 2008 edition of the Tällberg Forum opened with a session called "Defining planetary boundaries and tipping points," the webcast of which was promoted in the 350 advertisement that the Tällberg Foundation had taken out in the four newspapers. Its scientific panel consisted of former International Geosphere Biosphere Programme (IGBP) director Will Steffen, Oxford geographer Diana Liverman, Stockholm Environment Institute (SEI) director Johan Rockström, and James Hansen of NASA, who had in a recent scientific article argued that CO_2 levels beyond 350 ppm risked triggering dangerous tipping

FIGURE 7.4 Convening and connecting at Tällberg. Here is a panel discussion in 2008 with British geographer Diana Liverman, NASA scientist Jim Hansen, climate scientist Will Steffen (Australia), Bangladesh environmental scientist Tariq Banduri, facilitated by climate scientist Johan Rockström. Photo: courtesy of the Tällberg Foundation.

points in the climate system.[3] Hansen's 350 threshold would constitute one of the nine pillars of a new conceptual framework that was under development by an international network of scientists centered on the recently established Stockholm Resilience Centre (SRC). During the Tällberg Forum's opening session, the panelists provided a sneak preview of what would a year later become one of modern environmental history's most impactful, controversial, and all-encompassing conceptualizations of the human–environment relationship, with implications for both scientific understanding and governance of the global environment: the Planetary Boundaries framework.

The four panelists were among around twenty of the framework's intellectual architects that had arrived in Tällberg in advance of the Forum to further develop its conceptual and scientific basis. The ideas and activities behind Planetary Boundaries (PB for short) date back to the early 2000s, although, as is the case with so many conceptual developments, it is hard to pinpoint a particular moment in time and place when the idea was initially conceived. In a recent book based on the

[3] James Hansen, Makiko Sato & Pushker Kharecha, et al., "Target Atmospheric CO: Where Should Humanity Aim?," *Open Atmospheric Science Journal* 2(2008):1, 217–234.

framework, Rockström and his co-author Owen Gaffney describe the birth of Planetary Boundaries as an intellectual process that evolved over time. In a chapter centered on the Scottish amateur scientist James Croll, who discovered the astronomical reason for the ice ages, Rockström and Gaffney cite a proverbial quote attributed to Alexander von Humboldt, "There are three stages of scientific discovery: first people deny it is true; then they deny it is important; finally they credit the wrong person."[4]

The quote fits well in explaining not only Croll's unlikely nineteenth-century scientific achievement, which was of course denied and disregarded, but also for the Planetary Boundaries idea. The Planetary Boundaries framework was published in *Nature* in September 2009 under the title "A Safe Operating Space for Humanity," and has since become well known, and with time, even famous. But where does the boundaries idea actually originate? Rockström and Gaffney focus mostly on the boundaries' content and actual meaning. They say little about the process that led up to the article, although they do say that it took place in Sweden, a circumstance to which we will return in some detail. It should also be mentioned that the Planetary Boundaries article in *Nature* has achieved phenomenal visibility and made a huge impact, especially in scientific circles, approaching a stunning 20,000 citations on Google Scholar. The world of environmental policy and governance, especially in the Global South, has, however, been somewhat less impressed. The framework has also been controversial, drawing criticism from North and South, and from left, right, and center.[5]

Another way of telling the PB story is to start with a broader article published in 2015, with Will Steffen as the lead author together with several Stockholm-based scholars, in the then recently established journal *The Anthropocene Review*.[6] In that article, Steffen, a central co-author

[4] Johan Rockström & Owen Gaffney, *Breaking Boundaries: The Science Behind Our Planet* (London: Dorling Kindersley, 2021), ch 15. The original attribution to Humboldt for a quote that has multiple roots and attributions is actually about Louis Agassiz' theory, for a long time controversial, of the Ice Age. This theory was in fact previously suggested by other scholars, and in addition, it was a theory Humboldt first did not believe in. It is cited in Andrea Wulf, *The Invention of Nature: Alexander von Humboldt's New World* (New York: Knopf, 2015), and earlier by Bill Bryson, *A Short History of Nearly Everything* (2003), new ed. (London: Doubleday, 2016), 508.

[5] Frank Biermann & Rakhyun E. Kim, "The Boundaries of the Planetary Boundary Framework: A Critical Appraisal of Approaches to Define a 'Safe Operating Space' for Humanity," *Annual Review of Environment and Resources* 45(2020):1, 497–521.

[6] Will Steffen, Wendy Broadgate, Lisa Deutsch, Owen Gaffney & Cornelia Ludwig, "The Trajectory of the Anthropocene: The Great Acceleration," *The Anthropocene Review* 2(2015):1, 81–98.

of the *Nature* piece as well as the lead author of the second, follow-up PB article in *Science* in 2015, and his colleagues trace the longer intellectual trajectory of Anthropocene thought. They point in particular to the integrative work conducted at the IGBP, which Steffen directed from its secretariat in Stockholm in the 1990s up until 2004, and in similar international fora of science and governance.

Steffen and colleagues emphasize the importance of meetings, just as we do in this book. In fact, some of the major conceptual and institutional advances during this multi-decadal trajectory from the 1980s to the 2000s were made at conferences of various kinds. One of the more intellectually consequential was the IGBP meeting in February 2000 in Cuernavaca, Mexico, where Paul Crutzen first uttered the word "Anthropocene," conceptualizing the link between the Earth System, its science, and human agency. Another was a 2005 Conference in Dahlem, a leafy suburb in the academic quarters of Berlin, when the newly formed interdisciplinary IHOPE network – Integrated History and Future of People on Earth – organized a comprehensive meeting from which the idea of "The Great Acceleration" is said to have emerged.

Meetings of scientists and thinkers from fields wide apart make possible a kind of interaction that traditional seminars and congresses devoted to individual disciplines do not. They relieve the participants of the preset agendas and free them from the methodological routines and theoretical shackles that typically define disciplinary gatherings. They create the space of intellectual freedom that is necessary and the confidence that the presence of a wide range of expertise provides, so that even very large and complex problems can be investigated and discussed.

The 2015 *Anthropocene Review* article starts by noting that Earth System science objects under IGBP had been in the making for more than a decade from the late 1990s, when the Programme decided to embark upon a stock-taking and synthesizing project to get a better overview of the field. It was conducted between 1999 and 2003, building upon the growing evidence that demonstrated how rapid change was becoming increasingly legible along a wide set of indicators, including ocean acidification, atmospheric CO_2, phosphate circulation, biodiversity loss, freshwater use, and multiple others. Little of this was entirely new information. However, what was unprecedented was the massive effect that these pressures were imposing on the Earth System if they were looked at *together* and not divided up along the lines of existing disciplines and deferred to different seminar rooms in separate faculties. This *integrative approach*, taking into account the combined and summative effect of the

multiplicity of Earth System indicators, became the central issue of the analysis and provided, in all its simplicity (one may say afterward), the added value of the enterprise. As the article states already in its first paragraph: "The increasing human pressure on the Earth System was a key component of the synthesis."[7]

FINDING A FRAMEWORK – THE USEFULNESS OF HISTORY

Also new was the interpretive framework. Scientists knew the facts, but they were not at the outset of the synthesis project so well aware of how formidable the rates of change in the trajectories of the Earth System dimensions were, especially when they were seen as an ensemble. This was, however, already discussed, not least by historians. In the year 2000, John R. McNeill, an environmental historian at Georgetown University in Washington, DC, published a book on the history of the twentieth century as seen from the angle of human relations with the natural world. It was entitled *Something New Under the Sun* to underscore the main point of the book, namely that, in contrast to the well-known biblical words, in *Ecclesiastes* 1:9, the twentieth century was precisely *not* something that wasn't new under the sun. On the contrary, almost everything was new. It was the century when humankind's impact on the Earth literally exploded. Not just the first atomic bomb, but population growth, the widespread application of chemicals and pesticides in agriculture, mass mobility and transportation, urbanization, the widespread application of fertilizers, the felling of rainforests, the extraction of minerals and fossil fuels, the exploitation of other natural resources, and much more. The twentieth century was the century when global GDP grew by almost 2,000 percent and the population of blue whales diminished by 98 percent.[8]

Was there a connection? Will Steffen and his co-authors suggest that it was a revelatory moment, when the insight of the rates of change of social, economic, and demographic indicators were set alongside those of the Earth System. And clearly, something had happened. In the IGBP synthesis volume, published in 2004, twelve "Socio-economic trends," including the global number of McDonald's restaurants (later replaced

[7] Steffen et al., "The Trajectory."

[8] John R. McNeill, *Something New under the Sun* (New York: W. W. Norton & Company, 2000). Global inflation-adjusted historical GDP data, retrieved May 20, 2024: ourworldindata.org/grapher/global-gdp-over-the-long-run.

by primary energy use), were presented as graphs demonstrating exponential growth from around the mid-twentieth century and juxtaposed with twelve similarly steep curves, the "Earth System trends."[9] It was to further investigate the historical trajectories reflected in what would come to be known as the "Great Acceleration curves" that the 2005 Dahlem meeting was organized. The meeting was expanded to include archaeologists as well as historians, such as John McNeill, who was on the meeting's organizing committee, to further integrate the Earth System and its societal dimensions.[10] It was at Dahlem that the concept "the Great Acceleration" was coined,[11] later to become the title of a book by McNeill and historian Peter Engelke.[12]

The Steffen et al. article not only sums up the trajectory of the Anthropocene, it also brings to light the ongoing changes in the composition of the multiple pressures on the Earth System. The research team presents the recent leveling off in the building of new dams and the exponential growth rate of the global population and notes the reduction of stratospheric ozone following the Montreal Protocol coming into effect in 1989. But, by and large, the trends prevail and are in some cases reinforced. The article also takes up criticisms of the Anthropocene concept – the most articulated versions coming from scholars in the humanities and social sciences, but also from politicians and activists in developing countries and among less privileged social groups in the West.[13] This

[9] Will Steffen, Angelina Sanderson, Peter Tyson, Jill Jäger, Pamela Matson, Berrien Moore III, Frank Oldfield, Katherine Richardson, John Schellnhuber, B. L. Turner II & Robert Wasson, *Global Change and the Earth System: A Planet under Pressure*, IGBP Book Series (Berlin, Heidelberg, New York: Springer, 2004).

[10] Robert Costanza, Lisa J. Graumlich & Will Steffen, eds., *Sustainability or Collapse? An Integrated History and Future of People on Earth, Dahlem Workshop Report 96* (Cambridge, MA: MIT Press, 2007).

[11] Steffen et al., "The Trajectory," 82. According to John McNeill, he, at Dahlem, first proposed the Great Acceleration framing of the post-war period as an adaptation of Karl Polanyi's concept and 1944 book *The Great Transformation*. John McNeill, personal communication (Paglia), July 11, 2014. See also Eric Paglia, *The Northward Course of the Anthropocene: Transformation, Temporality and Telecoupling in a Time of Environmental Crisis*, PhD diss. (Stockholm: KTH Royal Institute of Technology, 2016), 11.

[12] J. R. McNeill & Peter Engelke, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge, MA: Harvard University Press, 2016).

[13] Among the more vocal and articulate humanities critics, Eileen Crist, "On the Poverty of Our Nomenclature," *Environmental Humanities* 3(2013):1, 129–147. See also, for a broad register of critical responses, Gísli Pálsson, Bronislaw Szerzynski, Sverker Sörlin, John Marks, Bernard Avril, Carole Crumley, Heide Hackmann, Poul Holm, John Ingram, Alan Kirman, Mercedes Pardo Buendía & Rifka Weehuizen,

critique, which has been intense, points to the fact that only small portions of the global population have in fact contributed to the pressures on the Earth System, while the Anthropocene literature – from the first articles in the early 2000s – has treated "humanity" as a single entity. The 2015 Steffen et al. article provided new data and trend curves, with the global population broken down into Organisation for Economic Co-operation and Development (OECD), BRICS (Brazil, Russia, India, China, and South Africa), and low-income countries in the rest of the world. Unsurprisingly, the data demonstrate gross historical differences but also clear signs that the BRICS and some middle-income countries had started taking up significant space in several indicators and that China had by 2012 surpassed the per capita CO_2 emissions of Europe.

