Chapter 5

Overshoot: Interrelations between Population, Consumption and Ecosystems

Anne Ehrlich

Introduction

Most people today have little appreciation of the magnitude of change that human beings have wrought on the planet we inhabit. Still less do most people understand the implications of those changes for the lives of future generations. The modifications have been gradual and increasingly widespread over centuries and millennia, but the human lifespan is too short to perceive it. Nor do most people travel widely, so the pervasiveness of change remains unseen – the disappearance of a patch of forest or a marsh is ordinarily viewed as an isolated, local event, not part of a process affecting the entire world.

This chapter first describes the nature of the predicament humanity is currently facing, through a brief historic overview of how mankind has been changing most of the Earth's original ecosystems. It then addresses the global population growth problem and the difference in wealth between the industrialised nations and the developing part of the world. The interconnections between the principal driving forces of the destruction of humanity's natural capital are assessed in the following two sections. The chapter ends by explaining how the 'overshoot' could be reversed and by providing some conclusions.

The Human Predicament

After evolving over several million years as a medium-sized animal as much at the mercy of its environment as any other animal, human beings collectively have massively and rapidly transformed their earthly home in just a few hundred generations. In 10,000 years (an eye-blink in geological time), the human population has expanded a thousand-fold in numbers, from perhaps 5 or 6 million to 6 billion by the turn of the twenty-first century. During that time, people domesticated animals and learned to plant and harvest crops to feed themselves, built cities, extracted and manufactured products from wood and mineral deposits, devised means to travel across continents and oceans, and created astonishingly complex social systems.

The global population reached a billion soon after the beginning of the Western European industrial revolution, which was quickly adopted in North America. Industrialisation facilitated an intensification of agriculture and better sanitation, and stimulated trade between continents and nations, dramatically changing power relationships among them and spurring an acceleration of population growth. All these accomplishments and advances enabled humanity to support an ever larger population by channelling the Earth's natural productivity more and more into human systems (Vitousek *et al.* 1986; Vitousek *et al.* 1997), and by exploiting new energy sources, especially stored energy from long-vanished life: fossil fuels.

Improvements in health and nutrition in the nineteenth century reduced death-rates, and the population took off, rising to 2 billion worldwide by 1930. The newly industrialised nations led the surge of population growth, as infant mortality rates fell and life expectancies rose. After some delay, birth-rates gradually declined in Europe and North America in response to the increased survival of children and changing life-styles. But fertility remained high elsewhere in the world.

Industrialisation thus set in motion a divergence between the industrialised societies and the rest of the world (Pritchett 1997), even though many other nations eventually followed the industrial path. Among the early changes in Europe and North America, besides falling birth-rates, were assertion of women's rights, extension of universal education, and, especially, increasing material wealth and economic power – none of which occurred until much later elsewhere in the world. Feeding their industrial systems by drawing more and more materials from the rest of the world, the industrialising nations of Europe and North America grew richer, while the non-industrial regions of Africa, Asia, and Latin America remained largely excluded from the benefits of modernisation. By the second half of the twentieth century, the West had achieved economic dominance over much of the world, with only the military power of the Soviet Union opposing that dominance.

By the end of the twentieth century, the human enterprise had achieved and was exercising enormous power over the planet's resources and rich panoply of life. The industrial age has produced a six-fold increase in population size, the nearly complete occupation of the Earth's land surface for habitation and sustenance, and at least a 40-fold expansion of both industrial activity and environmental impact. In that time, human beings have become a global geological force, mobilising many minerals at rates comparable to or even exceeding those of natural processes.

Industrialisation also brought a new set of environmental impacts, many of them arising from the use of fossil fuels as energy sources and, later, as a feedstock for industrial chemicals. Pollution of air and water and the effects on natural systems and human health of using modern chemicals as pesticides and in other applications became subjects of mounting public concern in developed nations by the 1960s, giving rise to the modern environmental movement and efforts to address these problems. As the industrialised nations were gaining some control of pollution problems, they began to rise in developing regions, which lacked laws and mechanisms to control emissions and toxic releases.

But pollution problems are only a part of the damage humanity is causing. As the population has grown, human beings have reshaped land surfaces and exploited the oceans for their own purposes. In the process, our species has become by far the most influential organism on Earth, changing the biosphere to fit its needs in an unprecedented manner and disrupting the web of life both on land and in the sea. All too often this has been done with no clear understanding of all the consequences of such profound alterations. Earth nonetheless is humanity's only home and all we are likely ever to have. It is uniquely suited to life, including human life, and we are utterly dependent on its characteristics and capacities, which evolved and developed over more than 4.5 billion years.

