GLOBAL CHANGE AND ITS INFLUENCE ON BIODIVERSITY

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Abstract: The scale of the human enterprise has increased to the point where *Homo sapiens* has become a global force. Global change is the result, an altering the Earth's surface and atmosphere to a degree unknown since the great extinction episode at the KT boundary, and an unprecedented disruption because it is caused by a single species. The major impacts (*I*) driving this change are the three multiplicative factors of the *I=PAT* identity: population size (*P*) , affluence (*A* -- which equals per capita consumption), and the use of environmentally inappropriate technologies (*T*) and socio-economic-political arrangements to service consumption. The most serious impacts are the extinctions of populations and species of nonhuman organisms, the working parts of humanity's life-support systems. The failure of societies to come to grips with population, consumption, and power issues is itself tightly tied to the distribution of power. Ecologists must deal with these fundamental issues while they direct more of their scientific and policy research towards finding stop-gap measures to slow the decay of biodiversity.

It is difficult for most people to realize just how massively and rapidly humanity has transformed its earthly home in the process of becoming the dominant animal on Earth. In 16,000 years (an eye-blink in geological time), the human population expanded more than a thousand-fold in numbers, from a few million to over six billion by the turn of the twenty-first century. During that time, human beings spread across the planet, domesticated animals, learned to plant and harvest crops to feed themselves and to extract and manufacture products from wood and mineral deposits, devised means that allowed them to travel a thousand times more rapidly than their ancestors, and created cities and unprecedentedly complex social systems.

Even more startling is the accereation of anthropogenic global change just in the last 200 years: a sixfold increase in population size led to the nearly complete occupation and transformation of Earth's land surface for habitation and sustenance, and to at least a 30-fold increase in industrial activity and environmental impact. In that time, *Homo sapiens* has also become a global geological force, among other things altering Earth's albedo, changing the composition of the atmosphere, and mobilizing many minerals at rates comparable to those of natural processes of wind and water erosion.[1] All these accomplishments and advances enabled humanity to support an ever larger population by increasingly channeling Earth's productivity into human systems,[2] and by exploiting new energy sources, especially stored energy from long-vanished life: fossil fuels. In the process our species has become by far the most influential organism on Earth, reshaping the planet's surface to fit its needs in an unprecedented manner. Humanity has become *the* engine of global change.

Loss of biodiversity

The most crucial of all the modifications of ecosystems, the one that should be of greatest concern, is the accelerating loss of biodiversity, the most irreplaceable form of natural capital.[3] Biodiversity – populations, species, and communities of organisms – must be conserved not just for its own sake, but also for the sake of *Homo sapiens*. That's because other organisms are crucial to supplying humanity with an indispensable array of ecosystem services[4] and products.[5]

How, then, is humanity to preserve its natural capital and the vital ecosystem services that flow from it? There are, of course, innumerable short-term steps that could help. One is to do everything possible to preserve and protect biodiversity even as the scale of the human enterprise

continues to increase. That involves first finding ways to increase the amount of the planet's land area set aside to maintain nature. A recent study by Andrew Balmford and his colleagues estimated that the benefits to society of conserving the "wild nature"[6] still existing in 2002 would be at least 100 times greater than the costs. As the authors say, "Our relentless conversion and degradation of natural habitats is eroding human welfare for short-term private gain. In these circumstances, retaining as much as possible of what remains of wild nature through a judicious combination of sustainable use, conservation, and, where necessary, compensation for resulting opportunity costs makes overwhelming economic as well as moral sense."[7]

One reason for the continued mayhem is market failure. Most of the benefits flowing from natural capital are positive externalities to society (externalities are benefits or costs not captured in market prices). Positive externalities provided by natural forests include the sequestration of carbon (which otherwise would be in the atmosphere as CO_2), which reduces the chances of catastrophic climate change for all of us. Such functions are rarely given a value in markets today.[8] Similarly, calculations of the costs of habitat conversion usually do not capture many of the negative externalities, such as the increases in flooding, loss of biodiversity, and release of carbon associated with clear-cutting a forest.