In other respects, the article was a summation of state-of-the-art knowledge that had emerged over an extended period of time. It by and large reflected an understanding of the planetary human–environment relationship that had been the consensus view of the global change community since at least the 2001 Challenges of a Changing Earth Conference in Amsterdam. Largely planned at the IGBP secretariat in Stockholm,[14] the conference was a turning point in the evolution of Earth System science and resulted in the discipline-defining Amsterdam Declaration.[15] The general insight that the *Anthropocene Review* article put forward after the first fifteen years of Anthropocene science and debates may be summarized by this quote: "Hitherto human activities were insignificant compared with the biophysical Earth System, and the two could operate

"Reconceptualizing the 'Anthropos' in the Anthropocene: Integrating the Social Sciences and Humanities in Global Environmental Change Research," *Environmental Science and Policy* 28(2013):1, 3–13; Andreas Malm & Alf Hornborg, "The Geology of Mankind?: A Critique of the Anthropocene Narrative," *The Anthropocene Review* 1(2014):1, 62–69; J. J. Schmidt. "The Moral Geography of the Earth System," *Transactions of the Institute of British Geographers* 44(2019):4, 721–734. Equity issues were discussed in Kate Raworth, *A Safe and Just Space for Humanity: Can We Live within the Doughnut?* (Nairobi: Oxfam International, 2012), www.oxfam.org/en/research/safe-and-just-space-humanity, and in Will Steffen & Mark Stafford Smith, "Planetary Boundaries, Equity and Global Sustainability: Why Wealthy Countries Could Benefit from More Equity," *Current Opinion in Environmental Sustainability* 5(2013):2–3, 403–408. For an overview of the Anthropocene critique, see Biermann & Kim, "Boundaries."

[14] Interview (Paglia) with Will Steffen, December 6, 2018.

[15] Will Steffen, "The Evolution of Earth System Science." Available at: https://futureearth.org/2015/12/14/the-evolution-of-earth-system-science/ (accessed August 6, 2022); Jill Jaeger, personal communication, August 4, 2022. See also the declaration itself: www.igbp.net/about/history/2001amsterdamdeclarationonearthsystemscience.4.1b8ae20512db692f2a68000312.html (accessed January 1, 2023).

independently. However, it is now impossible to view one as separate from the other." It could be said that this, on one level, was a quite moderate articulation of a profound and entangled relationship, given that "the environment" as a social and political issue had been around for almost seventy years – about the same age as the Great Acceleration[16] – and that its advent as an idea was by and large the clarion call that instigated the 1972 Stockholm Conference. Certainly, "the Earth System" did not exist as a term in 1972. It emerged gradually in the decades that followed, not receiving significant application until the 1980s, with its evolution closely monitored by the Stockholm-based science and policy journal *Ambio* (Latin for surroundings, or environment) that had been launched in 1972 in conjunction with the Stockholm Conference.[17]

Even more important, therefore, was the understanding from around 2000 that the human enterprise, as a whole, in all its countless dimensions and copious and ever-expanding scale, is directly interacting, impacting, and interfering with the Earth itself, *seen as a system*. That is the Anthropocene idea. Sometimes it *is* important how things are actually articulated. Because, in the articulation, the deeper significance of the idea becomes evident. In 1972, Stockholm's year of global revelation, the understanding was predominantly dualistic. The societal realm was, as it had always been, kept quite separate from the natural, (geo)physical realm. True, they were connected; humans and societies impacted – or "destroyed" as it was often presented – "nature," or "the environment." Society was on one side of an invisible fence, and the environment was on the other. It was a *human* environment, still two separate spheres, but with that qualifying word to signal the link.

Thus, when the Planetary Boundaries article started taking shape in the minds of some of the scholars in the Anthropocene and Earth System science community, including a few from the human sciences, the framing of the environment had already undergone a profound change. It had added a historical dimension. Rates of change over time across a wide range of *linked* social and natural parameters had started to play a major role. The human–Earth relationship was dynamic, not a static war of attrition. Societies and the Earth were profoundly entangled into a dynamic whole. They co-evolved, just as another environmental historian, Alfred W. Crosby, had suggested in the likely most influential

[16] Warde, Robin & Sörlin, *The Environment*, ch 1.

[17] Sverker Sörlin, "The Environment as Seen through the Life of a Journal: *Ambio* 1972–2022," *Ambio: A Journal of Environment and Society* 50(2021):1, 10–30, on 24.

work ever of environmental history, *Ecological Imperialism*. In that 1986 book, Crosby showed that the expansion of Europe over the course of a millennium from 900 to 1900 – starting in Iceland and Greenland, continuing with the Canary Islands and Madeira, expanding into overseas continents that the Europeans baptized as America and Australia, and a range of Pacific islands – entangled the "new Europes" within a biological web of plants, animals, epidemic diseases, and the gene pool of the Old World. Similar transplantations had certainly happened before, not least when early humans made their exodus out of Africa and spread across the world in a process that took hundreds of thousands of years. Now it accelerated fantastically, spurred, Crosby argued, by the evolutionary and epidemiological benefits that the Old World populations and biota had gained from higher population densities, in addition to their technology, science, capitalist ruthlessness, Christian sense of exclusivity, and racial supremacy ideas.[18]

Crosby called this intercontinental trade with and travel of seeds, weeds, animals, and disease "the Columbian exchange." The phrase was also the title of an earlier book of his from 1972, referring to Columbus as precisely the kind of iconic, restless, and ruthless agent of history that the expanding Europeans had become at that historical moment.[19] Historical understanding of the deep entanglement of human societies with continent-sized, indeed global, biological realities was thus not new when the Earth System science community began to engage with such ideas. But intellectual developments at the turn of the millennium still represented a significant step forward in the understanding of the human–Earth relationship. First, they were interdisciplinary, allowing for a wider analysis. Second, the comparisons were systematic, across a number of planetary dimensions, with more researchers engaged and hence a greater scientific capacity. Third, they were quantified and presented in a fashion that allowed comparison. Fourth, it universalized and generalized the historical change, which, although limited to a few cases, had been largely detailed in previous versions, presented with the usual care and precision of history writing. The Earth System science community further exposed the deep human–Earth entanglement, as it were, and allowed for an act of intellectual engineering that could bring out and – fifth – visualize in graphs and curves the magnitude and rate of the changes taking place.

[18] Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900–1900* (Cambridge: Cambridge University Press, 1986).

[19] Alfred W. Crosby, *The Columbian Exchange: The Biological Consequences of 1492* (Westport, CT: Greenwood Press, 1972).

This process was further assisted by the increasing interest among small groups of historians to write history along much bigger timescales than before. Several books were published in the first years of the new century that located human history on a planetary, if not astronomical, timescale identifying connections across thousands and hundreds of thousands of years. One work often cited in the IHOPE community was David Christian's *Big History* (2004), soon to be followed by books on "deep history" with links to neuroscience. The interest coincided with new kinds of historiography inspired by Anthropocene thought and a search, which has since then expanded, for synchronization of temporal scales, both natural and historical.[20] These kinds of material histories of Earth System timescales circulated among the Earth System science community and were cited in the work of the latter. The discussions took place, for example, in the IHOPE community and at the Dahlem Conference in 2005. Their results were published in academic journals, typically less in history than in outlets oriented toward Earth System science and global change research, and in a handful of important books.[21]

[20] David Christian, *Maps of Time: An Introduction to Big History* (Berkeley: University of California Press, 2004). Daniel Lord Smail, *Deep History and the Brain* (Berkeley & London: University of California Press, 2008). Dipesh Chakrabarty, "The Climate of History: Four Theses," *Critical Inquiry* 35(2009):2, 197–222. Daniel Lord Smail & Andrew Shryock, eds., *Deep History: The Architecture of Past and Present* (Berkeley, CA: University of California Press, 2011). Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime* (Cambridge: Polity, 2017). Marek Tamm & Laurent Olivier, eds., *Rethinking Historical Time: New Approaches to Presentism* (London: Bloomsbury Academic, 2019). Anders Ekström & Staffan Bergwik, eds., *Times of History, Times of Nature: Temporalization and the Limits of Modern Knowledge* (New York: Berghahn, 2022).

[21] Some examples: S. Cornell, R. Costanza, S. Sörlin, S. E. van der Leeuw, "Developing a Systematic 'Science of the Past' to Create Our Future," *Global Environmental Change* 20(2010):3, 426–427. S. van der Leeuw, R. Costanza, S. Aulenbach, S. Brewer, M. Burek, S. Cornell, C. Crumley, J. A. Dearing, C. Downy, L. J. Graumlich, S. Heckbert, M. Hegmon, K. Hibbard, S. T. Jackson, I. Kubiszewski, P. Sinclair, S. Sörlin & W. Steffen, "Toward an Integrated History to Guide the Future," *Ecology and Society* 16(2011):4, 2. Robert Costanza, et al., "Developing an Integrated History and Future of People on Earth (IHOPE)," *Current Opinion in Environmental Sustainability*, 4(2012):1, 106–114. This trend has developed into new strands of nuanced Anthropocene history writing, both *about* the rise of the Anthropocene and its implications, as in Andrea Westermann & Sabine Höhler, "Writing History in the Anthropocene: Scaling, Accountability, and Accumulation," *Geschichte und Gesellschaft: Zeitschrift für Historische Sozialwissenschaft/Journal for Historical Social Sciences*, 46(2020): 4, 579–605, introducing an entire special issue with multiple contributions on the topic; Dipesh Chakrabarty, *The Climate of History in a Planetary Age* (Chicago, IL & London: The University of Chicago Press, 2021); and *as part of* the Anthropocene research enterprise and aligned with its main assumptions and claims, as in, for example, Jürgen Renn,

PLANETARY BOUNDARIES – FROM THE GROUND UP

Such was the situation among the Earth System sciences in the early years of the 2010s: a rapidly progressing discussion reaching across all possible disciplinary domains to establish a truer and more insightful image of the scale and impacts of the human dimensions of the human–Earth relationship. This emerging discourse and body of work aimed to better describe this relationship, and ultimately to be able to more effectively transform it or at least mitigate the most negative consequences of a co-evolution that was clearly moving in the wrong direction.

Seen in this way, it was perhaps not far-fetched to think that the dimensions of impact that the previous evolution of Anthropocene knowledge suggested could be turned into a set of quantifiable Earth System indicators, which are essentially what the planetary boundaries are. With the important qualification that these also have the potential to become policy objects, the term used in the text of the PB article is "guard rails," while in the title, these are described, perhaps more evocatively, as the "safe operating space for humanity."[22] The quantified boundaries represented a "space" within which "humanity" could "operate" without risking to tip the "Earth" out of its Holocene state. The latter was presented as a state of stability, in which humans had been able to proliferate, innovate, and evolve into complex modern societies. So progress was here defined as being related to Earth System stability rather than to other factors usually presented by archaeologists, anthropologists, and historians. This in some sense linked back to theories of geographical and climatic explanations, sometimes called "determinist," that had become less common after World War II. In retrospect, it may seem easy to explain, but before it had taken place, it was not obvious. The choice of Holocene stability as a boundary criterion, with all its vagueness, rather than precise calculations of risk,

The Evolution of Knowledge: Rethinking Science for the Anthropocene (Princeton, NJ: Princeton University Press, 2020); Julia Adeney Thomas, Mark Williams & Jan Zalasiewicz, *The Anthropocene: A Multidisciplinary Approach* (Cambridge: Polity, 2020); and, Julia Adeney Thomas, ed., *Altered Earth: Getting the Anthropocene Right* (Cambridge & New York: Cambridge University Press, 2022).

