Chapter 14

Why Conventional Economic Logic Won't Protect Biodiversity

William E. Rees

FRAMING THE ANALYSIS

Conserving biodiversity is one of the central planks in most policy platforms for achieving ecological sustainability. Remarkably, however, techno-industrial society remains somewhat perplexed about both the relevant core concepts – just what do we mean by "sustainability" and precisely where does so-called "biodiversity" fit in? This paper mostly addresses the second question: just why and how should society act to preserve the diversity of life on Earth? Because economic (monetary) valuation is often held up as essential for conservation, my main focus is on the actual and potential role of economic reasoning in biodiversity conservation. In the course of the analysis, we may also move closer to discovering the meaning of sustainability.

Types of Biodiversity

Biodiversity is a complex and somewhat abstract concept. In general it refers to the range of organic variability found among living organisms in all the habitats and ecosystems on Earth.[1] But to urge the preservation of the great variety of living things is not particularly helpful as a policy direction. For one thing, even assuming biodiversity is central to sustainability, we cannot preserve it all. We therefore need to know what kind of biodiversity, and in what quantity is it needed to "sustain" the global system (including the human enterprise). Most critically, we need to have explicit decision criteria by which to make critical choices among a variety of incompatible values that compete with biodiversity.

I begin, then, by recognizing that "biodiversity" can be subdivided into at least four tightly linked organizational levels:[2]

- *Genetic* diversity refers to within-species variation, to the nuanced information encoded in the DNA and chromosomes – in the genotypes – of individual plants and animals. This genetic information finds expression in the multiple qualities of the individual, in its phenotypic form and function;
- *Species* diversity refers to the total number of species, to the variety of viable life-forms, but even this simple measure presents a problem. While it might be possible to identify all the species making a significant contribution to the structure and function of a particular ecosystem, the aggregate number of species on Earth remains unknown. Fewer than two million have been described scientifically but estimates of the total range up to 30 million.[3] Only a few hundred thousand have been assessed for economic uses.
- *Ecosystems* diversity applies to the structural complexity of biotic communities, to the diversity of relationships and systems-level emergent properties that result from species interacting with each other and with the non-living components of their habitats. It is concerned with the relationship between biotic diversity and community stability and the role of keystone species[4]

whose presence or absence may determine the stability of the whole. This naturally leads to:

- *Functional diversity*, a measure of the capacity of life-support ecosystems to absorb some level of stress, or shock, without flipping from one stability domain to another (particularly one that may not be as amenable to human existence, as has often happened with fisheries collapses[5]). This definition is closely related to Holling's[6] concept of "resilience," the capacity of a system to persist and retain its functional qualities after a disturbance.

While the above classes of biodiversity are the most common foci for debate, Ehrlich and Daily[7] also make a strong case for consideration of "population diversity." Populations are geographic sub-groupings within species that may be defined either ecologically or genetically. An ecological or demographic population is an interbreeding group of conspecific individuals that are sufficiently isolated from other populations that changes in one group does not necessarily induce changes in others. A genetic or Mendelian population is a geographically delimited group that "can evolve independently of other such units; i.e., its evolutionary future is not primarily determined by flows of genetic information from other populations." Ehrlich and Daily[7] observe that "In many parts of the world the extinction of populations, rather than of species, may be the most important facet of the decay of biological diversity. Therefore, consideration only of species extinctions may greatly underestimate the rate of loss of organic diversity as a whole".

Why Care About Biodiversity?

> *Nothing momentous happened to the economy when passenger pigeons went extinct nor will anything momentous happen when/if western Atlantic bluefin tuna are gone. Nothing economically momentous resulted from the extinction of about 20 percent, or 2,000 species, of the world's birds over the past two millennia. As more and more biodiversity is lost, however, the rate of ecological change will accelerate with unpredictable outcome… there is little evidence that these changes will be beneficial to human cultures.*[8]

To many people, especially ecologists, it seems obvious why we must care about biodiversity. Human beings could not exist without biodiversity. We are utterly dependent on other life-forms for food and various less obvious life-support "goods and services." Apart from food, humans derive fibre for clothing, materials for construction and buildings, chemicals for industry, and pharmaceuticals for health, all from other species of plants and animals. Intact forests and other ecosystems moderate local weather patterns (and even the global climate), help mitigate runoff and flooding, purify our water, and provide habitat for fish and wildlife species and therefore the basis for recreational activities and regional economies. Some bio-diverse places may have special heritage or cultural values. And let's not forget that the sheer aesthetic magnificence of many natural ecosystems satisfies deep spiritual needs in many people. All these direct and indirect uses of living nature, each attributable in part to species, ecosystem or functional diversity, fall in the domain of what economists refer to as "use values".[9,10] In addition, some people delight in simply knowing that a particular ecosystem continues to flourish intact somewhere on earth even if they never intend to visit it. Its mere *existence* feeds their souls.

The fact that people need ecosystems services, and use other species to satisfy their own ends, represents "instrumental" and "utilitarian" reasons for biodiversity conservation. From this strictly anthropocentric perspective, other species and ecosystems exist exclusively to satisfy human needs, wants and preferences. We should therefore be concerned about global trends that threaten biodiversity because they may ultimately result in significant economic losses and spiritual bereavement.

Alternative approaches to valuing biodiversity rest on moral and ethical grounds. Other species simply have a right to exist independent of how humans perceive them. They have value unto themselves. Duty-based moral theories therefore argue that humans have moral obligations toward other living things and that this entails morally correct actions.[8] According to Ehrenfeld,[11] "The very existence of diversity is its own warrant for survival". Thus: "If conservation is to succeed the public must come to understand the inherent wrongness of the destruction of biological diversity". In sum, this view holds that humans have a moral obligation not to countenance the wanton destruction of biodiversity.

Further in this vein, some authors have argued that under idealized conditions, certain other species would enjoy something approaching equivalent legal standing to humans and therefore have near equivalent rights.[12] In these circumstances, rights are considered to be enforceable claims that cannot be altered without the consent of affected parties. In the case of biodiversity loss, the affected parties (non-human species) have intrinsic worth, value unto themselves that humans cannot arbitrarily take away. Such a contractarian approach, assuming a kind of "constitutional convention among all kinds of living things," may seem too "far-fetched" for the utilitarian pragmatists in most of us. However, accepting the basic principle would impose an obligation on humans to avoid further biodiversity losses on grounds that it "would violate the rights of the non-human biota under a just constitution".[9] Table 14–1 summarizes many of the ecological functions and human values associated with biodiversity.

There Will Always be Some Loss of Biodiversity: Assessing Value at the Margin

If humans could not exist without biodiversity, does this not mean that the value of biodiversity is effectively infinite? No doubt this is so, but only unambiguously so if we are concerned about the *totality* of biodiversity. Fortunately, that is not what is at issue; we are not facing the simultaneous extinction of all non-human life on Earth.

