

## **CARRYING CAPACITY AND SUSTAINABILITY: WAKING MALTHUS' GHOST**

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### **Summary**

The relevance of “human carrying capacity” to sustainability is much in dispute. Many traditional economists and technological optimists believe that the concept is defunct. They argue that trade and technology have historically pushed back the “limits to growth” and will continue to do so indefinitely. Resource depletion is therefore of no consequence and sustainability is best assured by staying our present growth-oriented course. Expansionist thinking is rooted in abstract economic models and monetary analyses that are devoid of biophysical data and ignore fundamental physical laws. This thinking drives world development.

By contrast, many ecologists and earth scientists insist that human carrying capacity remains a vital concern. They argue that the explosion of human populations and cultural artifacts made possible by trade and technology can only be temporary. Economic growth is increasingly based on the depletion of “natural capital”, rising pollution levels, and declining biodiversity. Since these trends undermine global life support, “human load” already exceeds global carrying capacity and is eroding future potential. Such conclusions are based on physical laws, complex systems models, empirical analyses, and global trends, but are essentially ignored in decisions by key decision-making bodies.

Studies of early civilizations support the ecological perspective. Human societies follow a predictable cycle of growth and development (complexification) followed by decline and collapse. This cycle is associated with progressively falling marginal returns from initially profitable investments in socioeconomic and physical infrastructure. The “complexification” of industrial society was funded by abundant fossil fuel. Cheap energy vastly increased the availability of resources (seemingly expanding carrying capacity) but at the expense of ecosystems integrity. Consequently, the world is experiencing declining marginal returns on various resource fronts and may be facing an energy supply/price shock. Any resultant implosion of biophysical limits would destroy prospects for sustainability and trigger the decline of contemporary society.

## **1. Introducing Carrying Capacity**

At first glance, “carrying capacity” seems like a fairly straightforward concept. Bridges are engineered to a specified load-bearing capacity; ocean-going freighters can carry only so much cargo. When it comes to ecosystems, ecologists speak of the maximum population deer or elk that can be supported indefinitely in a defined habitat without permanently impairing its productivity and any old-time dairy farmer knew just how many cows he could safely graze on the back forty without wrecking the pasture. It therefore doesn't seem like much of a stretch to estimate the human carrying capacity of a region or a country – or even the whole Earth.

Look again. The demands of non-human species on their habitats are fixed and limited to food and sometimes shelter, the simplest of material requirements. However, human demands are hardly simple and are constantly evolving. Thus, when biologist Joel Cohen asked, “How many people can the Earth support?”, he was able to find published answers ranging across three orders of magnitude, from less than a billion to over a trillion – a *thousand* billion! Some analysts argue that the present population of six billion is already several times over the sustainable carrying capacity of the earth; others purport to show that Earth is still practically empty of people. It seems like the short answer to Cohen's question is “it depends”– it depends on the quality of the data used in making the estimates and on the assumptions, values, and beliefs of the assessor.

This chapter examines competing interpretations of human carrying capacity. The weight of physical and historic evidence shows that carrying capacity remains a central element, and should be the organizing theme, of both local and global sustainable development initiatives.

## 1.1 Why Do Population – and Carrying Capacity – Matter?

“...I say that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.” (Thomas Malthus, 1798)

The Reverend – and economist – Thomas Malthus opened the modern debate on carrying capacity late in the eighteenth century with his famous essay *On the Principle of Population*. Malthus’ concern was based on elementary arithmetic. He observed that “population, when unchecked, increases in a geometric ratio, subsistence increases only in an arithmetic ratio.” A modern scholar might have put it this way: population increases exponentially (like compound interest) while food production increases only linearly, in constant increments.

However one chooses to express the relationship, “a slight acquaintance with numbers will show the immensity of the first power in comparison to the second...” Malthus knew that the reproductive powers of plants and animals, including humans, were such that if provided with adequate sustenance, they could fill hundreds of worlds in just a few centuries. He also knew that the earth was finite – that space and nourishment were limited – and that this reality restrained life within tightly prescribed bounds. In Malthus’ words, “The race of plants and the race of animals shrink under this great restrictive law. And the race of man cannot, by any efforts of reason, escape from it”. Clearly, to Malthus, humanity was caught forever in the grip of the earth’s limited “carrying capacity”.