[22] J. Rockström, W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, & J. Foley, "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 14(2009):2, 32. [online] URL: www.ecologyandsociety.org/vol14/iss2/art32/, on 7.

human lives lost, or other standard indicators, may in fact have made PB more palatable and more "scientific" than "human."[23]

So, how did it happen? How could the PB article emerge from this mass of circulating ideas and initiatives? In their above-cited book *Breaking Boundaries: The Science of Our Planet*, Johan Rockström and Owen Gaffney (who was not involved at the time; he came to Stockholm in 2009) talk about the origins of the article in a short paragraph in Chapter 6. "We" [Johan] "invited scientists to Sweden in 2007." "[W]e turned every scientific stone we could find," went through aspects of the Earth System, identified nine processes, and quantified them.[24] These are then presented in various ways in the book. Although that is a very short but correct summary of the origins of the planetary boundaries concept, a closer look shows that "Sweden" was in fact several venues across the country, and the entire genealogy of the article is quite a bit more complex and indeed revealing, not least of the convening and converging power that Swedish institutions, scholars, and civic society could offer.

One such venue was Tällberg, where we must first return. The year 2007 was an entire year before the *New York Times* advertisement and the Planetary Boundaries workshop. At that point in time, Planetary Boundaries as a concept did not yet exist. But the Stockholm Resilience Centre did, having been selected for funding in June 2006, with the news from the Mistra Foundation in fact breaking at the 2006 Tällberg Forum. Preparations to set up the Centre were made in the fall of that year, including debates over the name of the new institute, and on January 1, 2007, the SRC formally started. At the 2007 Tällberg meeting, a discussion took place over the idea of a "Tällberg consensus," which was intended to start as a collaboration between the Tällberg Foundation and the SEI, a constituent part of the SRC that was still headed by Rockström, who maintained directorships of both SEI and SRC during the first five years of the latter's existence.

In the fall of 2007, the idea of a Tällberg consensus was prepared by Åsa Persson of SEI in collaboration with consultant Mike Schragger.[25]

[23] This assumption, with which we concur, comes from Åsa Persson, personal communication, e-mail September 4, 2022.

[24] Rockström & Gaffney, *Breaking Boundaries*, ch 6.

[25] Some details and quotations in this and several following paragraphs stem, unless other attributions are indicated, from large numbers of e-mails and working documents that one of us (Sörlin, a PB co-author) received and sent from November 2006 through to the publication of the two PB papers in September 2009.

It was vague at first, with talk of changing the focus of "sustainability" from vision to "business." Funding was sought from the Swedish government, including ten dimensions for reinterpreting sustainability. Not much came of this effort at first, and no funding was granted. In a later stage, the focus shifted after discussions within the SRC, and by March 2008, a new twist upon the idea was presented. Along the way, some of the scholars had been in touch with Schragger, who assembled ideas and took notes. In February, Rockström invited Carl Folke, Kevin Noone, and Sverker Sörlin to participate in preparations for the 2008 Tällberg Forum where the consensus workshop was set to take place. By that point, the terminology had changed to "tipping points" and "boundary conditions"; the two were used almost interchangeably.

On March 17, after the planning session (where only Rockström, Sörlin, and Persson participated), Persson circulated notes from the meeting containing the following: "A concrete idea that Johan Rockström and colleagues is developing is to formulate around ten absolute social-ecological boundary conditions at the global level that address the various 'spheres' (atmosphere, biosphere, etc.), such as 350 ppm CO_2, pH >7 in the oceans, maximum rate of biodiversity loss, etc. We are convening an international workshop for this purpose in conjunction with this year's Tällberg Forum in June." This was a concrete outcome of the meeting. Something pointing in this direction had also been on the program of a consensus meeting at SRC on October 12, 2007, where Rockström addressed the following topic, "The tipping points that must not happen: The boundary conditions – the physical ecosystem limits we must not transgress."

FROM BREVIK TO TÄLLBERG – AND BEYOND

Nonetheless, it is clear that it was the meetings in the first months of 2008 that sparked the process and in earnest provided the momentum toward the eventual article. The meeting notes from March 17 were distinct in that regard. They already had references to ten "boundary conditions." By now, it was also clear that presenting these boundaries was a central aim of the process and that it could also be the foundation of a research effort conducted by SEI. Plans were drafted for a two-day workshop at the Tällberg Forum in late June 2008, with discussions of both the scientific foundation of the ten boundaries and the policy implications, as well as the "ethics" of the limits in the assumption that their introduction would imply ethical concerns. There was also mention of

a link to "Regime shifts," a line of research at the SRC that at this time engaged among others Carl Folke and Sverker Sörlin. The first decision bullet point read:

> The workshop shall aim to create agreement on about ten key boundary conditions, expressed in absolute terms and addressing not only the climate (350ppm) but also issues such as ocean acidity levels, biodiversity loss rates (i.e. geophysical and ecological indicators). Ideally, the workshop can communicate such "consensus messages" to the Forum audience. Ethical implications and various other aspects need to be addressed in this work, but the aim is also to provide a necessarily "simplistic" picture.[26]

Reference was also made to an existing "Zero paper" that was apparently on the table at the meeting on March 17, 2008. A later version of the paper, dated May 12, 2008, encompasses a provisional, yet fairly comprehensive, presentation not only of the ten boundaries – the last section of the Zero paper – but of the wider context of such an enterprise: to launch a set of science-based limits to human action on the planetary scale. At this point, the boundaries were ten (they would eventually become nine) and were in many ways different from the ones that later appeared in the *Nature* article. There was one on "fisheries," one on "cycles" (mentioning both nitrogen and phosphorous), one on the "Chemisphere," one on "Aerosols/Air quality." In the spring of 2008, a little over a year before publication, there remained quite a lot of refining and selection work to be done in building the eventual framework.

The Zero paper had a sizable section – more than half of the entire paper – called "The new understanding," discussing previous attempts to make future projections. Notably, this section discussed the nowadays little-remembered 1892 book, *Dans cent ans* (In a hundred years), a detailed and bold vision of the world in 1992 by the eccentric French physiologist/polymath Charles Richet, later to win the Nobel Prize in Medicine in 1913. Richet's projections, incidentally, failed on virtually all scores, which is precisely the main point made in the Zero paper: grand predictions and schemes tend to not turn out very well in the trial of history. They, very literally, rarely stand the test of time. The utopian tradition is also introduced, as are earlier attempts to suggest limits to the human enterprise, most prominently in the two 1972 reports on limits. One was *The Limits to Growth*, sometimes just "LTG," the famous

[26] "The Tipping Points we cannot cross: Defining the Boundary Conditions for Planetary Sustainability." Notes from the planning meeting on March 17, 2008, with Johan (Rockström), Sverker (Sörlin), and Åsa (Persson). With Åsa Persson, SEI, and the authors (personal archives).

Club of Rome-commissioned computer-based projection of world development and environmental indicators for the twenty-first century.[27] The other was *A Blueprint for Survival*, Edward Goldsmith's small-scale decentralized vision of a future civilization based on self-subsisting communities, which was originally published in the January issue of *The Ecologist* and released later in the year as a Penguin book.[28] Much of the prose in this section of the Zero paper, and certainly some of the specifics – Richet being the prime example – cannot have been everyday parlance among many scholars regardless of background.[29]

A critical link between the previous literature and the message from Earth System science was the following paragraph in that section of the Zero paper:

> We now understand better why Richet and so many others went wrong: they dealt with phenomena which involved human behaviour and societal performance, which are in principle not foreseeable. One could contrast this tradition of projections with an example of a projection that was made on the earth system only, Svante Arrhenius' 1895 calculation of temperature rise as a result of the greenhouse effect. His calculation gave by and large the same result as the IPCC scenarios of 2007. From this we can learn a lesson: projections based on assumptions of how societies change, how humans may or may not act, and what kind of ingenuity they may be able to demonstrate to deal with challenges – such projections are extremely difficult, if not impossible, to project with any reasonable degree of certainty. However, if we focus on parameters which reflect the properties of the earth systems themselves, we move on safer grounds.[30]

This paragraph is telling because it justifies the novel approach of Planetary Boundaries thinking and explains why this version of a limits approach would be different from previous ones. Speculation on future projections and attempts to limit the human enterprise have, by and large, had a checkered history or been relatively futile. In order to take

[27] Donella H. Meadows, Dennis L. Meadows, Jørgen Randers & William W. Behrens III, *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (New York: Universe Books, 1972).

[28] Edward Goldsmith & Robert Allen, *A Blueprint for Survival* (London: Penguin 1972).

[29] Johan Rockström, "PREVIOUS PATTERNS OF THOUGHT. *Zero Outline High-Profile Boundary Paper 12th May 2008*." Charles Richet, ed., *Dans Cent Ans* (Paris: Hachette, 1892, repr. 1920) was originally published as a series of four articles in *La Revue Scientifique* between December 1891 and March 1892. This part of the Zero paper was authored by Sörlin. Richet's utopian speculations had been introduced by him before, see Sverker Sörlin, *Naturkontraktet: Om naturumgängets idéhistoria* [The Nature Contract: Interaction with Nature in the History of Ideas] (Stockholm: Carlsson, 1991), 97.

[30] Zero paper (n.p.).

the risk to embark on yet another limit-setting project, something had to be done in order to make it credible and worth the while. Quantifying, Arrhenius style, was a possible way forward. In this regard, Earth System science sat on a new solution to an age-old problem. It could provide entirely novel, and stable, foundations for reawakening the limits project that the *Limits to Growth* debates had all but put to rest.

Another key idea of the Zero paper, in the same section, is that the politics of boundaries thinking can be less pessimistic than previous attempts had been.

> All these attempts, and many others here not mentioned, are different. What they share in common though is that they all represent a growing sense of unease with previous patterns of thought that in an unreflective way projected the future progress of humanity against a canvas of a bountiful and boundless natural world. They articulated the dark down side of the Anthropocene. In this new literature and in the computer-based projections that started to appear, Earth was a delimiting feature. However, the very way that nature was depicted in the models, and the choice of parameters, became, perhaps inadvertently, a constraining factor. By choosing parameters that were rooted in the supply side of the global metabolism – chiefly the availability of (cheap) natural and energy resources – there was an inbuilt pessimism in the prescriptions that followed. Recommendations tended to focus on modesty and restraint, which oftentimes turned global governance into a zero-sum game. Policy quickly turned into conflicts between the global haves and the have-nots. This was clear already in the aftermath of the Brundtland report and the Rio summit in 1992 and has not ceased since. As guidance for policy and governance, this was not very helpful.
>
> The approach to the issue of limits that we propose here is different. While we acknowledge the achievements from the past several decades, we use as a point of departure the stark and depressing fact that despite all intentions not much has happened to curb environmental decline and serious negative effects on social-ecological systems all over the world.[31]

The "we" assumed here is unclear, but the reasonable way to interpret it is to acknowledge the wider conversation among several scholars connected to SEI (Persson) and SRC (Folke, co-director, Steffen, affiliated, and Sörlin, a part-time employee during the SRC's first five years) or other parts of Stockholm University (Kevin Noone, who was also executive director of the IGBP from 2004 to 2008). It is also unclear to what extent the plus-sum game perspective was embraced by those engaged in the discussion of the paper. At any rate, it may be useful to observe that the idea articulated in this long quote stands in some tension to the quest for ethical concern that was also articulated in the paper, and

[31] Zero paper.

the previously cited words of caution based on earlier attempts to define limits. The tension in this early draft of the planetary boundaries idea contains elements of the debates that followed the publication of the finished paper. In the time that passed until the article appeared in print, the ethical and historical ideas largely fell by the wayside. The process honed in increasingly on refining and defining the boundaries themselves and securing a high-visibility publication. *Nature* was in fact already mentioned as a possible outlet at the meeting on March 17, 2008, a full year and a half before the paper appeared in print.