As noted at the outset, and forgetting the intrinsic values of other species for the moment, the most pressingly pragmatic question for policy in this rapidly developing world is how much biodiversity is enough to ensure the sustainability of the human enterprise? How can we most efficiently and effectively account for the marginal losses – the collapse of a fish stock here, the destruction of an ecosystem there – that seem invariably to accompany human encroachments into nature? To put it in economic terms, we want to know at what point the costs associated with the next increment of development, including the value of biodiversity sacrificed in the process, equal or just exceed any expected benefits of that development. At this stage in the overall development process, the net benefits of economic growth (total benefits minus total costs) will have reached a maximum. This is the point beyond which we should not go. Any further economic growth/development might produce additional dollar income or jobs but these benefits will be more than erased by associated costs, including biodiversity losses. In the best of all possible worlds, rational people would not destroy more value than they would gain in the development process. Instead, having reached the point of optimal economic scale, they would shift their focus from growth and attempt to engineer a steady-state economy.[13]

This sounds simple enough – basic economic reasoning seems to provide both an apparently rational framework (benefit-cost analysis or BCA) and a clear decision criterion by which we can "trade off" biodiversity for other economic benefits in the course of development. All we have to do is add up the total dollar value of the expected losses for each of the value cells in Table 14–1 and include these in our overall decision framework. If the expected costs exceed the expected gains, further development is uneconomic and should not go forward. Problem solved: nature gets her due and development is neatly balanced with biodiversity.

Of course, nothing important to humans is ever quite that simple. As we shall see, BCA is fraught with theoretical and technical problems. Indeed, conflict occurs at the most fundamental level. Many people object to the very notion that biodiversity can or should be "traded off" against other values. As Montgomery and Pollack[14] observe,

> Economists often exasperate environmentalists when they view biodiversity as one desirable goal among many, and insist that it must compete for scarce public and private resources with other goals…

Many environmentalists and biologists feel instinctively with Ehrenfeld[11] that biodiversity ought to trump "other goals" in the development process.

On one central point however, resistance to the economists is futile. The simple fact is that the very existence of humans necessarily compromises the welfare of various other species. Indeed, the history of *Homo sapiens* is one of escalating conflicts with biodiversity.[15] People have always had to make trade-offs between biodiversity and other things they needed or wanted, and mostly they have chosen the "other things".

Table 14–1. The Multiple Functions and Values of Biodiversity

Use Values			Non-Use Values
Direct Values	Indirect Values	Option Value	
Food production (including subsistence) Raw materials Genetic resources Education Recreational enjoyment Aesthetic enjoyment	Flood control Water purification Nutrient recycling Soil formation Wildlife habitat Air pollution mitigation Climate modification	Future use potential	Existence (it's nice just to know it's there) Intrinsic value (species have value unto themselves)

I will detail the economist's approach to making rational choices later. First let's explore the biophysical realities that make deadly conflict between humans and other species inevitable. This is the context that forces us to make economically and ecologically uncomfortable choices.

BIODIVERSITY LOSS: AN INEVITABLE "EMERGENT PROPERTY" OF HUMANKIND-ECOSYSTEM INTERACTION

> For every area of the world that paleontologists have studied and that humans first reached within the last fifty thousand years, human arrival *approximately coincided with massive prehistoric extinctio*ns.[16]

Throughout the history of "modern" humans, whenever people first came to occupy a particular habitat they produced significant effects on the structure and functioning of local ecosystems. I have therefore previously described[17] *H. sapiens* as an archetypal "patch disturbance species". Human patch disturbance is the inevitable consequence of two simple biological realities: first, human beings are large animals with correspondingly large individual energy and material requirements; and second, humans are social beings who universally live in extended groups. The invasion by significant numbers of people of any previously "stable" ecosystem will therefore necessarily produce changes in established energy and material pathways. There will be a reallocation of resources among species in the system to the benefit of some and the detriment of others. To this extent at least, even pre-agricultural hunter-gatherers affected the biodiversity of their world. In North America, South America, and Australia, about 72, 80, and 86 percent respectively of large mammal genera became extinct after human arrival[15]. Pimm *et al.*[18] estimate "that with only Stone Age technology, the Polynesians exterminated >2000 bird species, some ~15% of the world total".

Agriculture, which involves the permanent degradation of entire landscapes increased the impact by orders of magnitude.[19]

To understand better how this historic trend is coming to savage biodiversity in modern industrial times, I draw on recent developments in physics and biology, particularly far-from-equilibrium-thermodynamics as applied to self-organizing holarchic open (SOHO) systems.[20]

SOHO Thermodynamics

The starting point for this interpretation is the second law of thermodynamics. In its simplest form, the second law states that any spontaneous change in an isolated system (one that can exchange neither energy nor matter with its environment) produces an increase in entropy. In simpler terms, this means that when a change occurs in an isolated complex system it becomes less structured, more disordered, and there is less potential for further activity. In short, isolated systems always tend toward a state of maximum entropy, a state in which nothing further can happen.

Now, imagine a homogenized, totally disordered world in which everything is evenly dispersed – there are no distinguishable forms or structures, no gradients of energy or matter. In effect, no finite point in the ecosphere would be distinguishable from any other. For purposes of this discussion I will take this hypothetical randomized distribution of all naturally occurring elements and stable compounds to represent a state of maximum local entropy. This is also, by definition, a state of local thermodynamic equilibrium. This is the state toward which the ecosphere would spontaneously descend over time in the absence of sunlight and life. (The tendency toward increasing entropy can be likened to a relentless form of biophysical gravity.)

Of course, the real world could hardly be different from this randomized primordial soup. The ecosphere is a highly ordered system of mind-boggling complexity, of many-layered structure and steep gradients represented by accumulated energy and differentiated matter. In the course of several billion years, the trend in the ecosphere has been one of increasing order and complexity (even after allowing for occasional catastrophic setbacks). In general, the number of species has climbed from zero to many millions; these highly differentiated life-forms became distributed among hundreds of different ecosystems with multiple trophic levels as organisms adapted to the many physical environments on Earth and co-evolved in response to each other. In short, over geological time, biodiversity at all levels of organization has tended to increase.[21] The ecosphere has clearly been moving ever further from thermodynamic equilibrium. So fundamental is this process that, according to Prigogine[22] "distance from equilibrium becomes an essential parameter in describing nature, much like temperature [is] in [standard] equilibrium thermodynamics".

How is it that the ecosphere can apparently exist and evolve ever greater complexity in the face of the second law? The key is in recognizing that all living systems, from cellular organelles through individual organisms to entire ecosystems are complex, dynamic, *open* systems that can exchange energy and matter with their host "environments." As Erwin Schrödinger[23] observed, organisms are able to maintain themselves and grow "…by eating, drinking, breathing and (in the case of plants) assimilating..." Schrödinger recognized that, like any isolated system, a living organism tends continually to "produce[s] positive entropy – and thus tends to approach the dangerous state of maximum entropy, which is of death. It can only keep aloof from it, i.e. alive, by continually drawing from its environment negative entropy…" ("negative entropy" – also called "negentropy" or "essergy" – is free energy available for work).