There are important scientific remaining issues in the allocation of the pathetic funds available for the attempt to preserve humanity's natural capital. Concern was focused early on the slowing of a frightening acceleration in the extinction of species.[9] Several decades ago it was realized that humanity has entrained an extinction episode comparable or greater than the one which exterminated the dinosaurs and many other organisms 65 million years ago.[10] British ecologist Norman Myers, who has been one of the most important scientists calling attention to major environmental problems, was not only a key player in pointing out the extinction crisis, but also in noting that much of species diversity could be preserved by protecting relatively small portions of Earth's surface that had high concentrations of such areas – "hotspots," Myers called them.[11] As a result, many organizations have put substantial funds and efforts into the task of preserving hotspots.

Later, it was recognized that there was a parallel and equally important problem of a loss of *population* diversity.[12] First estimates of the diversity of populations were made by Jennifer Hughes, now of Brown University, and her colleagues. They concluded that there were roughly 6.6 billion populations (excluding those of microorganisms, fungi and nematodes). In addition, a frightening rate of population extinction was projected.[13] That rate is much higher than that for species. As a first approximation, to cause the loss of half of the species present in an area requires that about 90 percent of the habitat be destroyed. To exterminate half of the populations only about half of the habitat need be lost. Population extinctions, of course, precede species extinctions – many populations of great auks were wiped out long before the last one was destroyed by hunting on the tiny island of Eldey near Iceland, leading to the extinction of the species. And population extinctions lead to the loss of ecosystem services. If the population of *Picea abies* in the canyon upstream from your house in the alps is cut down, their flood protection service that population supplies will be lost. That the same species of spruce has abundant populations elsewhere will be of little consolation as you struggle to keep your head above water as you float downstream with your house.

Indeed, it would be theoretically possible to lose no more species diversity at all and still suffer such a decline in those services that humanity itself would go extinct. If every species were somehow reduced to a single minimum-sized population, humanity, for example, could not feed itself (think of there being only one small plot of rice, wheat, and corn, only a couple of bulls and five cows, two hives of honey bees, etc.). Population extinctions, of course, both precede species

extinctions and lead to the loss of ecosystem services.[14] A serious issue has arisen as to how to allocate scarce resources to the two important goals of preserving hotspots and "coldspots," places not incredibly rich in species diversity but with many populations of relatively few species that deliver essential services to humanity.[15] If the one-to-one relationship of habitat-loss to extinction holds, population extinction rates in tropical forest regions are losing something like 16 million populations annually, or close to 2000 populations per hour.[16]

Nature's Services

The critical services provided by natural ecosystems include: the creation and maintenance of qualities of Earth's atmosphere that are essential for life; modulation of climate and weather; stabilization of the hydrological cycle, assuring supplies of fresh water, and moderation of floods and droughts; recycling of critical nutrients, detoxification and disposal of wastes, and the generation and replenishment of soils so essential for agriculture and forest growth; pollination (including of crops); control of pests and vectors of human diseases; the provision of medicines and industrial materials from wild plants, fungi, and animals; the provision of forest products and non-agricultural foods from land and sea – and much more. Without nature's services, human societies simply could not exist.

As the rapidly expanding human enterprise has asserted control over natural capital and diverted more and more of its productivity to its uses, the result has been a progressive loss or disruption of natural ecosystems and mounting symptoms of interference with the basic geochemical processes that make Earth habitable. Meddling with these natural systems and processes poses grave risks to our civilization, yet we persist in playing mindlessly with the future of our home, and thus with the future of humanity.

Climate Change

Among the most critical ecosystem services that are now faltering is stabilization of the climate. The basic reason, of course, is the anthropogenic increase of the flux of greenhouse gases into the atmosphere, which in turn is a product of both human numbers and per capita consumption.[17] This is ironic, because biodiversity plays very important roles in delivering this service, and its degradation leading to rapid climate change poses one of the greatest threats to both population and species diversity. The scientific consensus is clear that climates around the world have begun to change, and that human activities are largely responsible.[18] Over the twentieth century, the global average temperature on Earth's surface rose about 1 degree Fahrenheit (0.6 degrees Centigrade), and the average sea level rose some four to seven inches (0.1 to 0.2 meters). Snow cover, sea ice, and glaciers around the world retreated significantly in the last few decades of the century. The 1990s apparently were the warmest decade since weather records have been kept, and probably the warmest in a two thousand years or more. Yet the changes that became increasingly evident in the late twentieth century are likely to be dwarfed by those in prospect for the twenty-first, and beyond.

