The Many, the Voracious, and the Lethally Successful:

The Influence of Human Population and Consumption on Biological Diversity

Robert Engelman

"Have technology, will grow and displace species," could be the calling card of *Homo sapiens*, based on a pattern of human expansion and species disappearance that began as early as 46,000 years ago in Australia[1] and continued in North America and Africa at the close of the last Ice Age[2]. *Sapiens*, of course, means "wise." A key question is whether and when human wisdom will find and implement ways to stop threatening the biological survival of our only known companions in the cosmos. One trend related to human population appears hopeful. The number of people on the planet may reach its peak in this century, and then begin a slow descent. As humans, we can hope the coming population decline will not threaten our own survival as a species, and that it will be based far more on reductions in birth rates than increases in death rates. If nature has a will of its own, however, it might wish the decline fatal, whatever its causes.[3]

Ancient humans are the main suspect in the disappearance of mammoths, mastodons and other large (and some small) animals from the primeval Americas beginning roughly 12,000 years ago. Some scholars argue that climate change was the culprit in those extinctions, but each species had survived comparable previous climate shifts. The peopling of New Zealand 2,000 years ago led to the demise of the moa and dozens of other species there, and the arrival of humans in Madagascar around the same time proved fatal to the giant elephant bird and several species of lemur. In more recent history, the blinking out of charismatic species and subspecies - the passenger pigeon in the United States, the quagga zebra of South Africa, and more - were well documented acts of humanity. Extrapolating from this history and a growing understanding of extinction, biologists believe that nature is now approaching a bottleneck of genetic loss at the hands of the unprecedentedly successful species that is modern human beings. How narrow and long-lasting this bottleneck of loss will be are best considered with an exploration of humanity's future, especially in terms of its numbers and its behavior.

What are the key attributes of this species that might explain its unleashing of an extinction spasm predicted to rival the great dyings of past geological epochs? Technology, the outpouring of the unparalleled human capacity for invention, is one obvious answer. Closely linked are the ongoing growth of human numbers - population - and the materials-processing behavior of average individuals - consumption. According to the late anthropologist Marvin Harris, population growth and the evolution of technology are in a perpetual dance[4]. Technology solves problems created by dense populations, and these solutions then enable populations to grow even denser, thus creating new problems for which new technological solutions must be sought. The general historical trend has thus been for ever larger and more technologically capable human populations. This is a frightening prospect for the survival of non-human species, except for those like the Norway rat or the German cockroach that hitch their wagons to the star of human demography and behavior.

As this reasoning suggests, the study of the complex linkages between human population and consumption and the survival of the earth's biological diversity requires a mixing of disciplines and perspectives that is rare in the scientific literature. What follows represents the tentative conclusions of one close observer of these connections and the author's colleagues at Population Action International. Much of the material that follows is drawn from our report, *Nature's Place: Human Population and the Future of Biological Diversity*[5]. Other material comes from subsequent literature review and secondary research by the author and PAI colleagues.

Several aspects of humanity distinguish us utterly from all other living beings. No single species approaches us in our ubiquity on the earth. None approach us in our modification of that surface and the atmosphere above it. The species that outnumber us are insects, worms, aquatic creatures and micro-organisms a minuscule fraction of our individual organism mass. Compared to other species, we are very big and extraordinarily numerous. In recent decades we have learned how to marshal energy and other natural resources in ways that turn us into the equivalent of leviathans as we move, eat and sleep among the rest of living beings. We wielded environmental influence for millennia when our individual energy processing was comparable to that of dolphins, which use about 2,500 kilocalories a day. Today, however, the average human being processes the energy equivalent of a pilot whale, using 31,000 kilocalories a day - most of it provided by fossil fuels - to eat, move around and control our personal climate. An American must multiply this figure by six. As environmental writer Bill McKibben has noted, we can consider ourselves, metaphorically, sperm whale in human bodies.[6]

Shall we compare ourselves to our closest relatives in the animal kingdom, the great apes? Chimpanzees, handy enough to have mastered the use of twigs to root out insects from decaying wood, use no more energy than any other creature their size. Nor do any other apes. More human babies are born each day - about 350,000 - than all of the chimpanzees, bonobos, gorillas and orang-utans now alive, and each of these species is endangered or critically endangered.[7]

Humanity seems to have evaded the biological laws that for all other species tend to govern the ratio of their organism size and their needed habitat area per individual. Typically a creature weighing around 65 kilograms (about 145 pounds) would need from one-tenth of a square kilometer to two square kilometers (0.04 to 0.8 square miles) per individual to make a decent living, depending on diet[8]. Today, human beings live at densities more than 30 times higher than any level these ratios would predict. These densities are possible only through agriculture, the massive use of fossil fuels, and the synthesis of fertilizer from air-born nitrogen.