Let's now put this in the context of self-organizing holarchic open (SOHO) systems theory. In the past few decades, systems scientists have come to recognize that complex self-producing systems exist in loose nested hierarchies, each component system or "holon" being contained by the next level up and itself comprising a chain of linked sub-systems at lower levels.[24] Each sub-system in the hierarchy maintains itself and grows by "importing" available energy and material (negentropy or essergy) from its host "environment" and processes it internally to generate a more highly organized state. It also exports the resultant degraded energy and material wastes (entropy) back into its host.[25] In short, living systems, as far-from-equilibrium-systems, maintain their local level of organization at the expense of increasing global entropy, particularly the entropy of their immediate host system. Because all such self-organizing systems survive by continuously degrading and dissipating available energy and matter they are called "dissipative structures".[22]

It follows from SOHO systems structure that the integrity and internal diversity of the entire systems complex can be maintained only if the highest level in the hierarchy is resilient and productive enough to support the development and maintenance of all lower level holons and capable of assimilating or dissipating their aggregate entropy production. The highest order dissipative structure on Earth is the ecosphere itself. The ecosphere comprises all the biomes and ecosystems on the planet and maintains itself in a far-from-equilibrium quasi steady-state by assimilating light energy from the sun (the next level up in the thermodynamic systems hierarchy). In effect, using photosynthesis and evapotranspiration, the ecosphere feeds on solar energy to develop and to support all lower order holons – species, populations, individuals, etc. – in the holarchy.

The Ascendancy of the Ecosphere

The fundamental hypothesis of far-from-equilibrium thermodynamics is that life has evolved as a dissipative process in response to the existence of steep gradients of available energy. Certainly, *the existence of essergy gradients is a prerequisite for life*. The theory predicts that whole ecosystems should "organize themselves, in accordance with the second law, to increase the degradation of the [essergy] in incoming energy." A corollary is that "material flow cycles will tend to be closed... to ensure a continued supply of material for the energy-degrading processes".[25]

Over time, therefore, we would expect greater species diversification, more extreme niche specialization, ever more complex structure, and increasingly efficient use of systems resources due to competition and autocatalytic processes, particularly in climatically stable environments. Ulanowicz[26] describes this entire process as the "ascendency" [*sic*] of living systems. His work shows that in the absence of overwhelming external disturbances, the ascendancy – distance from equilibrium – of an ecosystem will exhibit a natural tendency to increase.

Empirical evidence of ecosystem ascendancy is available in the form of infrared scanner surface temperature experiments involving over-flights of terrestrial ecosystems in Oregon. Luvall and Holbo[27] show that surface radiation varies with ecosystem maturity and type. The warmest temperatures were recorded over a rock quarry and a clear-cut; cooler temperatures prevailed above a 25 year-old naturally re-growing forest and a plantation of similar age. The coldest site (26 °K cooler than the clear-cut) was a 400 year-old natural douglas fir old growth forest with a three-tiered canopy. The overall trend reveals that the more developed and diverse the ecosystem, the cooler its surface temperature and the more degraded its re-radiated energy. The clear-cut and quarry were found to have degraded 62%, and the old-growth 90%, of the incoming solar radiation.

Satellite data on outgoing long-wave radiation from the Earth's surface suggest the same phenomenon at a global scale.[24] Deserts, which are biologically impoverished, emit 280 watts/m^2 compared to less than 200 watts/m^2 (29% less) by tropical rain forests. The latter are among the most structurally complex and species-rich ecosystems on Earth. Other biomes fall between these extremes. The low temperatures over the rain-forest are due, in part, to the low temperature of the convective cloud-cover forming over the cool, multi-layered forests below. These low temperatures result from the fact that most of the essergy dissipated by terrestrial ecosystems is degraded into molecular motion, particularly that associated with the evapotranspiration of water.[28] Apart from illustrating the developmental direction of ecosystems, these data suggest that the species, ecosystemic and functional diversity of the ecosphere contribute significantly to the thermodynamics of the global climate.

The Far-from-Equilibrium Thermodynamics of the Human Enterprise

What does all this have to do with the human economy and biodiversity conservation? SOHO theory suggests that today's rapidly accelerating biodiversity losses are a grotesquely amplified version of the patch disturbance activities of early humans. This is because the human enterprise, like the ecosphere, is a self-organizing far-from-equilibrium dissipative structure but with a difference – the human system is also a wholly contained component of the ecosphere. As ecological economist Herman Daly[29] has posited, the human economy is an open, growing dependent sub-system of a materially closed, non-growing finite ecosphere, and this relationship clearly contains the seeds of potential pathology. Just as the ecosphere feeds on the sun, the human enterprise grows and maintains itself by feeding on the ecosphere. The economy therefore has the potential to become dangerously parasitic on the ecosphere.

I have already noted that the ecological integrity and sustainability of the entire SOHO systems complex depends on the capacity of the ecosphere to support the entropic load that lower levels in the holarchy impose upon it. Thus SOHO theory suggests that if the growth-oriented human enterprise comes to demand more useful energy/matter (essergy) than the ecosphere can produce, or discharge more waste (entropy) than the ecosphere can assimilate, then the ascendancy of the human enterprise will necessarily be at the expense of the disordering and potential collapse of the ecosphere (or at least of major host ecosystems).

As noted, the bioproductive capacity of the ecosphere is measured in terms of net primary production (or net photosynthesis) by green plants. It is the accumulation of available energy in plant biomass that provides the low-entropy "fuel" for animal life. This implies that all production by animals is secondary production derived from the consumption and dissipation of the products of primary production by plants. Even most human economic production is secondary production.

Secondary production is fundamentally a *consumptive* process. Vastly more energy and material first produced by nature is dissipated by economic secondary production than is contained in the product. This means that, beyond a certain thermodynamic limit, the accumulation of economic capital – the goal of neoliberal capitalist societies – is *necessarily* at the expense of the "natural capital," including species and ecosystems. Moreover, the law of mass balance ensures that the entire economic throughput of energy and matter – including the portion initially embodied in useful products – is eventually degraded and injected back into the ecosphere as waste. The SOHO model of the economic process thus predicts the pattern of escalating biodiversity losses, resource depletion and pollution that is the stuff of daily headlines today. Remember, in SOHO terms, the expanding human enterprise is structurally positioned to consume and degrade the ecosphere from the inside out.[30]

It is worth noting in passing that most of our economic think-tanks and statistical agencies monitor economic activity using money as the metric. Problematically, many of the material flows to and from nature, as well as the life support services provided by ecosystems remain *invisible* to monetary analyses. In these circumstances, market prices are unreliable indicators of functionally critical forms of ecological scarcity and can have only a limited role in fostering sustainability. I return to this point in a following section.