Malthus’ warning caused no little controversy in its time, but while his theory seemed undeniable, the threat to contemporary Europeans seemed so far off (the entire world population was then less than a billion and there were whole new continents to be peopled) that it was shortly forgotten in the growing optimism of the dawning industrial age. Indeed, those who did remember Malthus would later dismiss his “dismal theorem” on grounds that he had not anticipated the ability of technology to keep food production expanding a step ahead of population growth.

It was not until the 1960s that the “Malthusian specter” raised its head once again. It had taken until 1930, more than a century after Malthus’ death, for the world population to gain its second billion, but the growth rate itself was increasing. The third billion was added in just 30 years, by 1960. Not surprisingly, the “population question” began to re-emerge as a matter of public concern, culminating with the publication of Paul Ehrlich’s *The Population Bomb* in 1968. Just six years later (and only 14 years after reaching three billion) the human population passed the four billion mark. Meanwhile, the economy had been expanding even faster than population and, with it, anxiety about urban, industrial, and agricultural pollution. Rachel Carson’s *Silent Spring* (1962) had sounded the warning and galvanized the public. By the end of the decade, the “environmental movement” had emerged as a real political force.

By now it was clear that any new concern about human carrying capacity would necessarily extend far beyond mere population size. Humanity’s impact on our earthly habitat was scaled not only by sheer numbers of people, but also by average levels of resource consumption and by the relative sophistication of our industrial technologies.

Biologists Paul Ehrlich and John Holdren captured the matter handily in 1971 with their concise formula for environmental impact:  $I = PAT$ , where ‘I’ is impact, ‘P’ is population, ‘A’ is a function of affluence (consumption), and ‘T’ is a function of technology (type and efficiency).

Despite the increase in public anxiety and the flurry of environmental legislation in the 1970s, Malthus’ geometric multiplier continued to grind away and the industrial juggernaut plunged ahead as never before. By November 1999, the human population had topped six billion, having doubled since 1960. (It had taken two million years for the human population to reach three billion; the second three billion were added in just forty years!) Meanwhile the economy had expanded more than three-fold.

The result of these inexorable trends would seem to have been predictable on a finite planet. At the dawn of the twenty-first century, the massive scale of human activity ensures that many environmental impacts are global in scope. Stratospheric ozone depletion now affects both the Southern and Northern Hemispheres; atmospheric carbon-dioxide has increased by 30% in the industrial era and is now higher than at any time in the past 160,000 years; mean global temperature has reached a similar record high; the world seems to be plagued by increasingly variable climate and more frequent and violent extreme weather events; more atmospheric nitrogen is fixed and injected into terrestrial ecosystems by humans than by all natural terrestrial processes combined; up to one-half of the land on Earth has been directly transformed by human action; more than half of the planet’s accessible fresh water is already being used by people; two-thirds of the world’s major fisheries are fully- or over-exploited; and biodiversity losses are accelerating.

The question is whether any of this matters to the survival “technological man”. Certainly many of the world’s top scientists are warning that humans have become a threat not only to the ecological integrity of the planet, but also to themselves. And on the evidence of words alone, the world *seems* to be listening. For at least the past dozen years “sustainable development” has been a stock phrase in virtually every politician’s rhetorical repertoire.

## 1.2 Defining Sustainable Development

On one level, “sustainable development”, like carrying capacity, seems like a simple idea. In its strongest form it recognizes that people and their economies are an integral part of the ecosphere and that they depend for their survival on a steady flow of goods and services – food, water, energy and mineral resources, a stable and predictable climate, etc. – from nature. From this perspective, deteriorating global ecological conditions are seen to pose a threat to human physical well-being and ultimately to geopolitical security. Learning to live sustainably implies taking the measures necessary to ensure that all members of the human family can live satisfying lives within the means of nature (i.e., within the long-term carrying capacity of the earth).