This calculation illustrates the circular interaction of human population and biodiversity. Farming is the management of plant and animal species for human purposes by the appropriation of wild ecosystems on a massive scale. Plant and animal species are unwelcome on farms unless they contribute to production. Human population could not have achieved anything like its current size of 6.4 billion people without this large-scale conversion of forest, prairie and other once-natural land to cropland, pasture and orchard. Thus, our demographic success has resulted in large part from a competition that humans have won and wild species have lost. Not every farm, of course, condemns a species, but there's no doubt that farm expansion generally can do exactly that. When wild populations reach thresholds of low numbers, inappropriate age proportions, and sub-population separation, the process of endangerment and eventual extinction begins. Habitat destruction is the dominant cause of this species endangerment on land. Farming historically has been the biggest single source, hectare for hectare, of habitat conversion from natural to human ends.

The other side of the circular linkage comes not only from the impacts of farming on biodiversity but from the non-farming activities of 6.4 billion human beings. The direct harvesting of the oceans' living bounty has collided with an apparent upper limit since human population passed the 5 billion mark in the mid-1980s. Most of the world's ocean fisheries have had either falling or stagnant production since then.[9] Consumption of wood products on a global scale is the principle alternate driver to agriculture itself in the destruction of the world's forests, which are home to most of the land's species. Construction of residential, commercial and industrial buildings and related infrastructure (roads, reservoirs, and pipelines, for example) adds a kind of coup de grace to the habitat destruction that farming began. While most farmers can tolerate the wanderings of the occasional fox or deer, few homeowners do so willingly, and suburban malls and parking lots are completely inhospitable.

Many human behaviors that threaten non-human life occur remotely, all but unrealized by the perpetrators. Sewers and surface run-off carry pollutants from vehicle exhaust or chemicals used in farm fields or suburban yards. Toxic substances released by industry settle randomly on land and then concentrate in the tissue of fish, amphibians and other animals through the natural dynamics of food chains. Finally, and perhaps most ominously, the average human being releases a metric ton of carbon into the atmosphere each year in the form of heat-trapping carbon dioxide, along with other greenhouse gases. Scientists agree with few exceptions that the resulting changes in the atmosphere's composition are altering the earth's climate, though they can't predict specifics. Future human-induced climate change will add significant stress to plant and animal species already under assault from non-climatic human pressures.

The scale of interacting forces is all-important to environmental change, and this obvious fact is at the heart of the linkage of human population and consumption and the extinction of species. The wood fires that *Homo erectus* ignited 1 million years ago sent pollutants and carbon dioxide into the atmosphere, just as a coal-fired power plant outside Denver does today. But there were only a few million *Homo erectus*, at most, and none drove a sports utility vehicle or heated a 17-room cave with electricity. It is safe to speculate that any changes in the atmosphere introduced by the population and consumption levels of proto- and early humans were minuscule, evanescent and without influence on global climate and the health of non-human life.

Not so modern *Homo sapiens*, and it is not hard to see why. When billions of people do any one thing involving the processing of energy and natural resources, it is likely to have a significant and lasting impact on the environment. This is even more true when 1 billion or more of these people are wealthy enough to have dozens of times the environmental impact of the average human. Consumption can be visualized as a kind of sub-set of the demographic effect. In most environmental realms, it is unlikely that a realistic level of individual consumption would modify the environment significantly or permanently today if human beings had maintained the low numbers that characterized our first few tens of millennia on earth. By contrast, even survival levels of food, water and energy consumption have implications for the sustainability of non-human species when the earth is supporting billions of human beings.

The Pleistocene experience with North American animals, which had much to do with the extreme vulnerability of large animals to a new and highly skilled predator, does suggest, however, that even the consumption of what we consider small populations can have unexpected ecological results. We cannot predict how small a human population must be to minimize its ecological impacts, but it is clear that growing more numerous tends to magnify those impacts.