What Makes Humans Unique?

It might be argued in our defence that the human ecological niche is actually structurally little different from that of any other large consumer organism. After all, many other large social animals from beavers to elephants also qualify as patch disturbers. This reassuring thought is only superficially true. Humans have evolved certain unique qualities that separate us ecologically from all other animals and help to explain the sustainability crisis. Again, we can interpret the result in terms of SOHO theory and far-from-equilibrium thermodynamics.

Ludwig Boltzmann, one of the fathers of thermodynamic theory, was familiar with the concept of Darwinian natural selection. Boltzmann[31] recognized in 1886 that the Darwinian "struggle for existence is a struggle for free energy [essergy] available for work." The reason is simple – the availability of energy makes everything else possible. Drawing on Boltzmann's insight, Lotka[32] later hypothesized that "systems that prevail" (i.e., successful systems) will be "those systems that evolve to maximize their use of the energy [and material] resources available to them." In other words systems (species, ecosystems, etc.) that draw on more resources and use them more efficiently, will eventually competitively displace less effective and efficient systems. This general idea is known today as the "maximum power principle".[33]

Understanding maximum power is central to understanding the contemporary sustainability dilemma. Simply put, *H. sapiens* has evolved unparalleled competitive superiority in appropriating the energy flows and material resources of the ecosphere.[34] Most critical to our success is our capacity for language, particularly written language. This ability has enabled generation after generation of humans to pass on their cumulative knowledge. For thousands of years, the expanding human enterprise has been getting more effective and efficient at exploiting the natural world. Human intelligence and technological prowess have unleashed our species' full expansionary powers.

One result is the remarkable ascendancy of *H. sapiens* relative to all competing species. This general process, which began in earnest with agriculture and the emergence of complex societies eight to ten thousand years ago, has been accelerating rapidly in recent decades.[35] For example, witness the increasing structural complexity and diversification of world's major economies since the beginning of the industrial revolution. Economic ascendancy is exemplified by the sequential layering of economic structure as primary activities (agriculture and resource extraction) gives way to manufacturing, and manufacturing is succeeded by high-end service- and knowledge-based industries. It is also characterized by the emergence of specialty products and niche markets, particularly in larger centres (one doesn't usually find designer boutiques and caviar shops in northern mining towns). Meanwhile, the human population has twice doubled to over six billion people since the beginning of the last century and *per capita* incomes and material standards (material consumption) have been rising exponentially since the beginning of the industrial revolution.

As is the case in ecosystems, the ascendancy of economies is accompanied by a prodigious increase in dissipative capacity. Indeed, the evolution of the economy since the beginning of the industrial revolution has been propelled by the constantly expanding use of "exosomatic" (outside the body) energy supplies, particularly fossil fuels (a cumulative stock of essergy derived from ancient photosynthesis). By the early 1990s, this energy subsidy amounted to 407.5×10^{15} Btu by a population of about 5.5 billion people. "It is as if every [person] in the world had fifty slaves. In a technologial society like the United States, every person has more than 200 such 'ghost slaves'" [at an assumed working level of consumption of 4000 Btu $person^{-1}$ day^{-1}]. So dependent is industrial society on cheap fossil energy that some authors predict the decline and collapse of civilization as supplies run out in coming decades.[36]

Much of this exosomatic energy, along with increasingly sophisticated methods of resource extraction, has been used to exploit the rest of nature, to increase the human "harvest" of everything from fish and logs to ground water and petroleum itself. As a result, humans have become the dominant consumer organism in virtually all the major ecosystems types on earth. In terms of bioenergy and material flows, we are clearly the most significant marine mammal. Fossil energy and modern technology enables the global fishing fleet to appropriate seafood for humans that represents 25-35% of net marine primary productivity from shallow coastal shelves and estuaries, that 10% of the oceans that produces 96% of the catchable fish.[37] Despite diminishing returns to fishing effort, the collapse of several major fisheries, and the unambiguous warnings of fisheries scientists there is no evidence that the pattern of exploitation is changing. Christensen *et al.*[38] and Myers and Worm[39] report that after only fifty years of industrial fishing, the large predatory fish biomass of the world's oceans is only about 10% of pre-industrial levels.

Similarly, humans are the principal consumer in most of the world's significant terrestrial habitats, diverting from grasslands and forests at least 40% of the products of photosynthesis for direct and indirect human use.[40,41] Consequently, by 1988 eleven percent of the 4400 extant mammal species were endangered or critically endangered, and a quarter of all mammal species were on a path of decline which, if not halted, is likely to end in extinction.[42] Meanwhile, increasing human populations and rising consumption levels maintain a subtle but steadily increasing pressure even on long-settled landscapes. McKee *et al.*[43] suggest that human population growth alone will increase the number of threatened species in the average nation 7% by 2020, and 14% by 2050. Their data thus strongly support the view that reducing human population growth is a necessary, if not sufficient, step in the "epic" attempt to conserve biodiversity on the global scale.

The situation in the UK may be typical of densely populated countries. Thomas *et al.*[44] have recently shown that "28% of native plant species have decreased in Britain over the past 40 years, that 54% of native bird species have decreased over 20 years, and that a majority of butterfly species (71% over ~20 years) has declined." Two butterfly species became totally extinct and population extinctions were recorded in all the main ecosystems in the country. The authors suggest that if insects elsewhere are similarly sensitive, then insect extinction rates may well parallel the known extinction rates of vertebrate and plant species "strengthening the hypothesis that the biological world is approaching the sixth major extinction event in its history." This would, however, be the first major extinction caused by the overwhelming domination of a single life-form – humans have become a kind of ecological plague on non-human biodiversity.

Is* H. sapiens *Inherently Unsustainable?

Reasoning that, for sustainability, humans should resemble other "similar" species in key ecological parameters, Fowler and Hobbs[45] tested the hypothesis that *H. sapiens* is "ecologically normal," i.e., that humans fall within the normal range of natural variation observed among such species for a variety of ecologically relevant measures. They found that humans rarely showed normal ecological tendencies. In terms of population size, energy use, carbon dioxide emissions, biomass consumption and geographical range, humans differ from other species by several orders of magnitude. Fisheries collapses and related biodiversity losses are partially explained by the fact that human consumption of biomass was two orders of magnitude greater than the 95% confidence limits for biomass ingestion by 96 other mammal species. In short, Fowler and Hobbs' analysis shows humanity to be an outlier species along many axes in terms of our exploitation of life-support goods and services of nature. They ask whether, in the circumstances, *H. sapiens* is sustainable.