By May 2008, the plans had matured enough for a slightly larger team to assemble at Villa Brevik in Lidingö, the same island in the inner Stockholm archipelago where so many previous environmental meetings had taken place (see above, Chapters 3–5). In fact, the May 12 version of the Zero paper was intended for precisely this occasion. At this three-day gathering that started on May 14, those present were Will Steffen, Carl Folke from SRC and the Beijer Institute, Bo Ekman of the Tällberg Foundation, Uno Svedin – an SRC associate who worked for a major Swedish funding agency, and Rockström, Sörlin, and Persson, who had been the first to meet on March 17. During the May meeting at Villa Brevik, slides and other visuals were shown of the, at the time, ten boundary conditions, and deep, extensive discussions were conducted. One of the themes was how to avoid putting all the focus on climate and the 350 ppm boundary. In fact, much of the rationale of the whole enterprise was to build a strong argument for maintaining a wide range of Earth System parameters that were mutually dependent.

In late June, the tipping points meeting was held in Tällberg, with a range of international scholars present. Some showed up on fairly short notice, including UK science writer Mark Lynas and tipping points specialist Tim Lenton, a physicist at the University of East Anglia. Many of the attendees would later become co-authors of the article, a network of contributors that would continue to grow over the coming year. In preparation, yet another and much more ambitious and elaborated version of the paper had materialized, based on the Villa Brevik conversations the month before. It was now a massive piece of writing, 22,000 words over nearly sixty pages. Some of it was no doubt a result of Will Steffen joining the writing team. Much of the "Zero paper" remained. For example, long, verbatim reiterations of the quotes above and some of the key references to "previous patterns of thought," still a subheading in the June version, including the eccentric Richet and the neo-Malthusian precursors of setting planetary limits, this time also including the iconic

Swedish food and resources specialist Georg Borgström. The substantive expansion and elaboration were on the boundaries. They were now thoroughly penetrated, with references and visualizations. They were also called "Planetary Boundaries," a change that happened at some point between May 12 and June 18, when the Tällberg paper was finished for distribution to the impressive list of participants.

THE IDEA AND THE NARRATIVE

Limits, or boundaries, were a key idea, but perhaps even more seminal to the originality of the paper was some of the thinking around tipping points and regime shifts. The June 18 version articulated more than previous iterations the idea that humans, or "humanity" – still seen as a collective with little internal differentiation – had now, during the Great Acceleration, gained the capacity to move, or "tip" the "Earth" out of balance. The moral obligation not to do so, as put forward in the paper, was a fundamental principle of global environmental governance that became fully revealed and articulated by Earth System science. The Zero paper had also at this point been given a proper title: "Steering Away from Catastrophic Thresholds: Planetary Boundaries for Human Survival." After intensive debates at Brevik and again at Tällberg, "planetary" became the preferred framing of the boundaries, as "global" was deemed to be too vague and as carrying a fair amount of negative baggage.[32] The title summarized this moral idea. The limits were actually thresholds to spaces that were unknown to mankind. If humanity were to cross these thresholds and enter these spaces, even if inadvertently, the entire planet would be in peril, and humanity with it. Hence the word "survival,"

[32] Åsa Persson, personal communication. Persson adds that the group was surprised that so few attempts to quantify boundaries had been made. She was asked by Rockström to do a first screening of global environmental reports, like UNEP's GEO reports. She found they typically had only lists of key global environmental problems and unlike the PB concept did not, "1) attempt to be exhaustive (identifying ALL critical Earth system processes/services) 2) spring from a systematic framework/concept/criteria and 3) were not quantified into limits." Persson also mentions that she wrote much of the Supplementary Information (SI) to the more comprehensive *Ecology and Society* paper (Appendix 1 here www.ecologyandsociety.org/vol14/iss2/art32/appendix1.pdf). Concepts reviewed there were: guardrails/Tolerable Windows (by Schellnhuber), safe operating standards, limits to growth, and critical loads. Writes Persson: "My take-away from that exercise was that the PB concepts really filled a gap in terms of boundaries at the Earth system level, but it built on a standard approach…: scientists propose critical thresholds/loads/norms and policy-makers then set the (legally binding or not) boundary." Åsa Persson, e-mail to authors September 4, 2022.

harkening all the way back to William Vogt's 1948 diatribe, *Road to Survival*, or for that matter Edward Goldsmith's manifesto, *A Blueprint for Survival* from that formative year 1972, or why not the terminology of early evolutionary thought by Charles Darwin and Herbert Spencer in the nineteenth century?

Still, few thoughts during that June 2008 Midsummer planetary boundaries festival in Tällberg were drifting back to the twentieth-century classics in the self-flagellating neo-Malthusian canon of constraints. Probably because this new manifesto of sorts signaled so emphatically *the opportunities* inside the limits, certainly much more than it articulated the potential for disaster. Yes, there was "catastrophic" danger, but there was also ingenuity and innovation, and yes, there could, and should, be growth. Planetary boundaries "do not set limits to economic growth," the paper explicitly stated. So, here it was a quantified planetary apocalypse presented along with, in fact right next to, an evangelical narrative of Cornucopian transformation. This combination of realist pessimism in describing existential challenges for people and planet alongside a hopeful permissiveness for human agency, embedded within a comprehensive outlook for the future, fostered few enemies, at least in the Global North. And it likely goes a long way toward explaining the success, if not the triumph, of the PB idea.[33]

The thorough vetting at Tällberg 2008 gave the framework's ideas both additional stability and a kind of rubber stamp from a relevant community of expertise, albeit one slightly biased in favor of the general train of thought. Another key participant with long-standing Stockholm connections was Hans Joachim Schellnhuber, the director of PIK, the Potsdam Institute for Climate Impact Research in Germany. Schellnhuber was cited more than anyone else in the new long paper, chiefly for his thinking since the 1990s about the "switch and choke point paradigm."[34] He had broken down the fraught human–Earth

[33] Johan Rockström, Will Steffen, Kevin Noone, Carl Folke, Sverker Sörlin, Dag Broman, and Uno Svedin [Core writing team], "Steering Away from Catastrophic Thresholds: Planetary Boundaries for Human Survival." Background Paper for the Tällberg Pre-Forum Workshop, June 24–26, 2008. SEI and SRC. FIRST DRAFT, June 18, 2008. Mimeo. [Support in drafting and data compilations: Åsa Persson, Björn Nykvist, Louise Karlberg.] Pages 1–59, quote on 15.

[34] Rockström et al., "Steering Away," on 8. Hans J. Schellnhuber, "Coping with Earth System Complexity and Irregularity," In: Will Steffen, Jill Jäger, David J. Carson & Clare Bradshaw (eds.), *Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference* [Amsterdam, The Netherlands, July 10–13, 2001] (Berlin, Heidelberg, New York: Springer-Verlag, 2002), 151–156.

relationship to a set of tension zones, for example, the West African tropical rainforest, the Indian Monsoon transformation, the reversed Albedo in Himalayan glaciers, and the fate of the Greenland ice sheet. In total, there were about a dozen literal battle zones, indicated on a world map, where humanity's war with the Earth System was raging especially hard. It was pedagogical, and again underscored the importance of heuristic visualizations. But perhaps even more crucial, Schellnhuber had successfully entered the Earth System into a comprehensive narrative. There was a story out there already, and to launch a Big Idea on the scale of Planetary Boundaries, a trust-building narrative arc surely came in handy. The process could move on with reinforced self-confidence.

By September 2008, when the next iteration of the paper arrived, both the project and the process would carry the name of Planetary Boundaries. The "Tällberg consensus" branding of the previous year was gone; it had served as a starter engine for an activity that had now found a distinct direction and identity in its own right, and which had become increasingly refined in the process. Not least because the original broad brush sustainability ideas, Tällberg style, had by then gravitated much closer toward the home turf of Earth System science, with a sizable number of co-authors from that community who had not been part of the original consensus now becoming directly engaged in the paper.

Distancing the new project from past limits concepts was considered important for its success. At one of the preparatory meetings in his SRC office, Johan Rockström leaned toward one of the participants and asked: "Are you sure that this idea of boundaries is not the same as that of the Club of Rome in 1972?" The response was that, yes, you can be confident that it is different, and the reason was given. Still, the question lingered on. When Cambridge geographer Susan Owens, later an honorary doctor at the KTH Royal Institute of Technology (2012), came to Stockholm to take up a visiting Mistra Foundation Royal Carl XVI Gustav professorship in 2009, this was a central topic in conversations with her.[35] Yes, the PB idea was novel, but at the same time, there was reason to voice similar concerns about the problem of homogenization of Earth, Humanity, and Stability (the Holocene) that were already in circulation in the spring of 2009 as the *Nature* paper

[35] Susan Owens, personal communication on several occasions during spring 2009 and again on September 15, 2009 (Sörlin). Documentation in e-mail (with the authors).

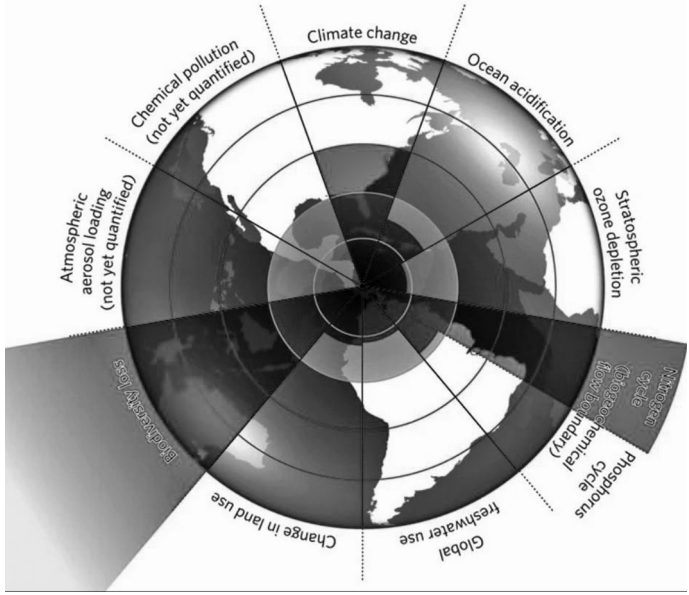


FIGURE 7.5 Planetary Boundaries diagram 2009. The diagram has evolved over the years. This is the original version. Courtesy of Nature Publishing.

started taking shape. Identical points that the humanities and social science critique would address in years to come, both with PB and the Anthropocene concept.[36]

The graphic representation of Planetary Boundaries was not obvious, and it came together late in the process (Figure 7.5). The original design was done by one of the paper's co-authors, Björn Nykvist at the SEI – "I was the data and visualization-person" – who was drawn in "half way" when the boundaries were given numbers and representations. He worked with a core writing team under the leadership of Johan Rockström, along with Åsa Persson, Will Steffen, and Kevin Noone. When they were finished, Nykvist drafted sketches that *Nature*

[36] The source for this paragraph is emails and recollections by one of us authors (Sörlin) and conversations over the years with several others involved in the winding PB process. See especially Sörlin to Rockström February 12, 2009, and Rockström to Sörlin February 14, discussing the status of the Holocene as a stability domain and homogenizing effects of concepts such as Earth and humanity, as well as tactical aspects of how to make the argument inclusive to the whole breadth of the scientific spectrum. E-mails with the authors. The Rockström quote is not documented but from memory by one of us (Sörlin), who also gave the affirmative answer.

then developed into their final form. He remembers that Rockström was clearly behind the visual idea and that several challenges arose, such as the wildly different scales of the boundaries.[37] The PB diagram quickly took on an iconic status and has been reproduced in countless versions, in textbooks and journal articles, on the internet, and in magazines such as *The Economist*. It underscores the role of visuals for communicating complex science-based relationships to wider audiences, both scientific and non-scientific, beyond the limited domain of "contributory" scientific expertise.[38] Surely, the striking, yet somewhat elusive, diagram that broke the rules of most science illustrations with its lack of comprehensive scaling helped the PB idea travel widely. It was a compelling demonstration of an idea rather than, strictly speaking, a diagram.