Perhaps most serious of all is the possibility of sudden climatic surprises, which are characteristic of the past behavior of this nonlinear system. The gradual warming after the last ice age was interrupted by a sudden return to glacial conditions in northeastern Canada and most of Europe some 13,000 years ago. Most of the trees and much of the other flora and fauna that had reinvaded Europe in the new warmth were killed off, and there was a half-millennium long mini-ice age, called the "Younger Dryas" after the pollen of an arctic plant that became common in marsh sediments at that time. The change appears to have occurred in less than a century, perhaps much less, possibly triggered by a huge pulse of fresh water into the north Atlantic when

a glacial dam broke and released the waters of a gigantic lake into the St. Lawrence drainage.[19] It was the sort of surprise that today could easily wreck much of industrial civilization by disrupting patterns of biodiversity (including those in crops and domestic animals) essential to the agricultural systems upon which the vast bulk of humanity depends.

Humanity is now gambling that we won't run into a similar nonlinearity as Earth is warmed by its activities. A sudden climatic warming of the same scale as the cooling of the Younger Dryas would have a much more catastrophic effect on humanity than that early episode. For one thing, human beings were nomadic hunter-gatherers during the Dryas, and only a million or so of them populated Earth. They were not tied down to specific locations and growing crops adapted to local conditions. They would have been mobile enough to relocate rapidly in response to climate change. And some of the effects of the Dryas may have increased local food availability, providing, for example, large herds of deer, bison, and woolly mammoths, for hunters in Europe.

The IPAT identity

The principal driving forces of those impacts, which are destroying our human life-support systems, 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.[20] This complicated formulation has been summarized in a simple identity: $I = PAT$. The equation is simplicity itself – all it says is the environmental impact of a society (*I*) can be estimated by multiplying the number of people (*P*) in the society by the affluence (*A)* per person, measured by their level of consumption.[21] That product is then multiplied by another factor that describes the technologies (*T*), including the social, economic, and political arrangements connected with them, that are used to supply what is consumed.

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 by the much more numerous poor. The wealthy and powerful minority draw resources and goods from the entire planet, heedlessly causing damage in the process. Although the poor may cause environmental damage locally, it is often because they lack the resources to prevent it.

By the end of the twentieth century, one major engine of global change, world population (*P*) was still growing by 1.2 percent annually.[22] The best news is that populations in most developed nations (notably excepting the United States) were no longer expanding, and some had even begun to shrink slightly. Those rich countries have been responsible for most of the environmental degradation and loss of biodiversity over the last half-century because their large population sizes (the U.S. is the third most populous country in the world) are multiplied by very high average per capita consumption.

The Population Driver

Some good news for the future of biodiversity is that human population growth is at least slowing down. It looks like the main force behind global change, the single species, *Homo sapiens*, that now co-opts almost half of Earth's terrestrial net primary productivity (NPP)[23] will not double again in size. In the last quarter of the twentieth century, the combined populations of the industrialized nations increased by only about 20 percent, while those of the developing world grew by some 60 percent.[24] But even in most of the poorest, least developed regions, birthrates had at last begun to drop by 2000, and some developing countries (many of which were quite developed by then) had attained fertility rates (average number of lifetime births per woman in

the population) that would soon bring an end to their growth. Population shrinkage in Europe and elsewhere is an incredibly positive trend from the perspective of global change and the future of our living companions on Earth. It is, after all, the high-consuming rich who place disproportionate demands on humanity's life-support systems,[25] and are disproportionately responsible for competing with the rest of biodiversity. They (and especially the United States under George W. Bush and his henchmen) are the ones who wield economic and military power to maintain their consumption, regardless of the costs to Earth's biodiversity and life support systems, to say nothing of the world's poor people, and future generations.