W.M. Hern[46] argues that it presently is not. He likens our species to a kind of planetary disease – the sum of human activities over time "exhibits all four major characteristics of a malignant process: rapid uncontrolled growth; invasion and destruction of adjacent tissues (ecosystems, in the case); metastasis (colonization and urbanization, in this case); and dedifferentiation (loss of distinctiveness in individual components)". Recent reports[47] suggest that should these trends prevail, by 2030, more than half of the world's population will be concentrated mainly in coastal areas and cities, driving resource consumption to even more unsustainable levels. Within a century, the 11 billion people sharing the planet will have encroached on the last vestiges of untouched nature rendering most attempts at habitat rescue futile.[48] Any remaining wildlife preserves will be heavily human-influenced. A distinct species of plant or animal disappears every 20 minutes, and half of all bird and mammal species will be lost within 200-300 years.[49] Hern[46] suggests we do have one theoretical saving grace that might head off a worst-case scenario. We can think and decide not to be a cancer.

All such findings and speculations are actually predictable outcomes of far-from-equilibrium thermodynamics and the fact that the growing human enterprise is a subsystem of the non-growing ecosphere. I have previously argued on these grounds that unsustainability is an inevitable *emergent property* of the systemic interaction of techno-industrial society and the complex systems dynamics of the ecosphere.[34] Like all species, *H. sapiens* has a genetic predisposition to expand to fill all the ecological space and use all the resources available to it. However, unlike other species, humans have been able to mitigate or eliminate many of the systemic negative feedback processes that normally hold populations in check. As a result, our extraordinary evolutionary success in terms of "maximum power," has succeeded not only in competitively displacing less effective and efficient species, but also in depleting many other species and resources upon which we may be dependent for our own long-term survival. The expanding global economy is quite literally dissipating the living ecosphere, putting the future of our own species at risk.[50] Marginal changes such as increased efficiency and improved environmental legislation may buy some time but don't affect the fundamental process.

CAN ECONOMIC LOGIC MITIGATE BIODIVERSITY LOSS AND RESOLVE THE SUSTAINABILITY CRISIS?

Economists argue that one reason for humanity's uninhibited destruction of "the environment" is the very abundance of nature. We naturally tend to undervalue any resource so plentiful that is free for the taking. Economics itself has long treated biophysical goods and life-support services as "free goods" whose contribution to life-quality is not accounted for in market prices. From this perspective, the ecological crisis reflects a fundamental economic axiom: underpricing leads to over-use.

There can be little question that the unpriced contributions of nature to human welfare have historically not been represented in markets and "are [therefore] often given too little weight in policy decisions".[51] Pearce[52] argues that the resultant "asymmetry of valuation" biases the playing field against conservation because, absent prices, the critical role of nature in sustaining the economy is not reflected in either individual or social choices. This example of classic market failure results in destructive policy decisions and inefficient economic performance.

Environmental economists[53] have therefore joined the (un)sustainability debate with a seemingly simple solution. With increasing ecological decay, the time has come to place a dollar value on nature's output – let prices tell the truth. If market prices accurately reflect the true value of the products of nature, then people will adjust their preferences and purchasing patterns accordingly. Just the right amount of current natural income will be consumed and economic efficiency will have been achieved.

The need felt need among economists to price "the environment" implies a sense of impending scarcity, and making sound decisions in a context of scarcity is supposedly what economics is all about. In this context, economists view price as a powerful decision tool – it provides an unambiguous criterion for individuals and communities to choose among mutually exclusive possibilities. We would do well to keep in mind however, that the valuation of nature represents the commodification of global life support.[54] As I have argued elsewhere,[55] "This is worrisomely serious business. For the first time in human history, it seems necessary to some to put a price on the biophysical structures and functions that make higher life possible on Earth".

Most critically, assigning a price to something implies the ability to compress a great deal of information about that thing into a single indicator or metric. In theory, this compacted information should enable us to make "better informed" decisions about the allocation of that thing among competing interests or even determine its fate in the event that it may have to be "traded off" in some economic development decision.[52,56] In this light, and given the risks associated with the destruction of global life support, if we are going to use money value as a decision criterion, the price had better be right!

Putting a Price on Biodiversity

Not long ago I attended an interdisciplinary workshop on strategies for biodiversity conservation. The two economists present couldn't understand what all the fuss was about. For them, biodiversity was simply not an issue. Their paper was founded on two assertions of fact. First, their data from so-called "genetic prospecting" suggested that only about one in 10,000 species of plant/animals show much promise of yielding a pharmaceutically interesting product, i.e., something of economic value. Second, the probability of any species going extinct as a result of any particular development project (e.g., a greenfield industrial park) was virtually nil. The marginal value of biodiversity losses associated with such a development was therefore perishingly small – one ten-thousandth times almost zero is a negligible number. Ergo, biodiversity could be ignored as a factor in most development decisions.

The ecologists' incredulity at these findings was palpable for the rest of the meeting but the form of economists' analysis was paradigmatically true to their discipline. As previously noted, economics is about money value at the margin and about the expression of individual preferences. As Randall[57] observes: "The ethical framework built on this foundation is *utilitarian, anthropocentric* and *instrumentalist* in the way it treats biodiversity [original emphasis]. It is utilitarian in that things count to the extent that people want them; anthropocentric, in that humans are assigning the values; and instrumental, in that biota is regarded as an instrument for human satisfaction".[58]

Environmental economists Pearce and Moran[59] recognize alternative perspectives – that species conservation is a moral issue or that other species may have intrinsic rights – but vigorously defend the utilitarian approach. In their view, debating other perspectives "risks being rather sterile *from the standpoint of getting things done* [original emphasis]…in the real world context of making choices." This argument is based on the view that the moral perspective, or any stand based on the rights of other living organisms (or even future generations of humans), lack criteria for making rational choices among mutually exclusive possibilities, even between different species or biological resources. Is the malarial parasite to be accorded the same inviolable status as the harpy eagle? Are both species ever and always to be granted equivalence in the sustainability debate? And if not, on what basis do we value one over the other?

Pearce and Moran[59] argue that human population growth and economic growth are a fact (and who could dispute this?); that biodiversity losses are inevitable in the competition for limited ecological space (the entire previous section underscored this reality); and that uncomfortable choices must be made. At the very least, then, a ranking criterion is required – if not everything can be saved we need a non-arbitrary way to make policy decisions. Under what circumstances should which species be spared? In a passage likely to chill the blood of any conservationist, they also declare that: "This view is reinforced by the fact that the world is extremely unlikely to devote major resources to biodiversity conservation. We can argue that it should, but we know it will not". (I return to this telling assertion below.)

As already implied, the "ranking criterion" of choice is monetary value. Money is the great leveller, the economists' way of comparing apples to oranges. It assumes that all things are essentially commensurable. From this perspective, *monetary price is a necessary precondition for making economically correct decisions*. The neo-liberal paradigm[60] argues that if we know the money value of some dimension of biodiversity, we have a rational basis for deciding, for example, whether to sacrifice it for the anticipated benefits of some development project. Similarly, if there are several alternative ways of implementing a project, differences among the biodiversity "opportunity costs" associated with the various options can help us to choose among them. In these ways, monetary analysis of biodiversity losses might well contribute to selecting the least social cost option for development.