Many international scientific and non-governmental organizations concur with this double-barreled imperative. In *Caring for the Earth* (1991), the World Conservation Union (IUCN), the World Wide Fund for Nature (WWF), and the United Nations

Environment Program (UNEP) defined sustainable development as “improving the quality of human life while living within the carrying capacity of supporting ecosystems”. Similarly, in their brochure, *Action for Global Sustainability*, the Union of Concerned Scientists advocates that “humanity must learn to live within the limits of natural systems while ensuring an adequate living standard for all people”.

The United Nations’ World Commission on Environment and the Economy (the Brundtland Commission) went even further when it published what has become the best-known definition of the sustainability concept in 1987: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” This formulation recognized, that in making legitimate use of the earth, contemporary society has an obligation to leave adequate supplies of essential natural capital – nature’s resources and life support services – intact for use by future generations. In addition to living within ecological constraints and greater intragenerational equity, the Brundtland Commission thus advanced intergenerational equity as a criterion for sustainability.

A casual observer might conclude from all this that an action-oriented consensus was emerging: sustainable development, understood as achieving a degree of social equity while maintaining the human population and economic activity within the carrying capacity of Earth, would be one of the great challenges of the twenty-first century.

## 2. Dueling Paradigms: The Debate Goes On

*“There are no... limits to the carrying capacity of the earth that are likely to bind any time in the foreseeable future. There isn’t a risk of an apocalypse due to global warming or anything else. The idea that we should put limits on growth because of some natural limit, is a profound error and one that, were it ever to prove influential, would have staggering social costs.”*

*(Lawrence Summers, Chief Economist, World Bank, November 1991)*

No such thing. Lawrence Summers’ remark makes clear that not everyone in high places agrees that carrying capacity has any relevance at all to human beings; that we have to respect *any* kind of biophysical limits; or that future generations would be grateful for a healthy endowment of natural capital if it meant they inherited less human and manufactured capital (material wealth). Different interests in society have contrasting “pre-analytic visions” (or paradigms) that shape how they interpret *any* set of facts or circumstances. Because they spring from differing values, beliefs, and assumptions, there is considerable variation among paradigms in their interpretation of human carrying capacity.

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### Bibliography

Beckerman, W.. (1995). *Small is Stupid: Blowing the Whistle on the Greens*. London: Gerald Duckworth and Company, Ltd. [An eloquent defence of growth paradigm against environmentalists' attacks by one of the most able advocates of neoliberal market economics.]

Block, W. (1990). *Economics and the Environment: A Reconciliation*, pp. 281-332. Vancouver, B.C.: The Fraser Institute. [This collection of papers compiled by the Fraser Insitutute (a right-wing think-tank in Vancouver, Canada) is not so much a reconciliation with, as a frontal assault on, the ecological perspective by advocates of sustained economic growth.]

Carley, M and Spapens, P. (1998). *Sharing the World: Sustainable Living and Global Equity in the 21<sup>st</sup> Century*. London: Earthscan Publications. [The volume, inspired by the Sustainable Europe Campaign, argues that humanity has overshot carrying capacity (over-filled environmental space) and that, for reasons of intra- and intergenerational equity, the developed world must adopt new technologies and lifestyles to reduce energy and resource consumption by 80% or more. This will create the "environmental space" required for necessary sustainable growth in the South.]

Catton, W.R. (1980). *Overshoot: The Ecological Basis of Revolutionary Change*. Urbana and Chicago: University of Illinois Press. [This is a classic treatise on ecological limits to growth by sociologist William Catton. Cartton argues persuasively that the (developed) world has just come through an unprecedented – and unrepeatabe – "age of exuberance," that we are now in overshoot and that it will take all our ingenuity to avoid collapse.]

Cohen, J. E., (1995). *How Many People Can the Earth Support?* New York, NY: W.W. Norton & Company. [Cohen has produced one of the best and most comprehensive ecologically-oriented studies of the human population growth, its history, alternative interpretations, and future prospects.]

Diamond, J. (1992). *The Third Chimpanzee*. New York: HarperCollins Publishers. [An outstanding account of the human animal, our relationship to other chimpanzees, our peculiar biological and behavioural traits, our evolutionary history and a glimpse at our clouded future.]

Duncan, R.C. and Youngquist, W. (1999). Encircling the Peak of World Oil Production. *Natural Resources Research* 8, 3: 219-232. [One of several recent studies that emphasize the finite nature of conventional fossil energy supplies, particularly petroleum. The authors show that world oil "production" (extraction) may well peak before 2010, marking a "watershed in human history" and placing the stability of oil-dependent global culture at risk.]