Few people recognize the positive importance to humanity of the beginning population shrinkage in rich countries. They worry because proportion of elderly people in the population will increase. As birthrates continue to fall, UN demographers project that the worldwide proportion of people over 60 will more than triple, from about 600 million to nearly 1.9 billion in 2050, accounting for more than 20 percent of the global population, and as much as 30 to 40 percent in some countries with shrinking populations.[26] This aspect of demographic change has been greeted with alarm in some circles. Some demographers and many politicians and pundits have expressed grave concern about the future of social security programs to support the elderly,[27] predicting dire problems for people in the proportionally shrinking younger, productive age groups who will be burdened with caring for their aged parents.

Their view, of course, neglects the trade-off represented by having far fewer children to educate and support. It overlooks also that crime, which mostly is committed by young people between ages 15 and 30, would, *ceteris paribus*, be reduced by an older age structure. Of course, a decrease in younger cohorts and an increase in older ones is an inevitable consequence of stopping population growth. Except to those foolish enough to believe that the population can grow forever, it is obvious that sooner or later the problems of changing age structure must be faced. Why not deal with those problems now, rather than pass them on to our children to solve in a world with less biodiversity and even more degraded life-support systems? There is no compelling reason to postpone the inevitable and every reason to welcome population shrinkage and increased average age. After all, most older people are not dependent in the sense that children are; most of them can take care of themselves and contribute significantly to society.

A recent newspaper article emphasizing Italian demography reported that Europe faced a "specter of sharply winnowed and less competitive work forces" and then later commented, "People are studying longer, and thus finding work later, *when there is work*."[28] Well, which is it – too few workers or too few jobs? A real problem from the viewpoint of the rich is a lack of willing cheap labor. Better-trained workers in industrialized nations do not want to collect garbage, harvest tomatoes, or work as nurses' aides – so those jobs in rich countries are often filled by immigrants from developing countries. The U.S., of course, has long used Mexico as a labor pool of last resort to handle those sorts of chores.[29] More reproduction among the Italians or other well-off peoples would not fill those jobs.

In today's industrialized nations, older people are significantly healthier and stronger than were those of previous generations. Perhaps, rather than attempting to turn back the clock and revive population growth, societies with aging populations should revise their retirement and social security arrangements instead. It seems highly unlikely that either the Pope's talk of "the crisis of the birthrate" or government bribes is going to lead to further overpopulation in Italy or other rich countries.

Changing age structures and labor pools do present genuine problems of equity, with consequences for patterns of consumption, migration, and the like – all tied to the ancient

Socratic question of how we should live our lives. These are serous issues that demand open social discourse in all nations.

Nonetheless, the drop in birthrates alone will not solve the problem of biodiversity loss. Because of the momentum of population growth – an unavoidable result of earlier high birthrates – continued growth of the world population to nearly 9 billion by 2050 is likely (give or take a billion or so, depending on fertility and mortality trends), reaching a peak size a few decades later around 10 billion. Somewhere between 1.5 and 4 billion or more people may be added before growth ends, and some 97 percent of them will be added to populations in developing regions.[30] Sadly, many of these regions are among the least able to cope with additional billions of people, and contain some of the most important reservoirs of biodiversity. Finally, people are increasingly moving into coastal areas, where their activities not only tend to destroy terrestrial biodiversity, but also have negative impacts on marine biodiversity. Increased siltation killing coral reefs is one example; destruction of coastal wetlands and mangrove swamps that act as nurseries for marine fishes is another.

Population size, structure, and movement are linked to another environmentally significant demographic element that is rarely considered – household dynamics. Throughout the world, the average number of people living together in a household is shrinking, a consequence of rising divorce rates, increasing affluence, and a decline in the frequency of multi-generational families living together. The decline in the number of household occupants, of course, means there must be more houses – adding substantially to suburban sprawl. This trend is further augmented by the proliferation of second homes in the United States and other rich nations. As a result, housing units are being built at a rate outpacing population growth.

This easily overlooked change is a particularly serious threat to biodiversity.[31] Fewer people in each household leads to higher per-capita resource consumption and a rapid increase in the number of households, even when population sizes are shrinking. Because fewer people share goods and services in smaller households, per-capita consumption of resources such as water, fuel for heating, power, and transportation, and demand for open space are greatly increased.

