

Threats to the Biosphere: Eight Interactive Global Crises

John Cairns, Jr., Ph.D.,

Department of Biological Sciences, Virginia Polytechnic Institute and State University,
Blacksburg, Virginia 24061, USA.

Abstract

Eight global crises – human economy, climate change, exponential human population growth, ecological overshoot, biotic impoverishment and the reduction of biodiversity, renewable resource depletion, energy allocation, and environmental refugees – affect each other and affect and are affected by the biosphere. Some, perhaps all, are close to tipping points that, if tipped, will result in irreversible change. And yet, no sense of urgency is apparent. If any one of the eight interactive crises passes a tipping point, it will probably act as a threat multiplier for the remaining crises. Both politicians and the average citizen believe that priorities can be established for these interactive crises, but such an option is not viable for a highly interactive system. Polls indicate that most people place economic growth as the highest priority for human society, even though the highest status should be given to the master biospheric life support system to which all other systems are subordinate.

Key Words: Resource depletion, Energy, Environmental refugees

An age is called Dark not because the light fails to shine, but because people refuse to see it. - James Albert Michener

The scientist is not a person who gives the right answers; he's the one who asks the right questions. -Claude Levi-Strauss

1. Tipping Points

Most complex ecological and social systems have one or more tipping points beyond which change is irreversible (e.g., Catton 1982). Passing a tipping point in any one of the eight, complex systems (human economy, climate change, exponential human population growth, ecological overshoot, biotic impoverishment and reduction of biodiversity, renewable resource depletion, energy allocation, environmental refugees) would produce a ripple effect in the other seven and probably throughout the entire biospheric life support system (Solomon et al. 2009).

Reducing risk in the context of the eight interactive global crises would be a difficult undertaking even if the task only involved scientific evidence. Mixed into the responsibility of reduction of risk and avoiding tipping points is the general public's assessment of important issues for the planet. Gertner (2009) quotes a poll, conducted by the Pew Research Center two days after President Obama was sworn in, that ranks "the issues Americans said were the most important priorities for this year [2009]. At the top of the list. . . jobs and the economy. . . Farther down, well after terrorism, deficit reduction and energy . . . was climate change. It was priority No. 20. That was last place."

Economic growth has both provided many benefits to humans and been a major forcing factor in the eight interactive global crises discussed in this manuscript. Perpetual material (i.e., physical) growth is simply not possible on a finite planet, which was recognized over 30 years ago by Economist Kenneth E. Boulding (1972) in his "Ballad of Ecological Awareness." It was published as the conference summary for Farvar and Milton's volume *The Careless Technology*. The conferees were seated in alphabetical order at a huge round table at the 1968 conference, so I had the honor of sitting next to Boulding. I still remember his asking me: "what rhymes with schistosomiasis?" I gave an inadequate reply, but found out later that he was writing a ballad. The ballad is as useful today as the year it was written.

"No growth" (i.e., steady-state) economics has been espoused by Daly (1991, 1994) and Daly and Townsend (1993). The economics of climate change is also discussed in the "Stern Review on the Economics of Climate Change" (Stern 2009). If natural resources were used within the biosphere's regenerative capacity, the probability of crossing tipping points would be significantly reduced.

2. The Human Economy

Hawken et al. (1999) note that "an economy needs four types of capital to function properly:

- human capital, in the form of labor and intelligence, culture, and organization
- financial capital, consisting of cash, investments, and monetary instruments
- manufactured capital, including infrastructure, machines, tools, and factories
- natural capital, made up of resources, living systems, and ecosystem services

The industrial system uses the first three forms of capital to transform natural capital into the stuff of our daily lives: cars, highways, cities, bridges, houses, food, medicine, hospitals, and schools."

Natural systems (fisheries, forests) are usually regarded as subsets of the human economy. However, in fact, the human economy is a subset of the biosphere (aggregate, global, natural systems).

The human economy is substantially different from the economy of natural systems. The genus *Homo* was spread thinly over the planet in small tribal groups for most of 4 million years. Upon the emergence of *H. erectus* and with the transition to *H. sapiens*, when an animal was killed, it was eaten and the hide was used for clothing or other purposes. Hides and human wastes nurtured the biosphere. The rate of growth of the human population was trivial. After the Industrial Revolution, wastes were often harmful to the biosphere because they could not be assimilated into the environment or they exceeded the biosphere's assimilative capacity for them. The human economy is in crisis because it wants "more" of everything for ever more people.