META-EXPERTISE

In combination, the planetary boundaries diagram and the article it appeared in did other things, too. The intervention reflected a particular role that Johan Rockström, as lead author, was now increasingly assuming: that of a "meta-expert," a torch bearer of "aggregative expertise" on the Anthropocene, resilience, Planetary Boundaries, and other conceptions and responses to global change. It was indeed a new way of looking at the world. The term, "aggregative expertise," has been used before to denote experts that do not limit themselves to speaking publicly on the particular, limited subjects that they have researched, that is, their own scientific specializations. They instead draw out the implications and produce, or circulate, narratives that also encompass results and concepts from others, for example, entire swaths of the Earth System science community and selected ideas from elsewhere to make a point that captures the attention and imagination of media, the public, and policymakers.[39]

While sometimes seen with skepticism by primary "micro" experts, "meta" (or "mega-") experts have been somewhat common in the history of "the environment." This type of actor has been extremely useful

[37] Björn Nykvist to Sverker Sörlin, e-mail April 6, 2018.

[38] P. Morseletto, "Analysing the Influence of Visualisations in Global Environmental Governance," *Environmental Science and Policy* 78(2017): 40–48. Birgit Schneider & Thomas Nocke, eds., *Image Politics of Climate Change: Visualizations, Imaginations, Documentations* (Bielefeld: Transcript, 2014). Harry Collins & Robert Evans, *Rethinking Expertise* (Chicago, IL: The University of Chicago Press, 2009).

[39] Warde, Robin & Sörlin, *The Environment*, 16, 25–46, 164–167, 173.

in advancing their cause beyond the scientific community. We can think of Rachel Carson (*The Sea Around Us* in 1951 and *Silent Spring* in 1962), Barry Commoner (zoologist, author, and eventually a United States presidential candidate), Bill McKibben (activist and author of numerous declensionist books since *The End of Nature* in 1989), Paul Ehrlich (Stanford biologist and author of the 1968 bestseller *The Population Bomb*), Garrett Hardin (the tragedy of the commons article from 1968), or Canadian geneticist David Suzuki (author, activist, and beloved television communicator). Some, like Ehrlich, had connections to Stockholm. Georg Borgström, originally Swedish and with a long career in the United States, appeared as an outspoken neo-Malthusian in the 1950s, a Scandinavian version of the arch-pessimist ecologist and contraception activist William Vogt, whose bestselling *Road to Survival* (1948) opened the discussion for ideas on "the environment." Remarkably, many of the post-war generation of meta-experts had a demographic outlook, wanting to restrict or reduce the world population, sometimes even the number of people in their home countries. A related focus was on resources. Borgström, an alarmist in word and deed, engaged millions of people in the specter of food scarcity, applying rhetorical skills he inherited from his preacher man father.[40]

A very different personality, but also matching the meta-expert profile, was the atmospheric scientist Bert Bolin, who pursued computer-based climate change research from the 1950s and became the founding father of the IPCC in 1988 as the climax of a long career as a world-leading science organizer (see Chapters 3 and 6). He segued discretely but importantly from active research to also assume the role of science diplomat, stitching together teams of scientists and huge collaborative programs, orchestrating their efforts to reach common goals. He was tirelessly presenting the meta-science of climate physics and chemistry to politicians and other leaders, signing off on reports and papers rather than putting in all the labor of collecting data and crafting equations. Bolin had learned a great deal from his mentor, Carl-Gustaf Rossby, a visionary genius and avid organizer of science (Chapter 3). Here was a rhetorical tradition going back to the famously outspoken, enticing, and versatile Svante Arrhenius (incidentally a distant relative of climate activist Greta Thunberg). Rockström was during the PB process taking on a similar kind of role, twenty-first century style, complete with a Netflix

[40] Björn-Ola Linnér, *The Return of Malthus: Environmentalism and Post-War Population–Resource Crises* (Cambridge: White Horse Press, 2003).

documentary (2021). He transformed, or the media turned him, into a meta-scientist, knowingly making himself dependent on many colleagues in order to achieve the "higher good" of establishing a synoptic, policy-friendly view of Earth System science.

This Swedish tradition of environmental meta-expertise, and the PB process, speaks to the same basic properties of Stockholm as a leading hub of environmental governance, namely the four "cons" of conceptualizing, connecting, convening, and contributing (Chapter 1). When the PB article was published in September 2009, it was the fruit of an over two-year-long process that had started with a pair of cons: contacts and conviviality at the Tällberg Forum in June 2007. It continued within a very small group of three or four Stockholm-based scholars that, at Tällberg in 2008, grew to more than twenty, mostly from other countries. In the end, twenty-nine co-authors had contributed to the framework's final formulation. It was a stocktaking process built on confidence, to name another con word.

Another thing that the article did was to communicate certain values that can be linked to Sweden. Then con-way was a Swedish way, of seeking consensus and common ground, and also to work on a level that was not overly esoteric and philosophical but robustly earthy and empirical. "A safe operating space for humanity" may be seen as a formula for the Swedish *Folkhem*, or welfare state, writ large in a planetary version. We may recall that in the 1990s, Swedish Prime Minister Göran Persson had, as part of the comprehensive and austere reform package to curb the country's fiscal crisis, launched the *Green Folkhem* as an optimistic, even cheerful, path forward in the midst of a political situation that was in other respects quite gloomy. In essence, Swedish policy, Folkhem-style, was a balancing act, navigating between guard rails. It was a policy of avoiding extremes, de-risking, and bringing everyone on board. A bit like Volvo cars, perhaps boring and not the sexiest vehicles on the road, but capable of safely taking you to your destination. It worked well for a good deal of the twentieth century, during which Swedish environmental policy was also, after all, pragmatic rather than radical, after protracted debates almost always settling for some modest but efficient version of mainstream modernism, grey rather than green (or even red).[41]

[41] Erland Mårald & Christer Nordlund, "Modern Nature for a Modern Nation: An Intellectual History of Environmental Dissonances in the Swedish Welfare State," *Environment and History* 26 (2020):4, 495–520.

The early Swedish Green Deal was perhaps the Folkhem's last hurrah before a more polarized politics of the 2000s set in (more on this in Chapter 9). The 1990s were Rockström's formative years as a scientist. The PB article is also at pains in not making nods in any particular political direction, probably intentionally. It is open to business and capitalism, and certainly comes across as one of the most outspoken attempts to launch the entire Earth as a "level playing field," where any forces – certainly including economic growth and development – can operate, as long as they help heal the planet.[42] But the planetary boundaries framework and its creators do not say no to socialism, either. The approach, especially if seen over the full fifteen years since the PB process started, is quite eclectic, to say the least. In later work, Rockström has spoken highly of "pragmatism," of state-led innovation (neo-Keynesian style, with reference to economist Mariana Mazzucato), and the necessity of equity in moving the PB concept forward. His latest book includes a foreword written by Greta Thunberg, a fellow Swede, but also a staunch radical, whose ideas Rockström has occasionally distanced himself from, but whose persona and presence on the world – or Earth – stage he has wholeheartedly welcomed. Rockström has occasionally talked about the need not just for transformation but "revolution."[43]

In this respect, the PB project can itself be seen as a convening enterprise, an initiative to build consensus around a new understanding of the Earth that may encompass some kind of politics down the road, although it is not entirely clear what type. It was a reconciliation of many opposites, not by design but a kind of tacit acceptance: between capitalism-socialism, environment-development, Global North-Global South, Holocene-Anthropocene. Coming out of the fields of development and agricultural policy, Rockström was rooted in expert management and could well use a firm guiding hand for development. Demonstrating the durability, or perhaps long gestation time, of certain ideas, the institutional and intellectual platform upon which Rockström gained much of his recognition, even fame since the late 2000s is built

[42] Based on email correspondence between Sörlin and Rockström during 2009 (with the authors).

[43] All examples and quotations from Rockström & Gaffney, *Breaking Boundaries*. For one of several statements in recent years about the need for "revolution," see an interview (in Swedish), "Rockström on Climate: Don't Know if We Will Pull This Off," *Syre* 2020: 2, https://tidningensyre.se/2020/2-januari/rockstrom-om-klimatet-vet-inte-om-vi-kommer-att-klara-det-har/.

upon a scientific theory from the early 1970s that was decades later mobilized through an international network of global change experts.

RESILIENCE – THE CONCEPT AND THE ALLIANCE

The Resilience Alliance was established in 1999 as an international network of natural and social scientists whose research revolved around the resilience concept first put forward by C. S. Holling in 1973. In addition to the core idea of *resilience* – the ability of a system to withstand disturbances while maintaining its core structure and functions – a suite of ancillary concepts and normative beliefs support "resilience thinking" among Alliance members.[44] The most fundamental of these is that human and non-human systems are inextricably linked, constituting coupled *socio-ecological systems* that can be scaled up to the level of the Earth System.

In the resilience worldview, interactions between different scales in space and time are of critical importance, with systemic changes understood as part of perpetual *adaptive cycles* taking place within a multilevel framework that the concept's followers call *Panarchy*.[45] To generate what are deemed to be positive outcomes, the Resilience Alliance promotes *adaptive management* as a scientifically informed method of environmental governance and embraces *transformation* of societal systems to increase resilience and achieve sustainability. Like the links between social and ecological systems, the coupling of science and governance is thus a fundamental aspect of the resilience concept as understood by its adherents within the Alliance.

Stockholm-based actors would, both before and after the founding of the Resilience Alliance, make a significant contribution to the institutionalization and popularization of the concept. This process began in earnest in the early 1990s with a series of workshops that facilitated international networking and resulted in interdisciplinary collaborations that helped further develop Holling's original concept, which was already twenty years old at that point. The institutionalization of resilience would expand significantly in the following decade

[44] Carl Folke, Stephen R. Carpenter, Brian Walker, Marten Scheffer, Terry Chapin & Johan Rockström, "Resilience Thinking: Integrating Resilience, Adaptability and Transformability," *Ecology and Society* 15(2010):4, 20.

[45] Lance Gunderson & C. S. Holling, eds, *Panarchy: Understanding Transformations in Human and Natural Systems* (Washington, DC: Island Press, 2002).

FIGURE 7.6 Brian Walker, Simon Levin, Karl-Göran Mäler, and Partha Dasgupta (left to right) in 2002 at the Beijer Institute's annual gathering of ecologists, economists, and other environmentally concerned scientists on the island of Askö, where Stockholm University manages a Baltic Sea marine laboratory. That same year, Mäler and Dasgupta – close friends and long-time scientific collaborators – were together awarded the Volvo Environment Prize. The Askö meetings have played a significant role in the development of the field of ecological economics since the early 1990s. Photo: Anna Sundbaum/ Courtesy of the Beijer Institute.

with the establishment of a well-financed scientific research institute in Stockholm that was mandated to inform policymaking both in Sweden and internationally. Moreover, the first major international conference dedicated to the concept of resilience would be convened in Stockholm shortly after the founding of the new institute.