In some affluent areas of the United States, ironically, the trend toward smaller household sizes has been accompanied by growth in dwelling size; the average size of a home built in the U.S. has nearly doubled in the last half-century.[32] Indian River County, on Florida's east coast, for instance, has seen floor space per housing unit increase by a third just since 1975. An even more marked expansion in home size has occurred in California's Silicon Valley, as average sized houses are replaced on their modest lots by "dot.com palaces." All these trends threaten biodiversity because they intensify the use of natural resources, such as construction materials and energy, and especially land.

The threats are particularly acute in hotspotareas, where extraordinarily rich stocks of native species are threatened by human activities. Some 75 "hotspot countries" have been identified, including Australia, Brazil, China, India, Indonesia, New Zealand, Nigeria, Syria, Turkey, the United States, and Vietnam. Between 1985 and 2000, growth in the number of new households throughout the world increased at a rate more rapid than population growth, but even more so in hotspot countries. Had the average number of occupants per household remained constant over that period, there would have been 155 million fewer households in hotspot countries in 2000. The assault on biodiversity from this neglected population factor is likely to escalate, since current household size trends are expected to continue as divorce rates and affluence become more prevalent in developing nations. Ignoring population growth, reduction in household size alone has been projected to add 233 million households to hotspot countries between 2000 and

2015. Even in hotspot nations where the population growth rate is approaching zero, such as Greece, Italy, Portugal, and Spain, the number of households is mushrooming due to fewer people living together. The worldwide trend is having a particularly damaging effect in places like the Wolong Nature Reserve in China, where the growth in new homes is adding to fuelwood consumption, deforestation, and loss and fragmentation of habitat for giant pandas.

The Consumption Driver

Of course, consumption plays a major role in creating global changes that threaten biodiversity. The amount of gasoline the average American or Italian consumes, for example, is an important element in promoting rapid climate change. But the assault on biodiversity is also fueled directly by overconsumption. Demand from people in rich nations have fueled an assault on species rich tropical habitats that few American or Italian citizens are aware of. A great deal of the destruction of rainforests over much of the world can be traced to activities designed to service consumption by the rich.[33] The escalating demand for sugar, coffee, tea, rubber, beef, tropical fruits, timber, and pulpwood – much of it destined for the United States – has had enormous but little appreciated impacts. Beginning as early as the 1800s, increased urban affluence in industrializing North America and Europe produced a middle class with a growing appetite for furniture and paneling made from tropical hardwoods such as mahogany and teak. The quantities were not so enormous, but the high-grading (removing only certain trees) caused disproportionate damage. Many other trees would be pulled down by the networks of vines that linked them to the forest giants being felled, and fragile jungle soils were destroyed by dragging the trunks to rivers down which they could be floated toward markets. And the rivers themselves were often deepened with dynamite, with no concern for fish and other aquatic life.

Late in that century, it was discovered that there was a market for bananas that could be shipped from Jamaica to the United States and Great Britain. It signaled the start of the United Fruit Company and the end of many of the coastal tropical forests of the Caribbean and Central America. Oil palms supply cheap (if health-endangering) cooking oil to poor people, so some benefit is derived from the creation of the vast biological deserts that most palm plantations are. In 1997 they covered some 6.5 million hectares (25,000 square miles),[34] and now doubtless cover much more. In 2003 we discovered vast areas of the lowland forest of New Britain had been converted to palm plantations, damaging much of the ecotourism potential of the area. But while some poor people may be helped by giant palm operations, others are dispossessed.[35] Palms are also the source of heart-unhealthy oil additives to many processed foods like soups, pizzas, crackers, and so on. Thus they wreak the rainforest's revenge on those indirectly and unknowingly acting as agents of its destruction.