Practices to increase material goods in one area of the world by using natural resources often has effects on other parts of the planet. China's impressive economic growth is fueled by coal: "In Shanxi, filthy coal is a part of daily life, providing a cheap, readily available source of energy that won't be replaced by renewables or reduced via conservation efforts anytime soon" (Minter 2010). "By one estimate, China was responsible for 85 percent of the world-wide growth in coal demand last year, and what it didn't obtain from the world's third-largest known reserves, it imported" (Pearse 2010).

Much of China's coal comes from Australia, which is paying a climate change price: "The driest inhabited continent has just endured its warmest decade on record and its worst drought in history. It's finally started raining again, but not before the 10-year "Big Dry" cost a quarter of all farm jobs" (Pearse 2010). In short, Australia is both feeling and fueling climate change: "Australians unwilling to see the irony of the situation sometimes have it forced on them. In 2007, cyclonic winds washed a coal tanker up on an iconic surf beach in New South Wales. Greenpeace seized the moment, projecting the words COAL CAUSES CLIMATE CHAOS onto the beleaguered ship's hull" (Pearse 2010).

3. Global Climate Change

Humans have evolved and flourished in the present climate – an alternative climate will probably be less favorable. Combustion of fossil fuels during the Industrial Revolution produced more carbon dioxide than the biosphere could assimilate, and anthropogenic greenhouse gas emissions began to change the climate. Reduction of anthropogenic greenhouse gas emissions is possible by switching to alternative sources of energy (e.g., solar, wind). Although remarkable increases have been made in the development of wind power (Sawin 2010) and solar power (Liu 2010), fossil fuel production is still increasing (Russell 2010) and anthropogenic greenhouse gas emissions are still rising. As a consequence, the atmospheric concentration of carbon dioxide is still growing, as are world carbon dioxide emissions from fossil fuel burning (Mulrow 2010). This situation has already caused glaciers to begin melting and has shifted rainfall patterns that cause both droughts and floods. Obviously, humans have affected the climate and vice versa. If emissions of anthropogenic greenhouse gases, such as carbon dioxide, continue to increase, more climatic tipping points will probably be passed.

The Intergovernmental Panel on Climate Change (IPCC 2007) presents a number of detailed reports that contain scenarios based on the level of greenhouse gases in the atmosphere. The reports summarize a vast body of literature that is analyzed by thousands of climate scientists. The IPCC reports tend to be conservative since many governments influence the executive summary but not the supporting scientific evidence. Also, no body of evidence exists in human history on the rate of climate change being experienced.

Although some evidence on global warming was published in the 1800s, most of the literature is from the last three decades, and the amount is breathtaking. The scientific process is designed to correct errors and generally does so quite well. However, when the number of printed pages is large, the probability is greater that some small errors will be found. In the context of climate change in the news media, these errors are pounced upon and given a great deal of attention. The errors typically have little or no impact on climate science and are usually corrected promptly. However, these small errors have left some doubt in the public mind about scientists and the scientific process, which is regrettable since the preponderance of evidence on climate change becomes more persuasive as the amount of evidence increases.

4. Exponential Human Population Growth

In 1927, the global human population was 2 billion; in 2010, it is nearly 7 billion, which is over a 3-fold increase in a single human lifetime on a finite planet. In 2009, the number of starving people and the number of malnourished people each exceeded 1 billion. In addition, billions of people lack potable water, adequate housing, education, and medical services. If every individual on the planet lived as individuals in the United States live, five planet Earths would be needed. No substantive discussion has been forthcoming on whether humankind's goal is for a populace living at subsistence levels or for a much smaller population leading a quality life. If humankind decided on a smaller population leading a quality life, then how could the population be reduced in a humane way? To achieve any goal, a free and open discussion is essential, but religious beliefs and ideology have blocked even the beginnings of such a discussion on exponential human population growth.

Climate change is already having adverse effects upon agricultural productivity in many parts of the world, which will probably reduce the global carrying capacity for humans. Major adaptation to new conditions will be essential if civilization is to survive. Sustainable use of the planet will be a distant dream as long as humankind thinks that the natural laws of physics, chemistry, and biology can be ignored as applied to exponential human population growth.