Flannery, T.F. (1994). *The Future Eaters: An Ecological History of the Australasian Lands and Peoples*. Chatsworth, N.S.W.: Reed Books (Also: New York: George Braziller, Inc.). [This is a brilliant highly readable history of the human occupation of Australasia and the Pacific Islands, and the resulting depletion/retreat of non-human species. It is over-flowing with subtle sustainability lessons for the present generation of global "future-eaters".]

Galbraith, J.K. (2000). How the Economists Got it Wrong. *The American Prospect* 11, No. 7. [In this paper, an assessment of the annual meeting of the American Economics Association, James K. Galbraith chides his fellow academic economists for their general failure to address the fact that the empirical evidence "flatly contradicts" conventional theory in all major areas of concern to macro-economics.]

Homer-Dixon (2000) *The Ingenuity Gap*. New York : A. Knopf. [This books makes the case that as world problems become simultaneously more numerous and more complex (partially as the result of continuous growth and ecological stress) the capacity for human ingenuity to meet with the demand for innovative solutions is being taxed to the limit, potentially putting much of humanity at risk.]

Homer-Dixon, T. and Blitt, J. (1998). *EcoViolence: Links Among Environment, Population, and Security*. Lanham, MD: Rowan and Littlefield, Publishers Inc. [The title of this volume is self-explanatory. Using case studies from several countries, Homer-Dixon and Blitt document the relationships of ecological degradation and resource shortages to social inequity, ethnic clashes, civil strife and related threats to human security.]

Lyons, G., Moore,E. and Smith, J.W. (1995). *Is the End Nigh?* Aldershot, UK: Avebury. [This is a depressingly well-documented account of the general failure of the neoclassical economic growth model, particularly its failure to address inequity and ecological destruction, the failure of politics to respond to this economic failure, and the likelihood that the end result will be the catastrophic collapse of civilized society.]

Morrison, R. 1999. *The Spirit in the Gene: Humanity's Proud Illusion and the Laws of Nature*. Ithica, NY: Comstock Publishing Associates (Cornell University Press). [Morrison's is a lively semi-popular account of the apparently genetically-based human capacity for self delusion. People regularly seem to place greater confidence in mystical beliefs and social myths that justify existing patterns of behavior than in the "cascade" of factual evidence that suggests major changes are necessary for sustainability.]

Ophuls, W. and Boyan, A.S. jr. (1992). *Ecology and the Politics of Scarcity Revisited: The Unraveling of the American Dream*. New York: W.H. Freeman and Company. [A classic study of the gulf between the demands of ecological science for firm collective action and the capacity of the political system to respond appropriately, this volume contains one of the best published descriptions of the common-property/public good problem (and recognizes that "common property" here really refers to "open access" resources.)

Ormerod, P. *The Death of Economics*. 1994. London: Faber and Faber. [A sweeping critique of neo-liberal market economics by a well-known professor of economics, this book makes the case, among other things, that "for all its apparent mathematical sophistication, the core model of theoretical economics, that of competitive general equilibrium, is premised on an entirely faulty view of the modern world."]

Ponting, C.(1991). *A Green History of the World*. London: Sinclair-Stevenson. [A sobering history of the world that focuses exclusively on the impact of the unfolding human story on non-human lifeforms, landscapes and the ecosphere.]

Rees, W.E. 2002. Globalization and Sustainability: Conflict or Convergence? *Bulletin of Science, Technology and Society* 22 (4): 249-268. [This paper draws on human social and bio-ecology, human evolutionary history, far-from-equilibrium thermodynamic theory and ecological footprint analysis to argue that all human societies carry the seeds of unsustainability, and that techno-industrial society in particular is inherently unsustainable.]

Rees, W. E. 2001. Ecological Footprint, Concept of. *Encyclopedia of Biodiversity* (Simon Levin, Editor-in-Chief). Vol 2, pp 229 –244. San Diego: Academic Press. [A good introduction to the basic theory, methods and rationale of eco-footprint analysis including a discussion of some of the strengths and weaknesses of the concept.]