The lowland tropical forests of the Malay Peninsula, Java, Sumatra, Borneo, Sulawesi, and the lesser Sunda Islands – collectively the Sundaic lowland tropical forests (SLTF) -- may house more plant species than any equivalent area on Earth, and are the tallest and perhaps most beautiful of all tropical forests. In addition they support an extraordinary array of mammals, including such charismatic species as the tiger, Asian elephant, orang utan, Malaysian tapir, clouded leopard, gaur, banteng and proboscis monkey. The bird community of those forests is no less exciting and includes nine species of hornbill; several pheasants including the spectacularly ornate Bulwer's pheasant of Borneo; large numbers of attractive woodpeckers and a mass of fascinating babblers.[36] And those forests have been almost completely destroyed, entraining, we fear, a regional extinction episode unprecedented since a collision with an extraterrestrial body exterminated the dinosaurs and many other life forms 65 million years ago.

As K. David Bishop, arguably the biologist with the greatest field experience across the region, recently put it: "Today, August 2003, there are virtually no pristine, primary lowland forests remaining on Sumatra. Those on Borneo have less than five years before they are eradicated and those on the Malay Peninsula are in a parlous state and the attack has already begun on the foot-hill forests. The lowland forests of Java and the Philippines were cleared long ago and were essentially destroyed before we had any idea of what they looked like. Few if any of the reserves located within the…region contain more than a mere fraction of the SLTF. Those reserves that do harbor SLTF are under immense and increasing pressure from illegal logging and greedy land-grabbers. As a direct result…hundreds if not thousands of species ranging from the tiniest invertebrate to many of the spectacular animals listed above are threatened with extinction."[37]

The lowland forests of the trans-fly area of southeastern Papua New Guinea, the third largest remaining lowland tropical forest (the Amazon and Congo are number one and two) are now threatened with similar destruction. When we were in the Kiunga region of the drainage of the Fly river[38] in 2003 we learned that Malaysian corporations were planning a massive deforestation campaign there. The start will be the decimation of more than one thousand square miles under the Kiunga Forest Management Agreement. The local people will be paid roughly 80 cents per acre each year for 30 years – hardly a reasonable sun when one considers that many of the individual closely-packed trees are worth hundreds of dollars each.[39]

The local people will have both their forests and their culture destroyed for a short-term gain of a pittance. They are already struggling with the problems of acculturation by the dominant global society. During our travel there, we stopped at one point to see a group of people processing sago palm, the traditional staple of the New Guinea diet. Both adults and children were wearing tattered western clothes (the traditional "ass-grass" has largely disappeared since we first were in New Guinea in 1965). And, amazingly, two of the barefoot children were holding game boys. The bright, traditionally very political New Guineans are no match for the globalized Chinese-backed Malaysian steamroller approaching them. They are too naïve about the ways of the outside world, national politicians in Port Moresby and local headmen are easily bribed with small amounts of money, alcohol, and access to prostitutes. The local people will also not be helped by the racist views of them held by many Malaysians.[40]

Such imperialist politics employed by rich-nation corporations (often with the connivance or outright support of their governments as well as consent from the governments of the exploited countries) has repeatedly hurt powerless peoples, were they indigenous peoples whose forest habitats were destroyed, subsistence farmers squeezed off the land, or imported slave or semi-slave labor. From Caribbean and Hawaiian lowlands to the hill country of Brazil and the forests of the Philippines, careless deforestation, erosion, and squalor has been generated by enterprises that bought governments and cared nothing for sustainability. It is not a pretty story, but it is a supremely important one, and one about to be repeated in New Guinea.

Biodiversity is also being directly and heavily attacked in marine systems. The oceans have increasingly been overexploited; as fish harvests have often gone unchecked, fishery after fishery has collapsed.[41] The story of ocean fisheries has consistently been one of overexploitation followed by a collapse and then a shift to another fish stock. But the number of remaining "underfished" stocks was diminishing. By 1994, about three-fifths of all important oceanic fish stocks were considered seriously depleted or in danger of being so.[42] Yields of more than a third of those fisheries were falling, and the rest had reached the limit of sustainable yield and were vulnerable to declines if pressure increased. Coastal populations of fish, shellfish, sea turtles, and marine mammals have been harvested so intensively that their populations, even where "underfished" today, tend to be very small in comparison with pre-historic levels.[43] It now

appears that the global oceans have lost more than 90 percent of their large predatory fishes, many of which, such as tuna, sharks, cod, and swordfish, are important sources of human nutrition, and all of which play important roles in maintaining ecosystem structure. Perhaps worse yet, the complex ecosystem of the ocean bottom, a critical fish habitat, is being destroyed over large areas by bottom trawling.[44] In the famous Georges Bank fishing grounds off of Nova Scotia, "Trawlers trailing dredges the size of football fields have literally scraped the bottom clean, harvesting an entire ecosystem – including supporting substrates such as sponges – along with the catch of the day."[45]