Natural ecosystems – tropical, temperate, and boreal forests, savannas, grasslands, wetlands of various sorts, river systems, and deserts – all help to provide 'nature's services' to humanity (Daily 1997). These services are part of the life-support system that makes all life on Earth possible and allows it to flourish. But they are generally taken for granted and unappreciated by most people, a perceptive failure that is heightened in our increasingly urbanised society. These critical natural services include the creation and maintenance of the composition of the atmosphere, moderation of climate and weather, operation of the hydrological cycle, maintenance and replenishment of soils so essential for agriculture and forest growth, cycling of essential nutrients, detoxification and disposal of wastes, pollination (including of crops), control of pests and disease vectors, and supply of forest products, non-agricultural foods, and seafood. Maintaining the provision of these services is absolutely essential for the perpetuation of civilisation.

Most of Earth's original ecosystems have been modified, however, sometimes extremely so, to produce crops, livestock, or forest products for human use (World Resources Institute 2000). The global extent of forests, for instance, has been reduced by about half in the last few centuries (Myers 1996). In temperate regions, deforestation has occurred nearly everywhere over many centuries, although second growth has replaced much of it. Tropical deforestation began more recently, but has proceeded very rapidly; little re-growth has occurred. Savannas and temperate grasslands have virtually all been converted to agriculture, and significant degradation of crop and grazing land has been documented on every inhabited continent (Oldeman *et al.* 1990; Turner *et al.* 1990). Even deserts have been made to produce crops by using irrigation. Irrigation water is provided by diverting water from rivers or from groundwater, which is often depleted by the process (Reisner 1986; Postel *et al.* 1996). Many wetlands, too, have been turned to food production. Oceans and freshwater bodies have increasingly been overexploited, as fishery after fishery collapses. About three-fifths of all oceanic fish stocks are considered seriously depleted or in danger of being so (World Resources Institute 1998).

The natural – normally renewable – resources, such as agricultural lands, forests, freshwater sources, fishery stocks and wetlands, now being lost or seriously degraded, are termed 'natural capital' by ecological economists. Like the profligate son of the biblical parable, many societies are spending their capital (depleting resources) rather than living on the interest that it could provide (replenished soils, regenerated forests, under-exploited fish stocks, etc.). Far too little value is given to natural capital in traditional economic systems, and losses or reductions in productivity are not customarily recorded in national accounts. Many nations thus are unwittingly impoverishing themselves, even though standard economic measures indicate increasing wealth.

This massive assault on Earth's ecosystems and often ill-conceived technological fixes for the damage done have needlessly cast a dark shadow over the human future. In the past, many civilisations have collapsed, from Mesopotamia, Egypt, Rome, the Classic Maya, and the Khmer to Easter Island, and destruction or degradation of natural capital has usually been a factor in the collapse. Sad though it was for the victims, impacts on other contemporary civilisations in such cases were minor. Most societies were relatively independent of one another, and the damage was localised. Today, however, the civilisation at risk of collapse is global. That worldwide civilisation is not yet very well integrated socially, as clearly indicated by the stark differences between developed and less developed regions and by the persistence of conflicts between societies, although it has become increasingly resource-interdependent and integrated economically. Most impor-

tantly, our civilisation has yet to come to terms with the limits of Earth's life-support capacity. Depletion and losses of natural capital are ubiquitous, and largely ignored. But by playing mindlessly with the productive capabilities of our only home, we are playing with the future of humanity. How have we gotten ourselves into such a predicament?

The Population Explosion

Clearly, the twentieth century outbreak of the human population has been one of the prime factors in generating the dilemma we face. While the outbreak had been building for centuries, it accelerated to an unexpected and, at the time, alarming degree after World War II. Then modern sanitation and medical technology were widely introduced to the non-industrialised regions, successfully – sometimes spectacularly – lowering death-rates without changing the high birth-rates. The result was a population explosion. Between 1930 and 2000, the world population tripled in size to 6 billion; the annual growth rate soared above 2% in the 1960s, falling only slowly after 1970 as birth-rates began to decline in some regions.