The human population is still growing exponentially. How did one species become so dominant that it could compete successfully with all the other animal species for resources and space? This achievement is accompanied by considerable risk because humans are damaging their biospheric life support system by both sheer numbers and environmental destruction (Ehrlich and Ehrlich 2008). Diamond (2005) has analyzed how human societies choose to succeed or fail. Some past societal collapses were not fatal to the human species

since isolated events affected only one or a few societies. Globalization may have ended isolation; however, since humankind depends on cheap, abundant resources and regeneration of natural resources, regionalization may soon return.

5. Ecological Overshoot

Ecological overshoot refers to using Earth's resources faster than they can be regenerated, which is due to both exponential population growth and excessive resource consumption. Sustainability requires living within the regenerative capacity of the biosphere (Wackernagel et al. 2002). The last Earth Overshoot Day was 25 September 2009 – the day on which humankind exceeded the regenerative capacity of the biosphere for that year. In economic terms, this circumstance is a huge ecological deficit, which goes beyond unsustainable to madness! Worse yet, ecological overshoot is not a recently discovered crisis – Catton (1982) published on this crisis years ago. By exceeding the biosphere's regenerative capacity for resources, humankind is using natural capital (and the ecological services it produces) at a rate that probably will result in passing a biospheric tipping point in the near future. A tipping point may already have been passed, but inadequate monitoring systems have not detected it. Other species also depend on the biosphere's regenerative capacity. Ecological overshoot is also an important component of intergenerational equity and violates both eco-ethics and sustainability ethics. Finally, without adequate resources, the human economy will collapse.

6. Biotic Impoverishment

A major study has confirmed that "the world's governments will not meet their internationally-agreed target of curbing the loss of species and nature by 2010" (Black 2010). Since many of the planet's species have not yet been named, calculating the precise extinction rate is difficult; however, the current extinction rate is estimated at 1,000 times the background rate and may climb to 10,000 times the background rate if present trends continue. This loss would easily equal those of past great extinctions. A major report – the Millennium Ecosystem Assessment Report (2005) – summarizes this crisis, and Benn (2010), the UK's environmental secretary, believes "The decline in the world's biodiversity is approaching a point of no return. . . The big challenge will be for the real benefits of biodiversity and the hard costs of its loss to be included in our economic system and markets." Fischetti (2010) notes that "a team of 30 scientists across the globe have determined that the nine environmental processes [biodiversity loss, land use, freshwater use, nitrogen and phosphorus cycles, stratospheric ozone, ocean acidification, climate change, chemical pollution and aerosol loading in the atmosphere]... must remain within specific limits, otherwise the 'safe operating space' within which humankind can exist on Earth will be threatened. . . . the world has already crossed the boundary in three cases: biodiversity loss, the nitrogen cycle and climate change."

Immediate steps must be taken to avoid further reduction of biodiversity (e.g., Myers et al. 2000). The general public and its political representatives might be more concerned with biotic impoverishment if they understood that species are the basic components of the

biosphere, which serves as a planetary life support system. Lovelock (2009, p. 33) states that the Earth system, which he calls Gaia, is in trouble, and "the climate war could kill nearly all of us and leave a few survivors living a Stone Age existence. But in several places in the world, including the UK, we have a chance of surviving and even living well." This statement is clearly a worst-case scenario, but does drive home the point that humans are part of Gaia and, when it suffers, humankind suffers as well. The biosphere is clearly a functional system that is more than a collection of millions of species. The charismatic species receive the most attention, but as Louis Pasteur stated: "The role of the infinitely small in nature is infinitely large." The little species ran the planet without humans for billions of years, and humans cannot currently do without them. However, most of humankind lives in cities and has little opportunity to develop a relationship with nature – referred to as biophilia by Wilson (1984).

7. Renewable Resource Depletion

Wastes from *Homo sapiens*, including industrial wastes, are often deleterious to natural systems. Wastes can be a threat to the regeneration of natural resources instead of being nurturing, as is the case for the wastes of the majority of species.

Moreover, in 2009, humankind used natural resources at 140% of Earth's regenerative capacity (<http://www.footprintnetwork.org>). Humankind must redesign its wastes to mimic nature's model (Cairns 2010), cease profligate use of natural resources, and stay within Earth's carrying capacity for its species. Without a steady output of renewable natural resources, the human economy would suffer a serious decline and Earth's carrying capacity for humans would decline precipitously.