Overshooting Earth's Carrying Capacity

There is thus plenty of evidence that *Homo sapiens* has already overshot the long-term carrying capacity of Earth – the number of people that could be sustained over the long term without reducing the population size that could be similarly maintained in the future.[46] In 2002 a large and diverse team of scientists used existing data to determine how much of the biosphere would be required to support the human population sustainably – that is, "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."[47] The team considered the need for space for croplands and grazing lands, forests for timber, productive fishing grounds, infrastructure (housing, transport, industry, hydroelectric power, etc.), and carbon sequestration (to prevent an atmospheric build-up of carbon dioxide). The study, while preliminary, conservatively[48] estimated that humanity's "load" was equal to about 70% of the biosphere's regenerative capacity in 1961, that it has exceeded that capacity since the 1980s, and has now reached over 120% of capacity. That summary of global change is not good news for the future of biodiversity.

So if one asks how close we are to seeing a breakdown of our life support systems serious enough for everyone to recognize, based on what I have just presented, a reasonable guess would be "half-way there." Given the built-in lag times in many systems and in social responses to slowly developing problems, a very conservative guess at how long it will take to double humanity's impact, would be 30 to 50 years. The truly critical question is whether we can somehow avoid that doubling altogether.

What to Do?

Obviously, there are two fundamental things that must be accomplished if we are to prevent the destruction of most biodiversity, and the collapse of civilization that would accompany that. One is to bring human population growth to a halt as rapidly as is humanely possible, and start a decline toward a sustainable population size (perhaps 1.5-2 billion people[49]). The second is to reduce overconsumption by the rich, and start to close the rich-poor gap. How to accomplish both of these is unclear, and what suggestions I have cannot be covered in a brief paper and are discussed in detail elsewhere.[50] Suffice it to say, a major blockade is the maldistribution of power in the world, and the current U.S. administration (arguably the worst in American history) is busily and successfully dismantling hard-won advances in environmental protection at home as well as undermining the fragile international system of military and environmental security that the world's nations have been struggling to create.

But while we attempt to change these key factors, we could be putting much more effort into doing things that will slow the decay of biodiversity and buy us time. We are learning more about how this can be accomplished all the time. For example, one very promising advance is the development by Gretchen Daily of countryside biogeography, the science of maintaining biodiversity, and the ecosystem services it provides, in human disturbed landscapes.[51] Many

species are dependent on relatively pristine habitats for their survival, but a substantial fraction can persist in quite highly modified areas and maintain important services. Gradually the approach of conservation biologists to the crucial job of preserving humanity's natural capital is getting more realistic. They are adding to the important issue of saving species diversity the equally critical one of conserving populations. That will help protect ecosystem services crucial for, among other things, supporting agricultural production.[52] And some progress is being made in aligning conservation goals with financial incentives – making protecting Earth's biological capital profitable.[53] For example, Costa Rica is paying farmers to preserve forests on their land, protecting ecosystem services (carbon sequestration, flood control, pollinator protection, etc.) that normally do not enter the financial economy.

Another very promising development is the demonstration of the value of creating marine reserves (sometimes called "no-take zones") in maintaining fisheries productivity, and moving toward their establishment.[54] It turns out that if sections of the ocean are protected from exploitation, fishes there can reproduce enough to restock surrounding fished areas.

There are, of course, many other stop-gap measures that can be taken in attempts to delay the inevitable clash between an expanding human enterprise and its life-support systems. It is essential that we ecologists escalate our efforts on short-term efforts to protect ecosystems, *and* put some of our time into trying to solve those more fundamental long-term problems. Many of my American colleagues are dedicating increasing amounts of time into the political chore of replacing the current American administrate with one not dedicated to environmental distruction; that effort is sure to expand as the 2004 election nears. I hope you will start equivalent action in Italy elect leaders who appreciate the environmental threats like the destruction of biodiversity that threaten the sustainability of society. Political action is central to preserving biodiversity, and ecologists should embrace it.