Resilience and social-ecological systems had been recurring themes at the Beijer Institute's annual Askö workshops, held in the seaward skerries outside Stockholm in the years leading up to the founding of the Resilience Alliance in 1999 (Figure 7.6). Ecological economics, the scientific focus of the second incarnation of the Beijer Institute, would serve as an interdisciplinary bridge for studying interlinked social and environmental systems that underpinned resilience thinking. In summarizing

the proceedings of the first Askö meeting in 1993, Beijer's deputy director Carl Folke concluded that ecologists and economists could indeed find common ground despite the significantly different perspectives on the human environment that had to date characterized their respective professions.[46]

As an essentially integrative concept, resilience offered the kind of common scientific ground on which experts from diverse disciplines could collaborate in pursuit of solutions to complex problems associated with sustainability. An early example was an article resulting from the 1995 Askö workshop, "Resilience in Natural and Socioeconomic Systems." Its seventeen natural and social science co-authors, some of whom would become founding members of the Resilience Alliance, included economists Karl-Göran Mäler, Partha Dasgupta, William Baumol, and Ing-Marie Gren; ecologists C. S. Holling, Simon Levin, Ann-Mari Jansson, and Bengt-Owe Jansson; biologist Paul Ehrlich, climate scientist Bert Bolin, and Carl Folke, whose scientific background encompassed both ecology and economics.[47] Like the Planetary Boundaries articles fifteen years later, and even the Tällberg Foundation's 350 advertisement, the programmatic paper from the Askö meeting in 1995 was an example of the big tent science that reflected the convening power of Stockholm. Not simply presentations of the results of scientific research, such pieces also served as proclamations for emerging intellectual movements that aimed to inform policy and influence the governance of socio-ecological systems at all levels of abstraction.

Many of the members of the expanding Beijer-Askö network would continue to collaborate across a range of projects and publications on related topics, as resilience became an increasingly prominent paradigm for understanding and addressing the challenges of the human environment during the 1990s and 2000s. With the retirement of Karl-Göran Mäler in 2006, Carl Folke became director of the Beijer Institute of Ecological Economics, which was at that point embarking upon a new collaboration to shape the institutional home for the Stockholm Resilience Center, bringing together Beijer and thereby the Royal Swedish Academy of Sciences, Stockholm University, and the SEI under the banner of resilience.

[46] Carl Folke, "Ecologists and Economists Can Find Common Ground," *Bioscience* 45(1995):4, 283–284.

[47] Simon Levin et al., "Resilience in Natural and Socioeconomic Systems," *Environment and Development Economics* 3(1998):2, 222–235.

The Stockholm Resilience Centre was inaugurated in 2007 with the unusual arrangement of Beijer's Carl Folke and Johan Rockström of SEI co-leading the new institution. In their capacity as science organizers and mediators of environmental knowledge, they would carry the mantle of Bert Bolin and Gordon Goodman, both of whom would pass away, each at the age of eighty two, in the year following the establishment of the SRC. While Folke had been engaged with the Beijer Institute's work on socio-ecological systems and the seminal Askö ecological economics workshops since the early 1990s, Rockström's specialization in hydrology and water management in semi-arid and tropical areas had seen him conduct extensive field research and development work in sub-Saharan Africa. His 2004 return to Stockholm from Zimbabwe came following a phone call from Bolin, who, on Folke's recommendation, recruited Rockström to become the executive director of the SEI – a position he would continue to hold until 2012, even after he took on the same title at the SRC in 2007.

Substantial support (the grant was around 25 million US dollars over ten years) for the SRC was provided by the Mistra Foundation (independent like all foundations, founded by the Swedish state in 1993) that finances strategic environmental research, usually of longer duration. Soon after its founding, the SRC would profile itself as a major international hub for the study of social-ecological systems (SES). Based on Mistra's call for an interdisciplinary research institute that could support sustainable governance in the wake of the Millennium Ecosystem Assessment, the strategic mission of the SRC would also include the production of science that was relevant for policy formation in Sweden and beyond. Hence, some thirty-five years after Holling's groundbreaking article, a cadre of Swedish and international resilience devotees would help establish the ideas for which they received handsome backing. Both directors had paid their dues for quite some time and performed impressively on most scores. This was a new step, with much broader support. Resilience and SES science had come of age, with Stockholm as a major hub within an extensive international network of experts.

However, despite the decisive gesture of establishing what was from the outset intended to be a world-class institution backed by long-term funding, staffed and supported by a network of renowned experts in their respective fields, the scientific niche and strategic purpose of the SRC were in its early years somewhat opaque to outside observers. The ambitious mission that combined producing cutting-edge research with ongoing engagement in societal decision-making processes, together

with the Centre's complex organizational structure and the wide array of stakeholders its leaders were answerable to, generated a fair amount of uncertainty and confusion, internally as well as externally.[48] Moreover, resilience was initially a relatively unknown and ambiguous concept outside a community of sustainability specialists, with the term often being associated with infrastructure, health, and civic organizations, rather than socio-ecological systems or sustainable development. A successful rollout and embrace of resilience thinking, both within and beyond scientific circles, was therefore far from assured at the time of the Centre's founding.

THE FRIIBERGH MANOR WORKSHOP – AND SUSTAINABILITY SCIENCE

These early challenges were elaborated in a Start-up Review commissioned by Mistra two years into the Center's first funding period. The review was conducted precisely by Harvard ecologist William C. Clark, who had been a key participant in the Villach-Bellagio process during the 1980s and thus had long-standing ties to Stockholm. Clark was also a leading figure in another network centered on a subject known as sustainability science. It was a similarly comprehensive scientific paradigm concerned with nature-society interactions, which had developed in parallel to the rise of resilience during the decade leading up to the founding of the SRC. In problematizing what its practitioners consider modern society's unsustainable development pathway, the new synthetic discipline was based upon the application of scientific analysis to increase understanding and devise progressive solutions to the myriad complex challenges endemic to the twenty-first century human environment.[49] In fact, and ironically, the very concept of sustainability science, often attributed to Clark, was one that the Centre actively distanced itself from in its first phase, largely as it fought hard to define itself as different from the very start. Little would Centre leadership know that Clark was going to be their first evaluator, and even larger was the relief when the outcome was so reassuring.

[48] William C. Clark, *Start-up Review of the Stockholm Resilience Centre* (Stockholm: Mistra Foundation, 2009).

[49] William C. Clark & Nancy M. Dickson, "Sustainability Science: The Emerging Research Program," *Proceedings of the National Academy of Sciences (PNAS)* 100(2003):14, 8059–8061. William C. Clark & Alicia G. Harley, "Sustainability Science: Toward a Synthesis," *Annual Review of Environment and Resources* 45(2020):1, 331–386.

The formative moment for the international sustainability science movement, which has since spawned dedicated research programs, a scholarly journal, and an entire academic discipline – and has also become a core aspect of the SRC's scientific profile – took place at the turn of the millennium at a seventeenth-century mansion an hour outside Stockholm. The five-day Sustainability Science Workshop at Friibergh Manor in October 2000 was hosted by the Swedish Research Council and sponsored by various Swedish and American governmental organizations and private foundations.

The workshop's organizing committee included Clark, Bert Bolin, marine biologist Jane Lubchenco, and Uno Svedin, a trained physicist who spent much of his career engaged with research policy in the realms of environment and sustainability. As the director of research at the Swedish Council for Planning and Coordination of Research (*Forskningsrådsnämnden*, FRN) from 1981 to 2001 and international director at the funding agency Formas until 2010, Svedin has played a crucial role in connecting research communities and organizing international scientific events, including an earlier conference at Friibergh Manor in 1986. Such meetings were instrumental in the development of emerging concepts and disciplines like resilience, sustainability science, and ecological economics. Svedin had also during his years at FRN been actively engaged in the funding of interdisciplinary leaning environmental scholars such as Carl Folke in their very early career phases in the 1980s and early 1990s.[50]

Sustainability science explicitly entailed transcending particular disciplinary boundaries to bring diverse areas of expertise to bear in addressing practical, yet seemingly intractable, problems at the intersection of environment and society. In addition to the range of experts representing the Earth and life sciences, the convergence of research communities at the 2000 Friibergh Manor workshop also included specialists in the human and societal aspects of socio-ecological and planetary systems. Among the founders of sustainability science in attendance at Friibergh were geographers Akin Mabogunje and Tim O'Riordan and economist Sylvie Faucheux. Also there was Jill Jäger, the Villach-Bellagio veteran who was at that point the executive director of the International Human Dimensions Programme on Global Environmental Change – the humanities and social science component of the Earth System Science Partnership that had been founded in 1990.

[50] Personal communication, Uno Svedin.

The new discipline would be widely promoted within international scientific circles in the months following Friibergh. In the tradition of producing multi-author manifestos to publicly pronounce new scientific and policy-relevant standpoints, the twenty-three workshop participants signed the Statement of the Friibergh Workshop on Sustainability Science and reiterated their adherence to the sustainability science approach to real-world problems in an April 2001 article in the journal *Science*.[51] Momentum continued to build in the lead-up to the July 2001 Challenges of a Changing Earth Conference that was organized under the auspices of the Earth System Science Partnership. At the Amsterdam Conference (earlier, note 15), William Clark presented sustainability science to the global change community in what amounted to a coming-out party for the new paradigm that combined the rigors of science with the concerns and convictions of social and environmental activism. Sustainability science thus resembled resilience in its aspiration to serve as a norms-based transdisciplinary tool for the governance of socio-ecological systems, with substantial overlap and cross-fertilization between the two communities of activist scientists.

CONVENING POWER: RESILIENCE 2008

The convening power of Stockholm demonstrated by the Friibergh workshop – one of many milestones in a long tradition that dates back to the science organizing efforts of Carl-Gustaf Rossby and Bert Bolin in the 1950s – was further amplified with the SRC's founding in 2007. In his Start-up Review of the Centre's first two years, Clark asserted that the concept of convening power could extend beyond physical meetings to also include orchestrating and providing intellectual leadership for international scientific initiatives such as the Planetary Boundaries project:

> Measured by convening power, the Centre's *Resilience 2008 Conference* [in April that year] brought together a substantial fraction of the world leaders in the field, and was referred to by several senior scholars I contacted as one of the most exciting research conferences they could remember. The SRC's convening power is also reflected in the forthcoming (and soon to be legendary) *Nature* paper on "Planetary boundaries: Exploring safe operating space for humanity." The co-authors of this paper include a Nobel Laureate, directors of most of SRC's top competitor institutions, and sundry luminaries from the natural and

[51] Robert W. Kates et al., "Sustainability Science," *Science* 292(2001):5517, 641–642.

social science … in short, people that any scientist would be proud to have as collaborators. Several of them that I contacted readily acknowledged the leading role played by first author Johan Rockstrom and other SRC scientists in conceiving and drafting this paper. I heard similar stories about other collaborative efforts driven by the Centre.

More than a strictly scientific event, "Resilience 2008: Resilience, Adaptation and Transformation in Turbulent Times" was a celebration of a concept that at times seems to transcend science to take on the trappings of an ideological or philosophical framework (Figure 7.7). "A central message of the Resilience 2008 Conference," according to its host institution, "was that resilience is not just an ecological issue – it involves ecological, economic, cultural, ethical and other social dimensions and values."[52] In its ambition to order earthly activity around the ideal of robust SES, resilience thinking had developed into something more than a scientific theory. It bears traits of a secular belief system, replete with a founding father in ecologist visionary C. S. Holling, a literary canon and cosmology in Holling's writings and his Panarchy framework, the Holy Ghost *qua* Hysteresis curve, the specter of Armageddon in ecological and planetary tipping points, and the promise of salvation in the case of societal transformation toward sustainability.