The environmental influence of these two forces - population and consumption - is next to impossible to untangle. Individual consumption becomes an issue to the environment when population has reached such high levels that feasible modifications of individual consumption might make a real difference to environmental impact of human activities. The importance of modifying personal consumption is elevated by the simple reality that consumption can change in either direction in short periods of time, while population size effectively cannot. A family might trade in a sports utility vehicle for bicycles (as unlikely as this might seem), but none will eliminate children to have a smaller family, even if they are teenagers.

Some researchers have pointed out the pernicious environmental impact of the reduction of household size in many countries as human fertility has fallen. Houses once typically sheltered six or more people in the United States, for example, but that average has fallen to just two or three. On a per capita basis, consumption of energy and materials is significantly higher in a small household than in a large one.[10] A similar relation would probably apply to the impact of small households on biodiversity, and this impact is no doubt amplified yet again by an ongoing increase in the size of new homes purchased by Americans.[11]

It is worth recalling, however, the different dynamics of population and consumption patterns over time. Human beings have offspring that in theory can increase population indefinitely, if fertility stays consistently above the roughly two children per couple "replacement value" that eventually stabilizes population.

Household size and per capita residential space, like other aspects of individual consumption, eventually reach limitations that allow for no further amplification of environmental impact. (Household size obviously can never drop below one person per home, for example, and the average will never approach that.) Population change thus remains the more deeply rooted and enduring force influencing the environment, and by extension the health of biological diversity.

What follows are the most important means through which population and consumption dynamics threaten the biological wealth of the earth. A key concept of human impact on biodiversity is the *human-dominated ecosystem*, a geographic expanse that may include abundant living organisms but is influenced more by its utility to humanity than the laws that would apply if humans were absent. The activities most directly threatening to non-human species survival are undoubtedly agriculture and housing (or, more broadly, settlement), both of which require the complete transformation of land from natural to human-dominated. Resource-extraction processes such as logging and mining are also important, but most often as "advance guards" for later, complete transformation. As increasing amounts of land are appropriated for agriculture and settlement, several processes conspire to reduce the chances for the survival of wild species. One is the fragmentation of ecosystems and the disruption of migration corridors. Land once intact and integral, available for mobile species to move in any direction, becomes progressively pockmarked with human settlement or degraded land. Not only do these pockmarks physically block movement, they tend to increase the likelihood of predation on wild plants and animals. Moreover, by fragmenting ecosystems, settlement and agriculture rapidly increase the ratio of ecosystem "edge" areas to "core" areas. The result is even higher predation and habitat destruction than would be the case if land alteration were concentrated. Eventually, the pockets of settlement unite in an integral whole where "nature" is found only in a sanitized park or garden.

Even during initial forays into natural ecosystems, humans often unwittingly unleash powerful biological forces that undermine biodiversity. The exotic species they bring with them - as pests, or pets or livestock - are very frequently devastating to native species. Free of their natural predators and often reasonably well suited to the new habitat, these "alien invaders" can make quick work of the local flora and fauna. The rats and cockroaches mentioned above illustrate this phenomenon, as do kudzu, Nile perch, and the bird-egg-gobbling brown tree snake of Guam. House cats prey on endemic warblers, reducing their chance of survival as species. Beef cattle alter the soil on which they walk, making it far less hospitable for wild plants and animals. Large-scale poultry production produces massive amounts of nitrogen-rich waste that can poison streams and kill fish.

As both population and individual consumption levels grow, these impacts become more frequent, more intense, and more likely to push past natural thresholds, or "tipping points," that spell doom for wild species. And biodiversity risk and loss are stubbornly resistant to the very technological innovations that often work to resolve other environmental imbalances. Intensification of agriculture, which increases yields while holding farmland area constant, may spare more land for nature, but it is accomplished through greater use of fertilizers and pesticides. These, like poultry waste, often end up poisoning ecosystems far from the farm. The potential spin-off effects of genetic modification are unknown but potentially more worrisome. Construction of reservoirs and related water-supply and sanitation infrastructure can at least temporarily resolve water scarcities brought on by population growth and increases in per capita water withdrawal rates, but these often come at the expense of natural ecosystems. The invention of chlorofluorocarbons reduced the toxicity of refrigeration in densely populated areas, but the wildlife of the earth's polar areas now suffers from increasing ultraviolet radiation as a result. This list could go on almost indefinitely.