Contingency Valuation: Who Can Say What Biodiversity is Worth?

Assuming for the moment that we can adequately identify and quantify anticipated biodiversity or losses on their own terms (as might be required for an environmental impact assessment, for example) the problem remains of assigning a monetary value. In rare cases, the market may actually provide a direct indication of perceived value as when drug companies sign contracts with governments for exploration rights and pay royalties, or when we have an accounting of the tourist revenues associated with a particularly attractive natural area.[61] In other cases, it might be possible to assign value based, at least in part, on the market price of near substitutes. Suppose a small number of moose are going to be lost to a micro hydroelectric project. Part of the value of this loss could be based on the price of a similar quantity of dressed beef in local supermarkets. More often than not, however, there is no formal trade in the goods and services derived from biodiversity. In these instances, economists rely on indirect ways of assigning dollar values and determining user preferences such as the travel cost method (e.g., how much do people spend on travel and equipment to go fishing?) or hedonic pricing (e.g., how much do the prices of similar houses differ when one enjoys a spectacular view lot or is close to some other nature-related amenity?). However, by far the most common approach to eliciting consumer values, particularly non-use values is "contingent valuation."

Contingent valuation (CV) usually involves the administration of a questionnaire survey to a statistically valid sample of people. The general objective is to determine how respondents would value a specified hypothetical change in their individual welfare. For example, they might be asked how much they would be willing to pay (WTP) to rescue some specified attribute of the natural environment from the threat of development. Alternatively, they might be asked how much they would be willing to accept (WTA) as compensation for the loss of that attribute. Obviously, the way people respond to such questions will involve elements of their personal perception of use and non-use values of the resource in question. It will also reflect their income or socio-economic status. In any event: "For society, the net value of a proposed change in resource allocation is the interpersonal sum of WTP for those who stand to gain minus the interpersonal sum of WTA for those who stand to lose as a result of the change".[55]

There are, however, many technical and behavioural problems with CV approaches. Fischhoff[62] asks whether there is actually "anything in there". In a particularly detailed critique, Vatn and Bromley[56] identify three major problems associated with valuation, particularly by non-experts:

- The Cognition Problem**:** The valid evaluation of goods and services by individuals assumes that people have perfect knowledge about all the functions of those goods or services. However, in the real world perfect knowledge is unattainable and people are differentially selective in their valuation of different known attributes of a good. Some important qualities may be disregarded out of ignorance.

  Perhaps most significant in the context of valuing biodiversity is the fact that many contributions of species and ecosystems are essentially beneath perception. They are cognitively "invisible." Vatn and Bromley[56] describe such "functionally transparency" to mean that "the precise contribution of a functional element in the ecosystem is not known – indeed is probably unknowable – until it ceases to function". Problem: we cannot value what we cannot know.

  A second cognitive problem is that most people have difficulty in converting ecologically significant attributes into monetary units for comparison with other goods. For this reason, the CV elicitation procedure used "may serve as a means to construct preferences rather than merely uncover them".[56]

- The Incongruity Problem: If the different attributes of an ecologically significant good are "incongruous," or fundamentally at odds with each other in the minds of assessors, then a single measure such as hypothetical price will not reflect all important information. As O'Neill[63] puts it: "Different values are incommensurable; there is no unit through which the different values to which appeal is made …can be placed upon a common scale." For example, some CV methods may force people to conflate the worth of an ordinary good such as fishing pleasure (use value) with existence value or intrinsic value (the right of salmon to live). Often people are intuitively put off at being asked, in effect, to commodify a moral principle. There are areas of interest where "social norms restrict or reject the commodity fiction".[56]

- The Composition Problem: According to Vatn and Bromley,[56] "the commoditization of environmental goods [as reflected in CV studies] can be looked upon as a product of the felt need to value them. It is not immediately obvious to many – other than economists – why it is necessary to characterize environmental attributes this way". There are several dimensions to this problem. First, in a complex dynamic ecosystem, the whole may actually be dependent on each of its fundamental parts so that the value of any single component cannot be understood independent of the value of the whole. Second, in the same complex systems framework, the value of individual ecosystem components should not be derived from their perceived uniqueness to humans but rather from their functional uniqueness in relation to the integrity of the whole system containing them. Finally, the market or "exchange value" of ordinary commodities depends on the property that their valuable attributes can be appropriated and controlled by the buyer. Biodiversity and related ecological goods and services hardly meet this test. Vatn and Bromley[56] suggest that the economist's disciplinary need to create commodities where they may not be thus encounters the possibility that some ecological goods and services may be technically impossible to price.[64]

Vatn and Bromley[56] summarize their reservations about CV studies in one simple but fundamental point: "Efforts to derive hypothetical values for the complex and interrelated attributes of the environment… result in a non-trivial loss of information". The failure to reflect potentially critical information means that attributes of nature, including biodiversity, will almost invariably be undervalued in any decisions based on the outcome of contingency valuation. Indeed, the inability to assign a valid money value to ecosystems goods and services strips pricing of much of its legitimacy and policy relevance. Contrary to Pearce and Moran,[59] Vatn and Bromley[56] conclude that the economic pricing of nature's goods and services "is neither necessary nor sufficient for *coherent and consistent choices about the environment"* (original emphasis). O'Neill[63] agrees, arguing the very idea money can be used to measure and compare values that are essentially incommensurable is mistaken. "Given the conflicts [among different values] there is no substitute for good practical judgement that is informed by debate amongst practitioners and citizens".

Benefit/Cost Analysis: Light – and Ultimate Darkness

The intractability of the pricing problem as applied to ecosystems values throws a dark shadow over benefit-cost analysis (BCA). And there are other shadows – as Lave and Gruenspecht[65] observe: "The problem with BCA in both theory and practice seems overwhelming yet economists continue to regard BCA as the definitive tool in making public decisions".

As noted earlier, the main strength of the benefit-cost framework is its apparent conceptual simplicity and transparency. However, in recent decades, the theoretical foundations of BCA have been eroded by modern moral philosophers and even some economists reject its economic assumptions. In practice, critical data – such as the monetary value of nature's goods and services – are missing or invalid; the method over-emphasizes economic efficiency while ignoring distributional equity (there may be little overlap between who benefits and who pays), including intergenerational equity (setting appropriate discount rates is problematic); agencies typically provide insufficient time and resources for an exhaustive analysis, and practitioners may be directed to justify a particular outcome or are simply biased by their own beliefs and prejudices. Lave and Gruenspecht[65] conclude that: "The difficulties with missing data, uncertainty, and [too few resources] combine with the theoretical difficulties to make ineffectual any serious claim that an applied study produces an optimal or theoretically justified outcome". In short, BCA is an unreliable tool for determining the true net worth of even isolated projects (and will ever remain a mere idealized construct in contemplating the optimal scale of the economy).