8. Energy Allocation

Earth is warming because the emissions of heat-trapping gases (greenhouse gases) exceed the biosphere's assimilative capacity for them. Heat-trapping gases have been present in the atmosphere for millions of years, i.e., Earth's past climate has resulted from natural causes. However, since the Industrial Revolution, anthropogenic greenhouse gas emissions have overwhelmed the biosphere's assimilative capacity. Consequently, the climate is warming at a rate unprecedented in human history. Not only has oceanic water changed from mildly alkaline to mildly acidic (<http://www.ocean-acidification.net/>), but multidimensional climate changes have threatened agricultural productivity, freshwater supplies, and ecologic systems – for example, flowers may bloom before pollinators are present.

The unrestrained burning of fossil fuels produced in an ancient biosphere has been a significant factor in climate warming, but a huge release of stored carbon in positive feedback could cause runaway climate change. Better insulation of buildings could markedly reduce demands for energy and decrease pressure for construction of new fossil fuel and nuclear power plants. However, exponential human population growth could increase use of fossil fuels even if per capita energy consumption remains constant. If

increased purchasing power of developing countries continues, coupled with increased per capita consumption of resources, energy demands will increase even more.

The goal should be to keep anthropogenic emissions of greenhouse gases within or below the biosphere's assimilative capacity for them. An equitable way to achieve this goal would be to establish a per capita anthropogenic greenhouse gas emission level (WBGU Presse 2009) that would not exceed the biosphere's assimilative capacity. The total emissions would be assigned to the nation states of the world with heavy fines and/or sanctions if emissions levels were exceeded.

A major problem, especially in the 21st century, has been a carefully crafted, well financed campaign to cast doubt on global climate science. The product – doubt – has been established in the minds of the general public (Hoggan 2009), and little or no public support is observable for remedial action such as reducing anthropogenic greenhouse gas emissions or rapid development of alternative forms of energy (e.g., solar, wind).

9. Environmental Refugees

The issue of environmental refugees has not yet reached a global crisis level, but could do so because of food shortages, coastal flooding, and loss of low-lying islands (e.g., The Maldives). If "business as usual" continues and anthropogenic greenhouse gas emissions are not reduced to match the biospheric assimilative capacity for them, the present numbers of environmental refugees will almost certainly increase. Sea level rise will increase the vulnerability of low lying islands and estuaries to storm surges. More ecological and societal tipping points will be crossed, and agricultural productivity and freshwater supplies will decrease markedly. The numbers of environmental refugees will increase markedly, and the nations to which they migrate with hopes for a better life may not be prepared to provide food, housing, medical care, education, and employment, to mention a few necessities.

If oceanic water warms more, methane will be released. Some methane is already bubbling to the surface, and no robust evidence is available on how long this release has been going on or how much is reaching the atmosphere. Carbon is also stored in permafrost, wetlands, soils, and timber. Climate change could release much of this as carbon dioxide. In a worst case scenario, this could cause runaway climate change, and many millions of environmental refugees. Many regions will already have exceeded the carrying capacity for humans, and the refugees will further destabilize an already hazardous situation.

Unsanitary refugee campgrounds are breeding grounds for a pandemic disease to start, and further migration would help spread the disease. In addition, environmental refugees would make conditions much worse in nations that run an ecological deficit, much like their getting into an overcrowded lifeboat. Nations are not prepared to receive the world's refugees.

10. Biospheric Context

The eight interactive global crises must be addressed collectively in a biospheric context. Some illustrative examples are presented in Power Point lectures in the Legacy Lectures/Supercourse at <http://www.bibalex.org/supercourse/nas/nas.htm> — John Cairns, Jr. This biospheric series is a work in progress, and more illustrative examples of relevant issues in a biospheric context will be added. The biosphere is central to resolving the global crises and also serves as the planet's life support system.

11. Decision Science

The developing field of decision science may be critical in coping with the crises that humankind faces. It is an "intersection of psychology and economics, . . . focuses on the mental processes that shape our choices, behaviors, and attitudes. . . . people can behave unexpectedly when confronted with simple choices. We have many automatic biases – we're more adverse to losses than we are interested in gains, for instance – and we make repeated errors in judgment based on our tendency to use shorthand rules to solve problems" (Gertner 2009).