Despite generally sparse scientific literature on these interactions, Cincotta, Wisnewski and Engelman have documented higher population densities and growth rates associated with conservation "hotspots" critical to the survival of biodiversity.[12] Harcourt, Parks and Woodroffe found a strong correlation between human population and human-caused animal mortality in Africa, apparently through the lens of shrinking wildlife reserves.[13] Hoare and Du Toit found a threshold of human population density at which wild elephants uniformly disappear.[14] And McKee argues that human population growth rates explain roughly half the risk of extinction of specific species.[15] There is a lack of peer-reviewed research challenging the thesis that human population growth is a major factor in the ongoing loss of the earth's biological diversity. On consumption, there is little scholarly research on either side of the argument that increasing individual consumption of energy and natural resources is an important factor in biodiversity loss.

Contemporary population trends offer some hope that the human assault on biological diversity will moderate as the 21st century proceeds. These trends are contradictory and hard to grasp in their totality. On the one hand, the planet gains about 200,000 new people each day, and the vast majority of these additions boost population density in the tropics, which also happen to be home to the majority of the world's biodiversity. Fertility rates in the tropics generally remain well above replacement value, which suggests that only unwelcome increases in death rates would keep population in these regions from growing for several more decades. Globally, however, population growth could continue to slow and within 50 years or even less shift into relative stability or gradual decline. Demographers have been surprised at the speed at which the world's population growth rate has fallen since its peak at slightly more than 2 percent annually around 1970.[16] Average world family size has fallen from roughly five children per woman in the early 1960s to around 2.7 today. The population growth rate has declined proportionately, to just over 1 percent a year. (Worrisomely, HIV/AIDS mortality is playing a role in this downward trend, although not the dominant one.) About one third of all countries - most of them industrialized, but several among the more rapidly developing countries in East Asia - have populations that have largely completed the *demographic transition*, the shift from short lives and large families to long lives and small families. In these countries population growth is approaching, or in a few cases has already reached, an end. Some governments are worrying about the aging of their populations and the likelihood of imminent population decline.

At least in theory, this could be the track on which all nations have their advancing positions, either in the front or the rear ranks. That prospect would suggest a respite for non-human species as human population stops growing and perhaps begins to shrink. The truth, however, is that the future is uncertain both for population and its impact on biodiversity. Between a third and a half of all pregnancies worldwide are not intended, and yet the modest public funds needed to assure that all births are both healthy and intended are not on offer by any government. (Indeed, under the current presidential administration, the U.S. government is perhaps the major obstacle to such funding.) The United Nations' often-cited medium population projection suggests that world population will peak in the neighborhood of 9 billion people between 2050 and 250 years following.[17] The assumption that this will simply happen "on its own," however, ignores the reality that this projection assumes near universal replacement-level fertility worldwide by about 2040. That could not possibly come to pass without significant governmental investments in family planning services in developing countries. This is an especially important issue in relation to biodiversity, which is richest in the tropics - where human fertility is the highest and the most governmental investment in reproductive health care is needed.[18] One hopeful sign is the apparent success of some community development projects in or near protected areas of high biological value. These projects link natural resource conservation with efforts to respond to women's growing demands for access to family planning and related health services.[19]

On consumption, the future is even less certain than on population. The human desire for comfortable living and possession-related status is close to universal. Perhaps a time will come when governments dampen consumption by taxing environmentally sensitive fuels and other raw materials. Or governments may otherwise invest in assuring that room for nature remains on an increasingly populous and high-consuming human-dominated planet.

Human population, however, may not reach a reasonable peak in the coming decades. Global economic growth, with its attendant increases in per capita consumption, may continue on its current track. If so, it is hard to imagine more than a fraction of earth's wild plant and animal species continuing side by side with humanity much beyond the current century. A lot is riding on the decisions that citizens and their governments make in the early years of the 21st century.