By the century's end, the world population was still growing by 1.2% annually, although populations in most developed nations were no longer expanding and some had begun to shrink slightly (Population Reference Bureau 2002; United Nations Population Division 2003). From 1975 to 2000, the combined populations of the industrialised nations increased by only about 20%, while those of the developing world grew by some 60%. Even in most of the least developed regions, birth-rates had at last begun to drop by the 1990s, and some developing countries (many quite developed by then) had attained birth-rates that would soon end their growth.

Nonetheless, because of the momentum of population growth – an unavoidable result of earlier high birth-rates – the world population is projected to grow to around 9 billion by 2050 (give or take a billion or so, depending on birth and mortality trends), reaching a peak size decades later around 10 billion. Of the 1.5 to 3.5 billion (or possibly even more) people to be added before growth ends, 95% or more will be in developing regions. Unfortunately, these regions are among the least able to cope with billions more people.

An important question for development agencies has been why people in less developed societies maintained high birth-rates even after most children survived early childhood. Research eventually demonstrated that certain kinds of development strongly influence reproductive decisions, but others do not. Industrial development – urbanisation and the rise of a manufacturing sector – is not important, but basic human development factors such as education and opportunities for women are crucial. Societies that educate girls and allow or encourage women to participate in economic activities outside the home, while providing basic health care and the means of birth control, have generally experienced significant declines in birth-rates. Also, societies that have developed more equitably, without great gaps in wealth between the richest and poorest groups, have been most successful in both family planning and economic development (UNFPA 2002).

Since the 1960s, and especially in the 1990s, birth-rates have turned downward almost everywhere, including the industrialised world. There, fertility has fallen below replacement (a level at which each generation just replaces itself, an average of 2.1 children per woman) in many nations, giving rise to concerns about 'aging populations' and the prospect of population reduction. Many European nations, Japan, the Former Soviet Union, and some East Asian nations now have total fertility rates (TFRs – essentially, average family sizes) of 1.5 or less, and some now have slowly shrinking populations.[1] Alone among developed nations, the United States has a TFR of 2.1; along with a high rate of immigration, this produces an annual population growth rate of about 1.0% (US Census Bureau 2002; Kent and Mather 2002). In the early 1970s, the US TFR fell to 1.7, but has steadily risen since then.

The developing world, where high fertility prevailed alongside widespread poverty in the 1960s and 1970s, is no longer uniform. Some societies now are more or less fully developed with high incomes and low fertilities, and several middle-income countries are not far behind. Many others remain desperately poor, however, usually with high fertilities (World Bank 2001). The highest birth-rates are seen in Africa south of the Sahara. Fertility has recently begun to fall in many African countries, but most populations are still projected to double or more in size before growth ends. Population growth in many countries, however, especially in Africa, is being markedly slowed by the AIDS epidemic; United Nations demographers have recently revised their population projections significantly downward, largely due to new estimates of the impacts of HIV/AIDS (United Nations Population Division 2003).

[1] Even with very low birth-rates, the momentum of previous population growth causes a delay before the growth rate goes negative.

A major argument connected with the population issue has been about the relationship between poverty and high fertility: does poverty cause high birth-rates or does rapid population growth cause poverty? The answer appears to be both. Rapid population growth clearly hinders the ability of governments and other institutions to meet the constantly growing needs of the people – to provide infrastructure, housing, schools, hospitals and clinics, and keep increasing food production – especially when a very large proportion of the population (as much as 50% in some cases) is under the age of fifteen. Simply keeping pace with a population that is doubling in twenty years or so is very difficult; making progress is almost impossible. Some of the poorest societies indeed have lost ground in the last few decades. The role of poverty in generating high fertility is less clear-cut, but poverty is usually accompanied by illiteracy and lack of access to social services, including health and family planning services. The poor in developing countries are often marginalised and left to meet their own needs under conditions of a deteriorating environment, thus falling even more deeply into poverty (Kates and Haarmann 1992).

An Unequal Enterprise

It is true, of course, that in the last half-century life for many millions of people has been made safer, more secure and comfortable, relatively free of hunger, diseases, and environmental hazards, with plentiful access to cultural amenities. Remarkable as these accomplishments are, however, they have mainly benefited the citizens of rich industrialised nations and affluent classes in developing nations. The average per capita gross domestic product (GDP) in North America and Europe rose (in 2000 dollars) from about US$ 7,500 in 1950 to over US$ 25,000 in 1999 (Worldwatch Institute 2002). This has allowed a colossal material expansion of the human enterprise, providing unprecedented security and comfort for hundreds of millions of people. It also allowed a mammoth increase in rates of exploitation and consumption of resources – consumption not only of mineral resources and energy sources, but also of natural capital, thus damaging or destroying the ecosystems that produce food and forest products and provide ecosystem services. Too often the natural capital of poor countries has been exploited to serve the consumption of the rich.