Conceding that the method produces less than optimal results, BCA's defenders argue that society should not make multi-million dollar decisions without having as much information as possible with which to compare policy alternatives. Moreover, the application of BCA may force new questions to the surface, identify significant data gaps that may yield to further research, expose social and institutional flaws in our public decision-making processes, and reveal how people perceive out-of-the-ordinary dimensions of life.

Certainly these incidental benefits of BCA are potentially valuable and can make useful contributions to project decisions. But the real danger lies in getting caught up in the *doing* of the BC analysis, in being blinded to its flaws and ultimately in taking its *results* as accurately reflecting biophysical reality. In these circumstances the analysts would certainly be guilty of what Ehrlich and Daily[7] call "'crackpot rigor' (detailed mathematical analysis of an intractable problem) or 'suboptimization' (doing in the best way possible something that should not be done at all)".[66] For all these reasons, many people will be relieved that at least in the case of publicly-owned natural capital, "the most fundamental environmental choices will continue to be made without prices – and without apologies".[56]

Does It Matter that We Can't Price Nature?

Recall that the purpose of economic valuation is to condense all relevant information about natural assets into a single metric and thus correct the "asymmetry of valuation" that has heretofore biased decision-makers against the environment. Environmentalists hope that better accounting for nature's goods and services will favour conservation. If we know the value of nature's goods and services, we might not destroy them heedlessly. At the least, full cost accounting should favour less ecologically destructive development options. The foregoing discussion shows, however, that despite the best of motives and intentions of economic analysts, it is simply not possible accurately to price biodiversity or many other ecosystems values. But let's stop for a moment: does this really matter over the longer term? Suppose things were different, that we could accurately monetize any attribute of nature. Would it really make much difference to the decision process in a world dedicated to economic growth?

The unavoidable answer in many situations is, "probably not". The purpose of monetization is to provide a common measure of worth that will allow direct comparisons between the value of biodiversity and certain mutually exclusive options. But, as previously noted, humans are necessarily anthropocentric and the world has increasingly adopted a utilitarian and instrumentalist attitude toward nature. In this context, "The sad fact that few conservationists care to face is that many species, perhaps most, do not seem to have any conventional [economic] value at all, even hidden [unpriced] conventional value".[11] This means that for many ordinary development decisions, the present value of anticipated economic gains will exceed the total of all use and intrinsic values of biodiversity sacrificed by the development. Whenever the marginal gain from depleting nature exceeds the value of saving it, people – acting rationally – will choose depletion.[67]

This is particularly true in the case of "open access" (unowned and poorly regulated) resources such as many fish stocks, where the benefits of exploitation accrue to a few individuals but the costs are shared by society at large.[68] In these circumstances, individuals have an incentive to over-exploit natural bio-resources even if the total social costs exceed their private gain. This problem even extends to land reserves ostensibly set aside for conservation purpose. Poaching is a growing problem in game and ecological reserves in Africa and other parts of the world, as sometimes desperate people exploit resident wildlife for their own subsistence or for the bushmeat trade.[69] Even in wealthy Canada, our better known national parks such as Banff and Jasper are under constant pressure from private hotel, ski-hill and related facilities developers wishing to cash in on the revenues generated by the very aesthetic and wildlife attributes that their operations jeopardize.

Some economists have suggested that the solution to the open access problem is the privatization of nature on grounds that the owners of private property have a direct incentive conserve their productive capital. But as Clark[70] famously showed, private ownership of valuable but slowly reproducing species is no guarantee that said "resources" will be carefully husbanded. Consider the choices available to the private owners of a whale stock or perhaps a forested area with a high biodiversity index. Such natural capital assets may have a reproductive / growth rate in the vicinity of two or three percent per year which thus defines the sustainable harvest (natural income) rate. However: "With normal rates of return on investment in the neighbourhood of 10%, the 'optimal' strategy for the whalers [would be] to simply wipe out the whales and invest the proceeds elsewhere".[71]

The problem here is rooted is the discount rate (which measures consumers' "time preference"). The whales or the forest would return only two or three percent of their capital value annually to their owners if harvested sustainably, and much of that return would be absorbed in the cost of the yearly harvest. However, if the owners liquidate the entire stock immediately they could enjoy an annual income of 10% of the capital value (minus a one-time harvest cost) in perpetuity. Clearly any rational self-interested utility maximizer would choose to extinguish his stock of natural capital rather than conserve it intact. So much for market valuation as a shield for biodiversity.

Finally, it might be argued that as "nature" becomes scarcer with human population growth, rising material demand or ecosystem collapse, the existence value and intrinsic worth of remaining biodiversity will increase to its advantage – i.e., the incentive for conservation will increase. To the extent that this slows biodiversity loss it is a point for money pricing. However, at least some of the immediate use or exchange values will also increase with scarcity, perhaps faster than any conservation values.[72] If this happens, the rising scarcity value of ecosystems goods and services is no assurance of protection and may even accelerate resource depletion (see the section on globalization and trade below). Once again, "…extinction may occur no matter what the price response".[8]

To summarize, and to the dismay of all those conservationists who have joined the valuation bandwagon in the hope it would play a preservationist tune, pure economic reasoning generally resonates more with the prevailing symphony of destruction. Recall Pearce and Moran's[59] assertion that "…the world is extremely unlikely to devote major resources to biodiversity conservation". In effect, this is an argument that, absent a crisis, the perceived value of biodiversity is likely always to be less than the measurable value of development. This effectively undermines Pearce and Moran's[59] own argument for pricing biodiversity – the valuation exercise becomes a mere formality that turns against biodiversity by rationalizing its destruction.

From "Safe Minimum Standards" to "Strong Sustainability"

Since econometric approaches do not necessarily conserve nature, some analysts have proposed alternatives compatible with moral or duty-based considerations. For example, Randall[9] argues that if we assume humans should make at least some sacrifice for biodiversity, then we should support a "safe minimum standard" (SMS) for conservation. This would entail preservation of a "sufficient area of habitat… to ensure the survival of each unique species, sub-species or ecosystem, *unless the costs of doing so are intolerably high*" (emphasis added).

The SMS approach clearly shifts the burden of proof "to the case against maintaining the SMS" and accepts the risk "that the costs of preservation may fall disproportionately on present generations and the benefits on future generations".[59] Nevertheless, Randall[9,57] also makes clear that the SMS does not demand unlimited sacrifice by people: human claims trump those of other species if the opportunity costs of conservation are deemed excessive. Once again, in the context of growth-induced scarcity humans will always win at nature's expense.

Many authors, particularly those writing from the perspective of ecological economics, argue that irreducible uncertainty favours a much more cautious approach to the destruction of biodiversity than is provided by the SMS.[73] Ecological economics recognizes the limits to growth[74] and argues the need for humanity to work toward a "steady-state"[75] economy. This implies there is an optimal scale for aggregate human economic activity characterized by a constant safe level of energy and material throughput.