Notes

[1] Roberts, Richard G., Timothy F. Flannery, Linda K. Ayliffe, Hiroyuki Yoshida, Jon M. Olley, Gavin J. Prideaux, Geoff M. Laslett, Alexander Baynes, M.A. Smith, Rhys Jones, Barton L. Smith, "New Ages for the Last Australian Megafauna: Continent-Wide Extinction About 46,000 Years Ago," Science, 8 June, 2001, Vol. 292, pp. 1888-1892.

[2] Alroy, John, "A Multispecies Overkill Simulation of the End-Pleistocene Megafaunal Mass Extinction," Science, 8 June, 2001, Vol. 292, pp. 1893-1896. Martin, Paul S., "The Discovery of America," 1973, Science, Vol. 179, pp. 969-974. Martin, Paul S., "Africa and Pleistocene Overkill," 1966, Nature, Vol. 212, pp. 339-342.

[3] Some pre-industrial legends imply that nature feels otherwise. Stories of dolphins saving threatened sailors go back to the ancient Greeks, and Celtic and early Christian legends include tales of wild animals coming to the assistance of human beings. An intriguing modern version of this conceit was made first into a novel and then film in the mid-1990s. In director John Sayles' The Secret of Roan Inish, supernatural seals capable of taking human form conspire, in the 1940s, to effect the return of people to a depopulated island off the northwest coast of Ireland. Such legends become a bit harder to imagine, however, in the more extinction-prone 21st century.

[4] Harris, Marvin, Cultural Materialism: The Struggle for a Science of Culture, 2001 (original edition 1979), AltaMira Press, Walnut Creek, CA, 381 pages.

[5] Cincotta, Richard P. and Robert Engelman, Nature's Place: Human Population and the Future of Biological Diversity, 2000, Population Action International, Washington, DC, 80 pages.

[6] McKibben, Bill, Maybe One: A Personal and Environmental Argument for Single-Child Families, 1998, Simon & Schuster, New York, pp. 70-71.

[7] Cincotta and Engelman, pp. 12-13. (Primary sources cited in publication.)

[8] Peters, Robert H., The Ecological Implications of Body Size, 1983, Cambridge University Press, Cambridge, UK, 329 pages.

[9] United Nations Food and Agriculture Organization, The State of World Fisheries and Aquaculture 2002, Food and Agriculture Organization, Rome, Italy, pp. 11-12, available at the World Wide Web at
http://www.enaca.org/NACA-Publications/World_Fisheries_Aquaculture_2002.pdf

[10] O'Neil, Brian C., F. Landis MacKellar, Wolfgang Lutz, Population and Climate Change,

2001, Cambridge University Press, Cambridge, UK, pp. 129-131.

[11] Sawin, Janet L., "Making Better Energy Sources," State of the World 2004, Worldwatch Institute, Washington, D.C., p. 32. (Primary sources cited in publication.)

[12] Cincotta, Richard C., Jennifer Wisnewski, and Robert Engelman, "Human population in the biodiversity hotspots," Nature, 27 April 2000, Vol. 404, pp. 990-992.

[13] Harcourt, A.H., S.A. Parks and R. Woodroffe, "Human density as an influence on species/area relationships: double jeopardy for small African reserves?" Biodiversity and Conservation, 2001, Vol. 10, pp. 1011-1026.

[14] Hoare, Richard E., Johan T. Du Toit, "Coexistence between People and Elephants in African Savannas," Conservation Biology, June 1999, Vol. 15, No. 3, pp. 633-639.

[15] McKee, Jeffrey K., Sciulli, Paul W., Fooce, C. David, and Waite, Thomas A., "Forecasting Biodiversity Threats Due to Human Population Growth," Biological Conservation, 2003, Vol. 115, pp. 161-164.

[16] This and most of the demographic information that follows comes from the United Nations, World Population Prospects: The 2002 Revision, 2003, United Nations, New York, two volumes.

[17] United Nations, World Population in 2300: Highlights, available on the Web at http://www.un.org/esa/population/publications/longrange2/Long_range_report.pdf
Figures on projected population available at
http://www.un.org/esa/population/publications/longrange2/LR_EXEC_SUM_TABLES_FIGS.xls

[18] Cincotta, Wisnewski and Engelman.

[19] Engelman, Robert, Plan and Conserve: A Source Book on Linking Population and Environmental Services in Communities, 1998, Population Action International, Washington, DC, 112 pages.