Thus, while the industrialised nations secured the lion's share of wealth, the poorest regions have gained little or nothing over the five past decades. Some 3 billion people – half the world's population – subsist on less than two dollars a day (World Bank 2001). The number of people the World Bank estimated to be in 'extreme poverty' (surviving on less than one dollar per day; too poor to meet basic food needs) remained essentially unchanged from 1987 to 1998 at about 1.2 billion. Meanwhile, Americans were buying houses with three-car garages to fill with gas-guzzling SUVs and facing an epidemic of obesity. Astounding affluence and power exist alongside extraordinary hardship and vulnerability, and the difference between the extremes has steadily increased.

While people in the wealthiest nations were tripling their incomes, the average incomes of people in Africa south of the Sahara increased slightly until the mid-1970s, and then declined again. Many African nations are saddled with huge international debts and embroiled in political conflict. Persisting rapid population growth, widespread corruption, and failed foreign aid programs have compounded the problems, leaving the populace mostly mired in poverty. In addition to those enormous problems, HIV/AIDS is decimating people in the most productive ages, especially in southern Africa (Lamptey *et al.* 2002). Southern Africa has suffered as well from a severe drought for several years, causing widespread crop failures and threatening famine. The loss of productive adults to AIDS compounds the tragedy: orphaned children and their grandparents are left struggling to maintain food production.

In Asia, some countries have all but fully developed and have per-capita GDPs resembling Europe's; others are still among the world's poorest. The two biggest nations, China and India, are ranked as lower middle and lower income, respectively, by the World Bank, although China's GDP has been expanding fast in recent years, with an annual growth rate in the 1990s around 8 to 10%. This has produced a widening gap between a prospering urban population, mostly in the rapidly growing coastal cities, and the rural poor. Incomes in India are also rising, and a middle class is emerging, but wealth is not broadly distributed. The majority of people are very poor, with 47% surviving on less than a dollar a day in the mid-1990s. India has the largest number of hungry people in any nation; an estimated 57% of children under age five were malnourished in the mid-1990s. Oil-rich Middle-Eastern nations contrast with the picture in most developing nations. per capita GDPs are relatively high, but so is fertility in most of these socially conservative societies, and income distribution is often quite inequitable.

The industrialised Soviet Union and Eastern Europe slowly increased their per capita GDPs until the union was dissolved in 1991. The entire Soviet bloc then suffered a severe economic setback,

from which its now-independent nations have only begun to recover. Average per capita GDPs by the end of the 1990s were less than a fifth those of the market-based industrialised nations. Latin American nations have made uneven economic progress; per capita GDPs there have roughly doubled since 1950. Yet many nations remain in the lowest-income group; and some of those with a measure of prosperity have substantial minorities in poverty, reflecting a serious maldistribution of incomes.

Today, the high-income nations together, with less than 15% of the world's population, account for nearly 80% of the world's wealth. The United States alone, with 4.6% of the world's people, accounts for about 29%. The 2.4 billion people in the lowest income countries have less than 3.5% of the world's wealth, and the 2.6 billion people in middle-income countries share the remaining 17% not held by the 900 million in high-income nations. In 1999, the per capita GDP of the United States was approximately 75 times that in the low-income countries, and the average for all high-income nations was 63 times that in poor nations (World Bank 2001). Such gross disparity represents an enormous and growing differential in affluence and power between citizens of the wealthiest countries and those of the poorest countries.

Interconnections

One thing to keep in mind is that the disparate trends in the human predicament are not independent. For instance, more than 800 million people, mostly in low-income nations, have too little to eat and cannot afford to buy more food. Many people believe that persisting hunger is caused by poverty and a malevolent economic system, and that population growth is not connected to the problem. Certainly, factors such as agricultural subsidies in rich countries and pressures to produce export (rather than subsistence) crops in poor ones have greatly contributed to problems of chronic hunger (Myers and Kent 2001). So have the gross inequities in income and power that plague civilisation. Even though roughly 15% of the world's people are undernourished, enough food is produced today to provide more than 6 billion people a reasonable diet. If everyone were willing and able to share more equally, and especially if the rich were willing to modify their current diets, hunger could be eliminated.