The April 2008 Conference was convened under the auspices of the Resilience Alliance, the Royal Swedish Academy of Sciences, and International Council for Science (ICSU). The latter was at that time led by Thomas Rosswall, a Swedish biologist and founding director of the International Geosphere Biosphere Programme, it too located in the Academy of Sciences building on the Stockholm University campus north of the city, just like so many other institutions and actors we have come across in the Stockholm story. Some 600 natural and human scientists would congregate in Stockholm for four days of what the SRC described as "a dense trans-impulsive program including science, art-exhibitions, music, culture, social events, and a high-level science-policy event."[53] In terms of scientific content, the Resilience 2008 Conference's call for papers announced nine overall themes encompassing a wide variety of human–environment interactions to be explored through the lens of resilience and its range of subsidiary concepts. The themes – inscrutable to

[52] SRC *Annual report* 2008.

[53] SRC *Annual report* 2008. On one of the art pieces presented, see Sverker Sörlin, "The Vulnerable Volvo," In: Jennifer Newell, Libby Robin & Kirsten Wehner, eds., *Curating the Future: Museums, Communities and Climate Change* (London & New York: Routledge, 2016), 215–218.

FIGURE 7.7 Concluding panel discussion of the Resilience 2008 Conference hosted by the Stockholm Resilience Centre. A milestone in the institutionalization of a scientific concept that had by then been in circulation for several decades, Resilience 2008 and the six panelists portrayed here embody the four fundamental con-words of this book: convening, conceptualizing, contributing, and connecting. From left to right: Sverker Sörlin, co-founder (with Nina Wormbs) of the KTH Environmental Humanities Laboratory; Elinor Ostrom, Nobel laureate in economics for her work on common pool resources; C. S. "Buzz" Holling, former director of IIASA who coined the resilience concept in ecology in 1973; Uno Svedin, an accomplished science organizer and research financer, as well as, along with Sörlin, a co-author of the 2009 Planetary Boundaries paper; Line Gordon, director of the Stockholm Resilience Centre since 2018; and Carole Crumley, a founder of Historical Ecology and former director and founder of the Integrated History and Future of People on Earth (IHOPE) community of researchers. All six held close associations with the Stockholm Resilience Centre from its founding in 2007. Photo: Jerker Lokrantz/azotelibrary.com.

those uninitiated into resilience thinking – included "Traps, regime shifts, and transformations," "Knowledge management and social-ecological learning," "Urban social-ecological system challenges," and "Adaptive governance and multilevel challenges."

The convening power of Stockholm, reflected in the success of Resilience 2008 and embodied by the Planetary Boundaries project,

would culminate in the convergence of two major scientific movements for which the Swedish capital had become a leading international node. The PB project was a collaboration between the SRC and the Earth System Science Partnership, with the Tällberg Foundation providing a policy perspective.[54] In line with this joint effort, the twenty nine authors of the 2009 Planetary Boundaries piece in *Nature* were drawn from international networks of resilience and Earth System scientists. The article's lead authors – Johan Rockström and Will Steffen – had held leadership positions in Stockholm-based institutions representing each of the respective scientific fields. What is more, three members of the 2000 Friibergh workshop's organizing committee – Uno Svedin, climate scientists Robert Corell, and the above-mentioned Hans Joachim Schellnhuber – were among the Planetary Boundaries co-authors, indicating the inclusion of a sustainability science angle inside the PB project as well as within the wider nexus of resilience and Earth System science.

In addition to the fundamental goal of producing knowledge on global change and aspects of the Earth System, the three intertwined networks were united in their ambition of creating concepts, tools, and frameworks for advancing sustainability and facilitating environmental governance at all levels. Corresponding to the holistic and interconnected outlook of Earth System science, the preferred perspective was planetary, with a common denominator in the idea that the global environment represents an indispensable life support system for human survival and civilization. Since the establishment of the IGBP in the mid-1980s and accelerating around the turn of the century, a variety of planet-level paradigms for environmental governance have been proposed by natural and social scientists associated with the resilience, sustainability, and Earth System science movements. A nonexhaustive inventory of maximalist concepts that have sought to render the Earth a governable object through synthesizing environmental science and politics includes "planetary management," "planetary stewardship," "Earth System stewardship," "Earth System governance," and, perhaps most prominently, the "Planetary Boundaries framework." Most of these emanated from Stockholm-based institutions, or from contexts that involved such institutions.

More than half of the Planetary Boundaries authors had SRC affiliations or other close connections to Stockholm. Published less than three

[54] SRC *Annual report* 2008.

months before COP15, the *Nature* article made specific reference to the highly anticipated UNFCCC Conference in Copenhagen that would take place in December 2009. Although the authors acknowledged that momentum was building in support of the "2°C guardrail" approach for containing climate change, the article advocated a limit expressed in atmospheric CO_2 concentration – a measurement pioneered by the Bert Bolin-collaborator Charles David Keeling – rather than the less precise benchmark of global mean surface temperature. In one of seven expert commentaries that accompanied, and in some cases criticized, the *Nature* article, the 350-ppm planetary boundary was questioned by climate scientist Myles Allen. In the critical lead-up to COP15, Allen saw the ppm-based boundary as a distraction to the more immediate 2°C target that had already been adopted by the European Union as its basis for climate policy.[55] Planetary Boundaries was thus, by design, embedded in environmental governance debates from the outset, and soon after the article's publication would serve as the foundation for a series of policy-oriented interventions by political scientists and other scholars at the SRC and elsewhere.

The 350 ppm climate threshold was one of three planetary boundaries that had already been transgressed at the time of the framework's publication. Despite the best efforts of many of the Planetary Boundaries authors to convince politicians on the imperative of decisive action on climate, and the fact that atmospheric CO_2 concentrations were in late 2009 well on their way to 400 ppm, COP15 concluded without reaching a binding global agreement on greenhouse gas emissions. The widely

[55] Richard S. J. Tol, "Europe's Long-Term Climate Target: A Critical Evaluation," *Energy Policy* 35(2007):1, 424–432; Samuel Randalls, "History of the 2°C Climate Target," *WIREs Climate Change* 1(2010):4, 598–605; Carlo C. Jaeger & Julia Jaeger, "Three Views of Two Degrees," *Regional Environmental Change* 11(2011):Suppl 1, 15–26; Sabine Höhler, "Two Degrees: A Global Climate Accord and Its Disparities," in *Creative Commensuration: Histories of Scaling in Science and Society*, Workshop Center History of Knowledge, Zurich, July 7–8, 2016. Eric Paglia, "The Socio-scientific Construction of Global Climate Crisis," *Geopolitics*, 23(2018):1, 96–123. Westermann & Höhler, "Writing History in the Anthropocene," esp. 590–591, 594, observing how scaling and global numbers tend to obscure historical actors, geographical particulars, and economic practices. Eric Paglia & Erik Isberg, "On Record: Political Temperature and the Temporalities of Climate Change," In: Anders Ekström & Staffan Bergwik, eds., *Times of History, Times of Nature: Temporalization and the Limits of Modern Knowledge* (New York: Berghahn, 2022), 277–301. See also Frank R. Rijsberman & Rob J. Swart, eds., *Targets and Indicators of Climatic Change* (Stockholm: SEI, 1990), produced by the SEI under the auspices of the Advisory Group for Greenhouse Gases, AGGG, discussed in Chapter 6, as a seminal early proposal for temperature targets as a basis for policy.

perceived failure in Copenhagen, which would demoralize much of the climate movement for months if not years after COP15, did however succeed in introducing the 2°C target into UNFCCC proceedings through the signing of the Copenhagen Accord. Although not immediately apparent amid the prevailing disappointment of COP15, the institutionalization of 2°C – which would become the foundation of the celebrated 2015 Paris Agreement – opened a new pathway for international climate politics. It also represented a relative success for one of the Planetary Boundaries authors, Hans Joachim Schellnhuber, who had advocated for a 2°C temperature target since the time of the first COP meeting in Berlin in 1995.

FAULT LINES IN THE STOCKHOLM CONSENSUS

While Schellnhuber is sometimes referred to as the father of the 2°C target, another Planetary Boundaries co-author – the Stockholm University-trained Paul Crutzen – could be regarded as not only the progenitor of the Anthropocene concept but also the leading proponent of the controversial idea of geoengineering. In a seminal 2006 editorial essay in the journal *Climatic Change*, Crutzen, who passed away in 2021, described the injection of sunlight-reflecting sulfate particles into the stratosphere as a potential "escape route" in the case of climate policy failure, which he considered likely given its track record, and the eventual rise of global temperatures above 2°C. His support for taking initial steps, such as modeling and eventual experiments, into exploring geoengineering options was reiterated in the heavily cited 2007 article in *Ambio* that he co-authored with Will Steffen, who passed in 2023, and John McNeill.[56] Crutzen's interventions on geoengineering as a last resort tool of climate governance punctured a perceived taboo on the topic, leading to a wave of new research and discussions – as well as recriminations – on the scientific, engineering, and ethical aspects of intentional climate modification.[57] International interest in geoengineering as a fallback option was

[56] Will Steffen, Paul Crutzen, & John R. McNeill, "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?," *Ambio* 36(2007):8, 614–621.

[57] Clive Hamilton, "Geoengineering and the Politics of Science," *Bulletin of the Atomic Scientists* 70(2014):3, 17–26. Mark G. Lawrence & Paul J. Crutzen, "Was Breaking the Taboo on Research on Climate Engineering via Albedo Modification a Moral Hazard, or a Moral Imperative?," *Earth's Future* 5(2017):2, 136–143. We have found no evidence, however, that Crutzen's co-authors, McNeill and Steffen, in earnest approved of Crutzen's predisposition toward climate geoengineering.

further enhanced following the COP15 failure to forge a new emission reduction regime, and the science of geoengineering is ongoing.[58]

Schellnhuber, for his part, was not as sanguine on the specter of solar radiation management as an escape route or silver bullet solution to the climate crisis. In his famous 1999 *Nature* article "'Earth System' analysis and the second Copernican revolution," he had listed geoengineering as one of five possible paradigms for proactive global environmental management or Earth System control. By 2011, however, Schellnhuber had signaled his opposition to solar radiation management, using geopolitical arguments based on the Cold War metaphor of mutually assured destruction. Yet both Schellnhuber and Crutzen had that same year, 2011, participated in a scientific working group on climate commissioned by the Pontifical Academy of Sciences that concluded it "may be prudent to consider geo-engineering if irreversible and catastrophic climate impacts cannot be managed with mitigation and adaptation." A degree of ambiguity, even ambivalence, can thus be discerned surrounding the personal convictions and eventual policy prescriptions that some Earth System scientists would, in the case of failed mitigation efforts, be willing to embrace on one of the most consequential global environmental governance questions of the twenty-first century.

PROMETHEUS VS. SOTERIA

No such ambiguity exists in the positions taken over the past decade by Mark Lynas and Clive Hamilton. The British and Australian, respectively, authors and public intellectuals have been two of the more prominent popularizers and outspoken supporters of Earth System science, the Anthropocene concept, and the Planetary Boundaries framework. Lynas and Hamilton have both employed the same scientific paradigms as points of departure for scholarly articles, media polemics and popular science books, and reports on the powers and prerogatives of humanity in confronting climate change and other environmental challenges. Nonetheless, they have come to see the relationship of people and planet in starkly different lights. Like Crutzen and Schellnhuber, both Lynas and Hamilton strongly support strict anthropogenic CO_2 emission reduction regimes under the UNFCCC as the primary political means for mitigating climate change. Yet in terms of the societal shifts required

[58] Jeroen Oomen, *Imagining Climate Engineering: Dreaming of the Designer Climate* (Abingdon & New York: Routledge, 2021).

to create an ecologically sound safe operating space for humanity, and the options that could be considered – or ruled out – in the case of an incipient climate catastrophe, the sustainability pathways they have espoused point toward dramatically divergent futures for the planetary human environment. Their contradictory perspectives and prescriptions reflect an underlying tension in what might otherwise be considered a Stockholm consensus on scientifically informed global environmental governance.