Schrödinger, E. 1945. *What is Life: The Physical Aspect of the Living Cell*. Cambridge, UK: Cambridge University Press. [This is the famed physicist's classic discussion of life and living processes, including his ground-breaking explanation of how living systems maintain themselves, in seeming contradiction of the second law of thermodynamics, by feeding on the negentropy of their environment and by injecting positive entropy back into it.]

Simon, J. (1981). *The Ultimate Resource*. Princeton, N.J.: Princeton University Press. [This is one of Julian Simon's most ebullient expressions of confidence in "the ultimate resource" (the human mind) to solve any environmental or technological problem confronting humankind.]

Simon, J. and Kahn, H. (eds) (1984). *The Resourceful Earth: A Response to Global 2000*. Oxford, UK: Basil Blackwell. [In this book, perennial technological optimists Simon and Kahn attempt a rebuttal of the 1980 Global 2000 Report to US President Jimmy Carter. (Many of the problems and trends identified in Global 2000 in fact came to pass or had worsened by 2000.)]

Tainter, J. (1988). *The Collapse of Complex Societies*. Cambridge: Cambridge University Press. [This volume describes and analyses the repeated cycle of flowering and collapse that seems to have characterized complex human societies throughout history.]

UNEP (1999). *Global Environmental Outlook 2000 (GEO-2000)*. United Nations Environment Program: Nairobi. [This is a systematic examination of current environmental trends and policy responses, both globally and region by region, with a prognosis for the future.]

Wackernagel, M. and Rees W.E.(1996). *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, B.C. and New Haven, CT: New Society Publishers. [The most accessible and comprehensive introduction to the background, theory, methods, and application of ecological footprint analysis (available in English, French, German, Italian, Spanish, Chinese, Latvian and Hungarian.)]

Wackernagel, M., Onisto, L., Bello, P., Linares, A.C., Falfán, I.S.L., Garcia, J.M., Guerrero, A.I.S. and Guerrero M.G.S.(1999). National natural capital accounting with the ecological footprint concept. *Ecological Economics* 29: 375-390.

WCED. 1987. *Our Common Future*. Report of the [UN] World Commission on Environment and Development. Oxford: Oxford University Press. [This is the UN report that popularized the concept of sustainable development by defining it in a way to which both environmentalists and economics growthists could subscribe. In the end, the greatest contribution of the report is the debate it stimulated over the practical meaning of sustainability.]

### Biographical Sketch

**William Rees** has always been fascinated by the bio-ecology of *Homo sapiens*, a trait he attributes to his youthful experience working close to the earth on his grandfather's farm. Taking his PhD in population ecology from the University of Toronto, he was astonished to find that human ecology *per se* was of little interest to academic ecologists. (Humans were not regarded as part of nature—and frequently still are not.) Switching disciplines to focus on humans, Prof Rees joined the University of British Columbia's School of Community and Regional Planning (SCARP) in 1969-70. He founded the School's 'Environmental Planning' concentration in the 1970s and from 1994 to 1999 served as Director of the School. Prof Rees' teaching and research focus on the public policy and planning implications of global environmental trends and the necessary ecological conditions for sustainable socioeconomic development. Much of this work is in the realm of ecological economics where Prof Rees is best known for his "ecological footprint" concept. (Ecological footprint analysis estimates humanity's impact on the ecosphere in terms of the area of productive ecosystems required to satisfy human material demands.) Prof Rees is a founding member and recent past-President of the Canadian Society for Ecological Economics. He is also a co-investigator in the "Global Integrity Project," aimed at defining the ecological and political requirements for biodiversity preservation. A dynamic speaker, Prof Rees has been invited to lecture on eco-footprint analysis and sustainability issues across Canada and the US, as well as in Australia, Austria, China, Finland, France, Germany, Hungary, Japan, Mexico, the Netherlands, Norway, Indonesia, Italy, Korea, Japan, the former Soviet Union, Spain, Sri Lanka, Sweden and the UK. In 1997 Prof Rees was awarded a UBC Killam Research Prize in acknowledgment of his research achievements and in 1999 he was recognized by *The Vancouver Sun* as one of British Columbia's top "public intellectuals".