Nonetheless, hunger *is* connected to population growth and size, and is likely to be more so in the future. But the need to feed ever more people has led to the expansion of areas supporting crops (especially in poor countries) and an intensification of agriculture (especially in rich nations). Agriculture, of all human activities, arguably has the greatest environmental impact, especially in the destruction of biodiversity (Ehrlich *et al.* 1995; Athanasiou 1996; Smil 2000). Farmland generally provides little habitat for organisms not directly producing for people, especially under intensive agriculture. Chemicals escaping from intensive agriculture can have devastating effects on local biological communities (which are involved in ecosystem services) and may affect distant ones. Agriculture also causes changes in climate, both by adding greenhouse gases to the atmosphere and, locally, by changing the albedo. The overall directions of that change are uncertain, but climatic stability is essential to maintaining the high levels of agricultural production required to feed a gigantic population.

Overpopulation, inequitable consumption, and lack of power also can interact to worsen the impacts of 'natural' disasters. In Honduras, too many people, over-harvested forests, and crops planted on steep slopes led to many of the poor living in dangerous situations. In 1998, Hurricane Mitch dealt the country a devastating blow, triggering floods and mudslides that would not have occurred if there had been fewer people, if the land had not been overexploited, and if it had been more equitably distributed.

Such interactions, like the interacting factors themselves, go largely unnoticed by the press and public. So do the problems of scale, thresholds, non-linearities, and complexity that plague analysis of environmental and social problems. A town of 2,000 people cannot sustain a measles epidemic; a city of 200,000 easily can. Scale problems also may contain threshold factors. River water may remain potable as more and more people are added until suddenly the density of a pathogenic micro-organism crosses a threshold at which a small glassful contains enough to cause serious illness. If the ancient Greeks ruined Attica, the Greeks suffered. There were only perhaps 200 million people in the entire world then, with little or no contact between population centres. Today, billions of people, all tightly interconnected in a globalised society, are using the planet and its atmosphere as a garbage dump.

Perhaps the clearest example of unbalanced responsibility imposing collective consequences is climate change due to global warming. If the industrialised nations keep dumping ever-greater amounts of CO_2 and other greenhouse gases into the atmosphere, and if developing countries follow the same pattern, everyone in the world will suffer the consequences. The climate is a nonlinear system, one in which a steady rise in an input does not necessarily result in a steady

rate of change, but perhaps a slow response at first which then accelerates as the input rises. The climate seems to have been in a rather stable and unusually favourable equilibrium for most of the last 10,000 years, during which the human enterprise developed. But there is no guarantee whatsoever, that it will remain that way. The history of Earth's climate suggests that other, quite different stable states have existed besides the present one. If we press hard upon the system (by continuing to inject greenhouse gases into the atmosphere), we might cross a threshold and push the climate into a very different stable state – one that could be disastrous for civilisation.

Clearly, the human predicament is composed of a complex of problems and deadly risks, among them the increasing differentials between and within societies in well-being and influence, the ecologically unsustainable behaviour of the human enterprise, an escalating assault against its own life-support systems, and a failure to deal effectively with social problems ranging from poverty and emerging epidemics to terrorism. These, together with the continuing risk of nuclear warfare and an apparently growing susceptibility to deadly conflicts, do not inspire confidence in the future. There is little dispute in the knowledgeable scientific community today about the sources of the human predicament, especially its ecological dimensions (National Academy of Sciences, USA 1993). This is a time of unprecedented, escalating, and well-documented environmental dangers. But the seriousness of environmental elements of the human predicament is still unrecognised by the vast majority of the general public and decision-makers worldwide, so policy responses remain far from adequate.

The IPAT Identity

Most scientists agree that the principal driving forces of the destruction of humanity's natural capital are population growth, overconsumption, and the use of faulty technologies combined with inappropriate social, political, and economic arrangements that facilitate, or even promote, that consumption. This complicated formulation has been summarised in a simple identity: I = PAT (Ehrlich and Holdren 1971; Ehrlich and Ehrlich 1991; Ehrlich *et al.* 1995). The equation is simplicity itself – all it says is the environmental impact of a society (I) can be assessed by multiplying the number of people (P) in the society by the affluence (A) per person, measured by their level of consumption. That product is then multiplied by another factor that describes the technologies (T) (including the social, economic, and political arrangements connected with them) used to supply what is consumed. For example, travel is a form of consumption, but going ten miles on shoes or a bicycle results in much less environmental impact than doing it on a train, which in turn causes less harm than doing it alone in a gas-guzzling SUV. One's choice of transport mode is determined by social, political and economic factors, including the availability, utility, cost and convenience of various options.