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[1] Study of Critical Environmental Problems (1970); the first mention we have found of humanity being a geological force was in Osborne (1948), chapter 3; Vitousek et al. (1997).
[2] Vitousek et al. (1986, 1997); Pimm (2001).
[3] E.g., Tilman et al. (1994); Heywood (1995); Myers (1996); Hughes et al. (1997, 1998); Tilman (2000).
[4] Chapin (2000).
[5] Beattie and Ehrlich (2001).
[6] Defined as areas still largely capable of supplying their original suite of ecosystem services sustainably.
[7] Balmford et al. (2002); quote is from page 953.
[8] This is changing (Daily and Ellison 2002).
[9] Myers (1979); Ehrlich (1981)
[10] Marshall and Ward [, 1996 #1394; Raup (1991).
[11] Myers (1988, 1990)
[12] Ehrlich and Daily (1993); Daily and Ehrlich (1995); Ceballos (2002).
[13] Hughes et al. (1997, 2000)
[14] Daily (1997).
[15] Kareiva and Marvier (2003).
[16] Hughes et al. (1997).
[17] Schneider (1989, 1997); Intergovernmental Panel on Climate Change (IPCC) (2001)
[18] Intergovernmental Panel on Climate Change (IPCC) (2002).
[19] Schneider (1997), pp. 90-92; Firor and Jacobsen (2002).
[20] Ehrlich (1971); Holdren (1974); Ehrlich (1990); Ehrlich (1995).

[21] *A* is used for affluence instead of *C* for consumption simply because *IPAT* is euphonius and *IPCT* isn't.
[22] United Nations (Population Division) (2001);United Nations (Population Division) (2003).
[23] Vitousek et al. (1986).
[24] Population Reference Bureau (1976);(2002).
[25] Ehrlich and Ehrlich (1989)
[26] United Nations (Population Division) (2003).
[27] E.g., Bruni (2002); Wattenberg (1987).
[28] Bruni (2002), our emphasis. Quoted material in next paragraph from here also.
[29] Ehrlich et al. (1981), pp. 206ff.
[30] United Nations (Population Division) (2003).
[31] Liu et al. (2003).
[32] Frank (1999), p. 3.
[33] Much of what follows is based on Tucker (2000).
[34] Carrere (2001).
[35] Siscawati (2001).
[36] Bishop (2003).
[37] Ibid.
[38] Nobody knows the origin of the name!
[39] Information in this paragraph is largely from Samuel Kepuknai, Kiunga, PNG, pers. comm., 1 August 2003.
[40] Edward Zackery, pers. comm.., Port Moresby, PNG, 12 August 2003.
[41] Pauly et al. (2002); Pauly and Maclean (2003)
[42] World Resources Institute (1998); Food and Agriculture Organization (FAO) (1997).
[43] Jackson et al. (2001).
[44] Lubchenco et al., (2003); Pearce (2003).
[45] Pauly (2003)
[46] With people, the concept of carrying capacity is quite complex – for details see Daily and Ehrlich (1992) and Ehrlich et al. (1992).
[47] Wackernagel et al. (2002)
[48] The numbers cited, for example, do not consider a buffer of land devoted to the critical task of biodiversity preservation. If the reserve for conservation of 12% of biologically productive land recommended by the Brundtland report (World Commission on Environment and Development 1987) were included in the figures, overshoot would have begun in the early 1970s and the current overshoot would be some 40% (Wackernagel et al. 2002)
[49] Daily et al. (1994).
[50] Ehrlich and Ehrlich (2004)
[51] Daily et al. (2001); Daily et al. (2003).
[52] E.g., Hughes et al. (1997, 2000); Ceballos (2002); Kareiva (2003); Luck (2003).
[53] Daily and Ellison (2002).
[54] Lubchenco et al. (2003); Pauly (2003).

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