Researchers in the Center for Research on Environmental Decisions (CRED) "consider global warming a singular opportunity to study how we react to long-term trade-offs, in the form of sacrifices we might make now in exchange for uncertain climate benefits far in the future" (Gertner 2009). Research of Elke Weber (as quoted in Gertner 2009) indicates "that we have a 'finite pool of worry,' which means we're unable to maintain our fear of climate change when a different problem – a plunging stock market, a personal emergency – comes along. We simply move one fear into the worry bin and move one fear out." Weber (as quoted in Gertner 2009) also describes a "single-action bias": "Prompted by a distressing emotional signal, we buy a more efficient furnace or insulate the attic or vote for a green candidate – a single action that effectively diminishes global warming as a motivating factor."

Although scientific studies of the eight interactive global crises is dauntingly complex, the global climate crisis has shown that, despite a huge, still increasing mountain of evidence, public concern about climate change diminished as the evidence increased. Doubts sown by climate change "skeptics" was undoubtedly a significant factor, but the human decision making process is probably the decisive factor. If so, then more research into the area of decision science would be prudent.

12. Conclusions

A tyranny surfaces when decisions are based primarily on components of any highly interactive system – decisions should be based on the whole rather than the parts. This situation is exacerbated when political concessions are made on individual components that are the focus of special interests groups and that are deleterious to the entire system (e.g., fossil fuel subsidies).

Most politicians and the general public favor **economic growth**, so discussion of climate change is likely to be regarded as subversive. At present, the most discussed interactive global crisis is **climate change**, but a well financed organization of "deniers" has blocked any effective remedial action. An unwritten, very effective taboo is active in discussions of **exponential human population growth**. **Ecological overshoot** is not regarded as a crisis because the consequences are not yet visible to many people in developed countries. Of course, most people in developing countries are well aware of the ecological overshoot crisis, although they would use different words to describe it. The **biodiversity crisis** has received much attention in the news media, but little effective corrective action has been attempted (e.g., polar bears). A huge number of people live in cities and have little or no connection to natural systems; however, this situation cannot be the main explanation for the lack of empathy for natural systems. **Renewable resource depletion** is a major problem (e.g., Amazon forests). Although a few sanctuaries have been established and portions of old growth forests have been temporarily preserved, depletion of natural resources is, in general, much more rapid than their regeneration. **Energy allocation** is mostly based on ability to pay, although some countries have subsidies for the poor. Combustion of fossil fuels, especially coal, has exacerbated global warming and other types of climate change. Better insulation of buildings would save much energy, but the incentives to do so on a massive scale are lacking. Development of non-carbon alternative energy sources (e.g., solar, wind) is beginning to pick up speed, but the need is greater than the action. Nuclear energy is non-carbon, but problems remain, such as terrorism; storage of long-term, high-level wastes; and the availability of huge amounts of cooling water. A massive wave of environmental refugees has not yet appeared, but flooding of low lying islands, estuaries, and heavily populated coastal areas is in the near future if present trends continue. Such incidents as a major decrease in agricultural productivity, greatly reduced freshwater supplies, continued exponential human population growth, further increases in environmental endocrine disruptors, or pandemic diseases could initiate massive migrations.

One hopes none of these crises will ever worsen, but robust information indicates they will. Regrettably, most people and most politicians are either unaware or in denial about the existence of these crises.

A full and open discussion of these interactive crises and the consequences of their continuing are badly needed now. Some of the crises are already political dynamite (i.e., global climate change, exponential human population growth, the human economy, sources of energy); others will become controversial as soon as the effects on people's lives become evident (i.e., biotic impoverishment, renewable resource depletion, and ecological overshoot). In addition, the news media will need investigative reporters with high scientific literacy to cover the unfolding of the events. Finally, humankind will need leaders with the courage to give Winston Churchill-type speeches ("Blood, sweat, toil, and tears") to convey the urgency needed to avoid making the crises worse.

Acknowledgments: I am indebted to Darla Donald for transcribing the handwritten draft and for editorial assistance in preparation for publication. Paula Kullberg and Karen Cairns also brought many important articles to my attention.

References

Benn, H. (2010). Biodiversity nears "point of no return." BBC News, 23Mar
<http://news.bbc.co.uk/2/hi/science/nature/8461727.stm>.