Much argument about the development process and the responsibility for environmental deterioration has centred around questions of the relative importance of each of these three factors. Is population size or level of consumption or malign technology the principal cause of environmental problems? Of course, much depends on the environmental problem under discussion. If one is concerned about the impact of persistent pesticides, clearly technology is a leading factor, although population size and consumption patterns have roles in generating the need for their use in the first place. On the other hand, deforestation and land degradation are more closely linked to both population size and consumption levels generally, although technology facilitates the processes involved, and socio-economic factors govern levels of demand for forest and agricultural products. Perhaps the most important lesson easily derived from the IPAT equation is that the most important and far-reaching assaults on ecosystems and natural services are caused by the relatively few rich people, with their enormous affluence and collective power, rather than the much more numerous poor.

An excellent device for helping to understand the scale of the human enterprise generally, and for comparing impacts among nations, is per capita energy use (Holdren 1990). Energy use, especially of fossil fuels, is involved, directly or indirectly, in most of the activities that cause environmental disruption, from producing most important air pollutants and providing feed-stocks for toxic chemicals to subsidising intensive agriculture, powering deforestation and other land-use changes, as well as transporting people, resources, and products around the globe. Fossil fuel use also is the chief cause of the buildup of greenhouse gases in the atmosphere, leading to global warming and climate change (IPCC 2001).

Energy use per capita thus provides a useful index for roughly estimating the environmental impact of a society. It is better than per-capita GDP for a number of reasons: in a service-based economy, the latter may be the same as in one based on heavy industry, but per-capita energy use might be considerably less; inefficient energy use is much more environmentally damaging while providing less service

than efficient use; and energy demand is affected by factors such as climate or transportation and settlement patterns. Because per capita GDP does not account for large differences between countries in purchasing power, energy use might also be a better index of a population's well-being.

Nonetheless, levels of energy use per capita are almost as skewed among nations as are per capita incomes. In 2000, the United States used about 23% of the world's commercial energy, and the 900 million people in the richest nations together accounted for about 50%. In the last half-century, as the human population has surged from 2.5 billion to over 6 billion, global energy use rose 4.6 times, and the world economy (in constant dollars) grew nearly seven-fold (Worldwatch Institute 2002). Most of the increased energy use occurred in the wealthiest and middle-income nations, while the billion or so people in the lowest income nations have seen little or no increase in per capita energy use. The rural poor in low-income nations mostly depend on fuel-wood or charcoal for cooking and have no access to electricity. An American uses 14 times as much energy on average as a person in a low-income country; citizens in the rich nations overall use an average of 9.5 times as much. During the 1990s, per capita energy use in low- and low-middle-income nations (including several former Soviet nations) fell by 10% or so, while continuing to rise in high- and upper-middle-income regions.

But the distribution of energy use is changing, nonetheless, and the developing world will soon account for well more than half of the world's energy use. China, despite its relatively low per capita income, is already the world's second largest energy user, but only at about one-eighth the level per person of the US and much less efficiently on the whole. China, India and many other developing nations are rapidly raising their energy use, while their populations are also still growing. Unless the trends are changed, these increases in global energy use, along with continuing population growth and rising consumption levels, point to a continuing escalation of human assaults on Earth's capacity to sustain civilisation in the long term.

As the human enterprise and its aggregate impacts on Earth's life-support systems continue to expand, evidence is accumulating that humanity has already overshot the planet's carrying capacity. A team of scientists has recently attempted to determine how much of the biosphere would be required to support the global population sustainably – 'to translate the human demand on the environment into the area required for the production of food and other goods, together with the absorption of wastes'. (Wackernagel and Rees 1996; Wackernagel *et al.* 1999). They considered the need for space for croplands and grazing lands, forests for timber, productive fishing grounds, infrastructure (such as housing, transport, industry and hydroelectric power), and carbon sequestration (to offset the build-up of carbon dioxide in the atmosphere). The study conservatively estimated that humanity's 'load' was equal to about 70% of the biosphere's regenerative capacity in 1961, that it had exceeded that capacity since the 1980s, and has now reached over 120% of that capacity.