Lynas made his mark in the mid-2000s with a pair of popular science contributions to the climate debate. *High Tide: The Truth About Our Climate Crisis* and *Six Degrees: Our Future on a Hotter Planet* drew heavily on IPCC reports and helped amplify the growing public and political perception of climate change as an emerging global crisis. A frequent visitor to Stockholm, Lynas' connections inside the Swedish scientific community led to his invitation to attend the planetary boundaries planning session ahead of the 2008 Tällberg Forum. The idea of quantifiable planetary boundaries as elaborated by the scientists on hand at the closed-door meeting was a revelation for Lynas, and it was there in Tällberg, where he also consulted with Johan Rockström, that he decided to structure his next major work around the framework.

The God Species: How the Planet Can Survive the Age of Humans would serve to popularize the planetary boundaries concept beyond the rather restricted realm of scientific literature, where the articles in *Ecology & Society* and especially *Nature* had already made a major impact.[59] Published in 2011, *The God Species* marked a personal turning point for Lynas, who would from that point forward publicly embrace the ethos of ecomodernism and promote controversial technological solutions for combating the climate and environmental crises. The god-like planetary agency that humans had acquired with the advent of the Anthropocene should, according to Lynas, not be wasted but instead wielded for the worthy purpose of increasing welfare while

[59] An October 2, 2010, email sent to the Planetary Boundaries authors by one of the twenty nine co-authors, who had personal contact with Lynas, asked if anyone in the group would be interested in reading and commenting on a draft of the *God Species* manuscript. Parts of the email read as follows: "Inspired by our Planetary Boundaries paper (and, as I understand it, with encouragement from Johan), Mark has written a new book on global environmental change currently titled: *The God Species: How our planet can survive the Age of Humans* … he has now finished the draft of the book and asked me if I would approach the 'team' to see if any of you are willing to read and comment on the draft. I have taken a quick look and it is a lively read – he certainly has an angle that will attract attention to the issues (and indirectly to our papers!)." E-mail with the authors.

keeping the Earth and its inhabitants within the scientifically determined safe operating space, where economic growth and most aspects of modern life could continue unabated. In his estimation, the vast majority of environmentalists – himself included – had been misguided in their opposition to powerful technologies like nuclear energy and the genetic modification of plants that would facilitate climate mitigation and adaptation efforts. If all else failed, Lynas' anointed God Species could as a last resort consider exercising its planetary agency by pursuing climate geoengineering options.[60]

By contrast, the Australian philosopher and professor of public ethics Clive Hamilton sees the increasing capacity of the human species to intervene in the climate system as a singularly frightening situation. Unlike the exaltation of human agency that underpins *The God Species*, the title of Hamilton's 2013 book *Earthmasters* is purely pejorative in its critique of the network of influential individuals and institutions – including certain scientists and research laboratories – that possess a "Promethean" urge to dominate the planet through geoengineering. Rather than a rational response to the prospect of runaway climate change, research on solar radiation management and the eventual implementation of large-scale climate modification schemes, such as spraying sulfate particles into the stratosphere, would, in Hamilton's view, constitute "the most dangerous experiment ever conceived."[61] Invoking the Greek goddess Soteria, who bestowed safety and preservation from harm to humanity, Hamilton – whose previous writings had criticized consumerism, climate denialism, and the fetish of economic growth – instead advocated a "Soterian" approach toward human interventions in the Earth System as a counter to the hubris and high-risk technological solutions of the Prometheans.[62]

Hamilton's outlook on geoengineering is consistent with his outright rejection of ecomodernism and the idea of a "good Anthropocene." Yet in some cases, on matters that are related but separate in terms of solutions, he also sides with some of the leading geoengineering advocates. Defending the prerogative of Earth System scientists such as Paul Crutzen to define and date the Anthropocene, Hamilton describes the onset of the human-dominated epoch as a very recent rupture in Earth history that

[60] Mark Lynas, *The God Species: How the Planet Can Survive the Age of Humans* (London: Fourth Estate, 2011).
[61] Hamilton, "Geoengineering," p. 25.
[62] Clive Hamilton, *Earthmasters: Playing God with the Climate* (London: Allen & Unwin, 2013).

cannot be ascribed to activities and technologies prior to the modern period, as some ecomodernists have claimed. The de facto destruction of the relatively stable Holocene at the hands of humans – a radical historical break that Hamilton attributes to "*homo faber*, the technological man of modern Western civilization" – represented a phase shift in the functioning of the Earth System, which has made the latter a more volatile and potentially hostile operating space for humanity.[63] Hence, in a no-analogue state of the planet, the past has become a less reliable proxy for the future, and the ability of previously resilient ecosystems and human societies to adapt to environmental change, which might become sudden and severe rather than gradual and foreseeable, can no longer be taken for granted. Ecomodernist expectations of a good or even great Anthropocene therefore represent, according to Hamilton, a "perverse reading of Crutzen's conceptual innovation."[64]

Geoengineering can thus be seen as a subset of a larger and deeper social and political, as well as technological and even theological, struggle between Promethean and Soterian perspectives on environmental governance and sustainable development. As demonstrated by the antithetical prescriptions of Lynas and Hamilton, a shared scientific point of departure for diagnosing the environmental and climate crises does not necessarily create a consensus view on how societies, economies, and the international system should adapt, invest, and transform to address the governance challenges associated with global change. This fundamental divide can be illustrated by two diametrically opposed documents released in the spring of 2015, a landmark year in global environmental governance that would witness the signing of the Paris Accord and the adoption of the UN Sustainable Development Goals.

Mark Lynas was one of the eighteen authors of *An Ecomodernist Manifesto*, a Promethean treatise released in April 2015 that celebrated the social, economic, and technological power of humanity to shape its own planetary operating space. While acknowledging that significant damage had been inflicted upon the biosphere in reaching this stage of development, the *Manifesto* rejected imposing restraints on human agency and argued that technology has not only made humanity far less dependent on the natural world (a positive for ecomodernists), but that

[63] Clive Hamilton & Jacques Grinevald, "Was the Anthropocene Anticipated?," *The Anthropocene Review* 2(2015):1, 59–72, on 67.

[64] Clive Hamilton, "The Anthropocene as Rupture," *The Anthropocene Review* 3(2016):2, 93–106, on 99.

it can also enable environmental protection and extend prosperity to greater numbers of people on the planet. In placing their full faith in technology to empower humanity and avert environmental crises, the *Manifesto's* authors consider the prospect of a great Anthropocene to be well within reach.[65]

In stark contrast to the Promethean perspective of the ecomodernists, Pope Francis' encyclical letter on the environment, *Laudato Sí': On Care for Our Common Home*, attributes environmental deterioration and endemic poverty to precisely the same forces that *An Ecomodernist Manifesto* identified as the basis of success and salvation for the human species: free market economics and the widespread application of science and technology in modern society. Published in June 2015, *Laudato Sí* singles out climate change, water pollution, and biodiversity loss as symptoms of a consumerist culture that degrades quality of life and social cohesion while also fostering global inequities. Underpinning these problems of modernity is what Pope Francis sees as misguided and excessive anthropocentrism, and a lack of care and appreciation for God's earthly creation. The Pope's encyclical letter, for which Hans Joachim Schellnhuber served as chief scientific advisor, represented a de facto repudiation – in a vein similar to the Soterian convictions of Clive Hamilton – of the ecomodernist idea that a human-dominated Anthropocene world could ever be considered "good."[66]

TOWARD HUMANIZING THE FRAMEWORK – PLANETARY BOUNDARIES 2.0

The divergent pathways put forward by Prometheans and Soterians, and a spectrum of positions in between, are evidence that science is not independently equipped or capable of determining the structure and direction of global environmental governance. Even politics are in a sense downstream from some of the more deeply held beliefs surrounding how humans ought to interact with the biosphere and the Earth System as a whole. Despite the epistemological power of the Stockholm scientific nexus – resilience thinking and Earth System science, Planetary Boundaries and the Anthropocene, ecological economics, and sustainability science – reaching a broad Stockholm consensus on a range of

[65] John Asafu-Adjay et al., *An Ecomodernist Manifesto* (2015), www.ecomodernist.org.
[66] Pope Francis, *Praise Be to You – Laudato Sí: On Care for Our Common Home* (San Francisco, CA: Ignatius Press, 2015).

basic principles, priorities, and practices for governing the global environment is therefore likely to remain elusive. Given the highly contested social and political aspects of contemporary sustainability politics, guidance, rather than technocratic forms of governance, is perhaps a more reasonable expectation that scientists and the results of their research can be called upon to provide.

As it were, that was precisely how Planetary Boundaries 2.0 would be framed, with an updated version of the framework setting the stage for the turning point year of 2015. In the interim period since the original Planetary Boundaries publications in 2009, scholars associated with the SRC had produced a body of work intended to demonstrate the utility of the framework as an instrument for illuminating, conceptualizing and supporting environmental governance imperatives.[67] Planetary Boundaries would also underpin British economist Kate Raworth's acclaimed doughnut economics model, introduced in 2012, which combined the framework's Earth System limits with a set of social boundaries to specify "a safe and just operating space for humanity."[68] Other initiatives, such as the Future Earth-funded "Seeds of a Good Anthropocene" project based at the SRC, sought to leverage science in real-world situations at the interface of environment and development. The network of Stockholm-affiliated experts also brought Earth System science to bear on international political processes by organizing the 2012 Planet Under Pressure Conference in London. The event, held under the auspices of the IGBP and the Earth System Science Partnership, was timed to contribute to the Rio+20 sustainability summit, where the new global agreement – the eventual Sustainable Development Goals of Agenda 2030 – to succeed the Millennium Development Goals would be at the top of the agenda.

[67] See, for example, an array of articles in special issues of the journals *Ecological Economics*, 81(2012), and *Current Opinion in Environmental Sustainability*, 4(2012), issue 1.

[68] Kate Raworth, "A Safe and Just Operating Space for Humanity: Can We Live Within the Doughnut?," *Oxfam Discussion Papers*, 2012. Raworth's model contains clear echoes of Barbara Ward's early 1970s conceptualization of "inner limits" of fundamental human needs and "outer limits" of the Earth's physical integrity. See, for example, the Ward-written Coyococ Declaration of October 1974, reprinted in the *Journal of the Atomic Scientists* 31(1975):3. The inner/outer limits conceptualization was also advanced by key Cocoyoc (and Stockholm Conference) participants Maurice Strong and Marc Nerfin in conjunction with an international conference organized by the Dag Hammarskjöld Foundation in Täljövik, Sweden, in June 1974. Dag Hammarskjöld Foundation, "50 Years Dag Hammarskjöld Foundation," *Development Dialogue* 60(2012).

By the beginning of 2015, as anticipation and anxiety mounted over the upcoming COP20 meeting in Paris and with the UN General Assembly scheduled to decide upon the Post-2015 Development Agenda that had emerged in Rio in 2012, a window of opportunity had opened. The time was ripe for providing additional precision on the contours of humanity's safe operating space, and for contributing updated guidance on how to remain inside it. Within a week of the January 2015 publication of "Planetary Boundaries: Guiding Human Development on a Changing Planet" in the journal *Science*, the new version of the framework would make its debut beyond scientific circles before global elites at the World Economic Forum in Davos.