Black, R. (2010). World's 2010 nature target 'will not be met.' BBC News, 29Apr
http://news.bbc.co.uk/2/hi/science_and_environment/10092320.stm.

Boulding, K. E. (1972). Ballad of ecological awareness. In Farvar, M. T., Milton, J. P. (Eds.), *The Careless Technology*, Natural History Press, New York, US.

Cairns, J., Jr. (2010). Expanding ecotoxicology to enhance the health of the biosphere. Supercourse Legacy Lecture: National Academy of Sciences Members' Lectures. Online at jcairns@vt.edu.

Catton, W. R. (1982). *Overshoot: The Ecological Basis for Revolutionary Change*. University of Illinois Press, Champaign, IL, US.

Daly, H. E. (1991). *Steady-State Economics: Second Edition with New Essays*. Island Press, Washington, DC, US.

Daly, H. E. (1994). Farewell speech to the World Bank. The World Bank, Washington, DC, US.

Daly, H. E., Townsend, K. N. (1993). *Valuing the Earth: Economics, Ecology, Ethics*. Massachusetts Institute of Technology, Cambridge, MA, US.

Diamond, J. (2005). *Collapse: How Societies Choose to Fail or Succeed*, Viking Press, New York, US.

Ehrlich, P. R., Ehrlich, A. H. (2008). *The Dominant Animal: Human Evolution and the Environment*. Shearwater Books/Island Press, Washington, DC, US.

Fischetti, M. (2010). Is Earth past the tipping point? *Scientific American*,
<http://www.scientificamerican.com/blog/post.cfm?id=is-earth-past-the-tipping-point-2010-03-18>.

Gertner, J. (2009). Why isn't the brain green? *New York Times*, 19Apr
http://www.nytimes.com/2009/04/19/magazine/19Science-t.html?_r=1.

Hawken, P., Lovins, A., Lovins, H. (1999). *Natural Capitalism*. Little, Brown, and Company, Boston, MA, US.

Hoggan, J. (2009). *Climate Cover-up: The Crusade to Deny Global Warming*. Greystone Books, Vancouver, Canada.

IPCC. (2007). http://ipcc.ch/publications_and_data/publications_and_data.htm

Liu, Y. (2010). Solar power experiences strongest year of growth yet. In *World Watch Vital Signs 2010*. The World Watch Institute, Washington, DC, US, pp. 18-20.

Lovelock, J. (2009). *The Vanishing Face of Gaia: A Final Warning*. Basic Books, New York, US.

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-Being: General Synthesis*. Island Press, Washington, DC, US.

Minter, A. (2010). Addicts: China remains wedded to dirty coal, despite huge investments in clean energy, when its own supplies lag, other nations are happy to feed its need. *Sierra*, 95(3), 56, 58, 60.

Mulrow, J. (2010). Climate change proceeds down worrisome path. In *World Watch Vital Signs 2010*. The World Watch Institute, Washington, DC, US, pp. 45-48.

Myers, N., Mittermeier, R. A., Mittermeier, C. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 402, 853-858.

Pearse, G. (2010). Enablers: Australia has suffered hellish wildfires and withering drought – and is asking for more through its massive coal exports. *Sierra*, 95(3), 57, 59, 61.

Russell, J. (2010). Fossil fuel production up despite recession. In *World Watch Vital Signs 2010*. The World Watch Institute, Washington, DC, US, pp. 24-29.

Sawin, J. L. (2010). Wind power increase in 2008 exceeds 10-year average growth rate. In *World Watch Vital Signs 2010*. The World Watch Institute, Washington, DC, US, pp. 12-14.

Solomon, S., Plattner, G.-K., Knutti, R., Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences*, 29Jan <http://www.pnas.org/content/early/2009/01/28/0812721106.abstract>.

Stern, I. (2009). *The Stern Review on the Economics of Climate Change*. In Heinberg, R. (Ed.), *Blackout: Coal, Climate and the Last Energy Crisis*. New Society Publishers, Gabriola Island, Canada, p. 147.

Wackernagel, M. and ten co-authors. (2002). Tracking the ecological overshoot of the human economy. *Proceedings of the National Academy of Sciences*, 99(14), 9266-9271.

WBGU Presse. (2009). Solving the climate dilemma: The budget approach.
http://www.wbgu_press_liste_engl.html.

Wilson, E. O. (1984). *Biophilia*. Harvard University Press, Cambridge, MA, US.