Much can be learned about the human overshoot of Earth's carrying capacity through the useful tool of ecological footprint analysis. The eco-footprint of a designated population is 'the total area of land and water ecosystems required to produce the resources that the population consumes, and to assimilate the wastes that the population produces, wherever on earth the land and water is located' (Rees 2002). Eco-footprint analysis indicates that humanity has already exceeded the long-term carrying capacity of the planet by some 40%. The eco-footprint of an average American is roughly 4 times the human average, and as much as 10 times larger than those of the citizens of very poor countries such as Bangladesh or Chad. If all human beings today adopted an American lifestyle, it would take about four *additional* Earths to support humanity sustainably (E. O. Wilson 2002).

In short, the human enterprise is already unsustainable – human demand is outstripping what nature can supply – even though the great majority of human beings have not even approached the North American or European level of gluttony. At least half of the world's people are barely subsisting, or even worse. Still, they aspire to the Western lifestyle, although they have been offered a model of 'development' that too often increases the misery of the majority. The continued failure to ask what human beings really want, and to assure the poor of a better level of well-being by their own standards, could easily endanger the standard of living in Western nations through social and political instability and the debilitating costs of continuous wars of empire.

Reversing the Overshoot

Lacking any extra planets to exploit, civilisation can ill afford the projected expansion of human numbers and the even greater impacts on our small planet's life-support systems that supporting them adequately will inevitably require. How then can we reverse damage that has already occurred and learn to live within our and Nature's means?

Here again, the IPAT identity may provide a few clues. The population outbreak may be on the way to ending and reversing itself, but it will take many more decades before that can be accomplished. Nonetheless, the process could be speeded up (or conversely, retarded) by implementing (or failing to implement) international policies that plainly work: development assistance focusing on basic health care, education and employment opportunities for women, and family planning services. Those same policies also clearly contribute to the development and modernisation process in fundamental ways.

The 'affluence' factor may be a tougher nut to crack, especially given its close connection to power relationships and economic arrangements. While some individuals in affluent societies are willing to make conscious choices and efforts to reduce their consumption, most people are not. Indeed, large portions of these populations perceive themselves as struggling economically and feel that their choices are constrained by circumstances largely beyond their control. Most people also resist any changes that they perceive as lowering their quality of life – although many options exist that would if anything increase it. Significantly restraining over-consumption therefore will require societal attention and mobilisation to succeed.

Perhaps the most important component of over-consumption is energy use, which is a useful index of a society's consumption patterns, precisely because it is so central to both consumption levels and environmental impacts, including those on natural ecosystems. Accordingly, strategies to reduce consumption surely should start with energy policies. People often feel especially constrained in their choices regarding energy use, both individually and collectively. Thus daily transportation to workplaces, to schools, to shops to obtain necessities, is governed by one's home location and the availability of convenient public transport. Urban planning and settlement and transportation patterns are therefore critical in determining energy use in an area. Modes of heating, cooling and lighting in homes, stores or factories also are determined by available options and (usually) short-term economic considerations.

Technology can clearly help in moderating energy consumption. Thus, improvements that are available today include making vehicles that get more miles (kilometres) per gallon (litre) of fuel, developing and deploying the most efficient technologies for generation and end-uses of energy, substituting wind or solar power for fossil-fuel-based electricity generation, et cetera. Many energy specialists believe that efficiency alone could reduce energy use per capita in industrialised nations by half or more, with no loss in the quality of life, given appropriate incentives (von Weizsacker *et al.* 1998; Myers and Kent 2001; Holdren 1990). But too often institutional and political barriers and a lack of incentives stand in the way of making the most effective use of better technologies.

Very low per capita energy use in low-income regions is also an index of poverty and development failure. At least a billion people lack access to any electricity, and millions have no access to any modern energy source, depending on fuel-wood, charcoal, or even dung for cooking, and on themselves or domestic animals for transportation and power. Their great need is to increase energy use per capita. Too often, however, when modern energy is introduced in poor countries, it is fossil fuel in outdated, inefficient, and highly polluting technologies. Thus in developing countries, especially where affluence is rapidly increasing, it is essential to deploy the most efficient and renewable means of energy generation and application available today, rather than, as one colleague puts it, to repeat the Victorian revolution (Schneider 2002).

The dilemma, in a world already threatened by global warming (IPCC 2001), is to provide an adequate level of energy use for the developing world without greatly intensifying that peril. The obvious converse of that huge task is to reduce fossil-fuel energy use in the rich societies. This principle has been enshrined in the Kyoto Protocol on global warming, and is being pursued by many industrialised nations – but not yet by the United States government, although many states, municipalities, and corporations are pursuing energy-efficiency policies.

The other critical form of over-consumption that must be contained and controlled is consumption of natural capital – productive agricultural lands, freshwater sources, natural ecosystems and biodiversity, especially forests, wetlands, and marine systems. All of these are putatively renewable, yet are under intense assault today. Both the affluent and the very poor are involved in the destruction of these irreplaceable resources. The difference is that the poor have little or no choice or ability to mitigate their actions. Demand by the affluent for timber and exotic and excessively rich foods and other products is a major cause of undermining or destroying resources in poor nations as well as their own (Smil 2000; Athanasiou 1996). That demand in turn is in large part shaped by the multinational corporations that fulfill it.

Technology has played a major role in increasing food production to meet the escalating needs of the twentieth century's population boom, principally through the technologies of the green revolution.

Although that challenge has so far been met with some success, if not completely, the outlook for the future is by no means reassuring. The population continues to grow by 75 million people per year, yet production of cereals (the feeding base for humanity) per capita has not increased since the mid-1980s. The green revolution has been adopted in nearly every region with suitable climates and soils, yet no technological *encore* of equal promise is in sight. Nor does green revolution technology lack drawbacks; its requirement of lavish water supplies, dependence on farm chemicals with their serious side-effects, and its focus on mechanisation and mono-cultures create new resource problems. Land degradation, accelerated by agricultural technology, has gradually undermined productivity in many areas, reducing potential harvests.

Seafood harvests similarly have reached, and probably exceeded, their sustainable yields, as fishery after fishery has been over-exploited to collapse. Technology has helped to compensate in the form of aquaculture, which helps maintain the overall oceanic harvest, but is achieved with many of the same destabilising techniques that are problematic in terrestrial agriculture.

While technology can undoubtedly make major contributions to making the human enterprise much more sustainable than it is now, it also has its dark side. Too often in the past, new technologies have been widely deployed without full understanding of all the consequences. Obvious examples are various pesticides and thousands of industrial chemicals, such as CFCs and PCBs, released into the environment, which have adversely threatened or impacted human health or the health of natural ecosystems. Among new technologies today, genetically modified organisms might also fit in this category. Thus, policies based on the precautionary principle will be essential to avoid repeating some of the mistakes of the past and to prevent unnecessary environmental damage, both to natural systems and human health.

Nonetheless, knowledge and technologies exist that could substantially reduce the impacts on both terrestrial and marine ecosystems; more ecologically oriented farming practices, sustainable forestry, and regulated fishing systems, among others, could change human activities to a much more sustainable basis. As described above, energy systems as well can be made far more sustainable, even in the face of continuing (but slackening) population growth for several decades more. Again, the principal barriers are social, political and economic. Until and unless economic and political decision-makers are convinced of the need for changed behaviour, business-as-usual will be the name of the game. And business is increasingly global in nature, outside the bounds of national governments. Business-as-usual could easily lead to a catastrophic collapse of civilisation, triggered by any of several potentially disastrous events: widespread crop failures and diminishing harvests, a worldwide economic depression, a global pandemic, or a world war involving nuclear weapons. Each is possible and made more so by our present collective behaviour.

Conclusion

Is a world government the answer? Yes and no. Global governance is certainly needed, and the core of such governance is in place, although its elements too often operate in isolation. International agreements on many social and environmental issues have been established, although they are not always carefully observed (Dernbach 2002). Also, many international agencies encourage the wrong trends, or simply monitor changes rather than trying to guide them in positive directions. And today, unfortunately, some countries seem inclined to abandon previously signed agreements altogether. But the creation and observance of international agreements and cooperative action will be fundamental to resolving the human predicament. Among the most critical will be changing the forces that continue to drive the rich–poor gap ever wider. Given the political will and application of appropriate technologies, over-consumption and environmental destruction could be substantially reduced in the industrialised world, and perhaps most of it could be prevented altogether in developing regions. Such a future is surely worth striving for.

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