The model argues that before we reach a crisis point of no return, global society should adopt a strong sustainability criterion in which both renewable natural capital and manufactured capital are held intact.[76] Since economic analysis cannot identify the crisis point, we will have to rely on scientific data, debate and seasoned judgment to make the call. The most risk-averse version of the so-called "constant capital stocks" criterion can be stated as follows:

> *Each generation should inherit an adequate per capita physical stock of both manufactured and self-producing natural assets no less than the stock of such assets inherited by the previous generation.*[77]

Note that, far from depleting biodiversity, this criterion suggests that if the human population increases, so too should the natural capital base that produces our natural income of life-support goods and services.

The argument for constant biophysical stocks is conceptually simple: The prevailing system of costs, prices, and market incentives fails absolutely to measure ecological scarcity (particularly functional scarcity) or to determine the appropriate levels of natural capital stocks. Prevailing trends, however, suggest that the economy's "dissipative" activities are already undermining the functional integrity of major ecosystems. Since certain critical natural assets maintain the life-support functions of the ecosphere, the risks associated with their depletion are unacceptable, and there may be no possibility for technological substitution, "conserving [at least] what there is could be a sound risk-averse strategy".[78]

Because its effect would be to preserve remaining biodiversity, the constant natural capital stocks criterion is seemingly more eco-centric than the SMS approach. In fact, however, it is really just a more sophisticated self-serving utilitarian argument, at best a form of ecologically enlightened self-interest. Even so, there is virtually no political or popular support for such a fail-safe approach among contemporary growth-oriented governments or "official" international organizations.

Globalization and the Biodiversity Costs of "Free" Trade

> *During [the 20th] Century, world agriculture has been transformed from a patchwork quilt of nearly independent regions to a global exchange economy. This change in social organization also contributes to the loss of diversity.*[79]

> *Off the remote north-east coast of Borneo, a Malaysian patrol vessel hailed a suspicious looking trawler last week. When marine police boarded, they found a catch of 160 dead giant leatherback turtles, the most endangered of all sea turtles. The poachers, who had poisoned the waters with cyanide, came from China's southern province of Hainan, more than 1,000 miles away.*[80]

> *Myanmar [is] mired in a deforestation crisis: China's appetite for foreign timber has the country's forests disappearing at an alarming rate.*[81]

I have already suggested that economic growth is the proximal cause of much biodiversity loss. Unfortunately, from the perspective of conservation, unimpeded growth is the unchallenged goal of global development theory. Indeed: "In recent years the governing elites of the market democracies have persuaded or cajoled virtually the entire world to adopt a common myth of uncommon power. All major national governments and mainstream international agencies are united in a vision of global development and poverty alleviation centred on unlimited economic expansion fuelled by open markets and more liberalized trade".[34] In this section I advance the hypothesis that globalization and trade may well pose the single greatest threat to biodiversity today.

On an infinite planet untrammelled trade might be an unqualified good. Even on tiny Earth, managed trade in the context of a steady state economy could improve everyone's quality of life without seriously impairing ecological integrity or biodiversity. Unfortunately, the growth ethic and prevailing economic logic give no quarter to the fact that the earth is actually both finite and fragile.

According to conventional trade theory (and common understanding), freer trade should be mutually beneficial to all trading partners.[82] Trade can relieve local shortages – thus seeming to increase local carrying capacity[83] – and catalyze growth at both ends of the trading relationship. Theory suggests that if each country specializes in those few goods or commodities in which it has a comparative advantage and trades for everything else, the world should be able to maximize gross material efficiency. Access to cheap resources and labour, together with economies of scale, results in lower prices. This encourages higher consumption and therefore increases total output. Since trade raises overall production/consumption and also increases the variety of goods and services available to all trading partners, it could potentially raise material standards for everyone. Little wonder that more liberal trade is a mainstay of contemporary globalization strategies.

With all this going for it, what can possibly be wrong with trade? From the perspective of sustainability and bio-conservation, the yellow flags should be obvious.[84] As noted, and consistent with the growth ethic, the objectives of more liberal trade are to relieve resource constraints on local economic expansion and to increase overall economic output. These factors allow population and material growth within all trading regions to be sustained beyond local biophysical limits that would exist in the absence of trade and they stimulate increased global demand for resource commodities of all kinds. To put this in terms of our earlier discussion, unconstrained trade is specifically intended to elevate the human enterprise further from thermodynamic equilibrium. But this both requires even deeper human incursions into remaining patches of natural habitat (displacing non-human species) and permanently increases the overall dissipative pressure on biophysical resources. There is simply no way around this problem – as previously argued, the second law is inviolable and the human enterprise is a dependent wholly contained sub-system of the ecosphere.

The mechanisms by which widening trade circles wreak their impacts on biodiversity can permanently transform both ecological and social systems. Consider the effect of specialization, which, by definition, implies the simplification of regional/national economies. In traditional bio-diverse agro-ecosystems, farmers often intermixed many varieties of the same crop, and different crops, in the same fields, or planted many crops at different times and in different places. This not only provided a natural method of pest control, but helped achieve a dependable food supply – "average production from year to year varied little because of the law of large numbers".[85]

By contrast, the integration of local crop production into producer-competitive global markets generally requires uniform, materially intensive (high-input) production methods. This has many deleterious effects on several levels of biodiversity. The most obvious involves the increasingly universal use of relatively few commercial crop varieties. Traditional varieties – often exquisitely and differentially adapted to local natural conditions – are giving way all over the world to a handful of commercially acceptable cultivars bred or engineered to respond best to increasingly uniform artificial inputs. These chemical inputs then produce their own negative effects. Excess reliance on fertilizers accelerates soil degradation including the destruction of the micro-flora and micro-fauna that comprise the majority of species in most ecosystems; the abuse of chemical biocides reduces the diversity and abundance not only of target pests (usually insects and weeds) but also of non-target organisms in several unrelated taxa, including birds and mammals. "Cropping" natural forests can have similar impacts. For example, clearcut logging in old growth forests may reduce soil biodiversity from thousands to hundreds or tens of species per square metre, with serious consequences for recovery. The resultant loss of vital mycorrhizal fungi is known to limit the success of even low-diversity plantation-oriented reforestation efforts.[86] The bottom line? Genetic, species, and population diversity are all negatively affected by trade-induced ecosystem simplification.

The compulsion to trade can also dramatically alter human behaviour by shifting the perceived value of various goods and services of nature. Economists distinguish between the "use value" and the "exchange value" of any good. Use value is the utility or enjoyment one experiences in using or consuming a good. The exchange value is the money price one could get for that good by selling it in the marketplace. Many local renewable resources such as fish stocks or forests would never be jeopardized if used only to supply the use-related needs of resident populations. However, once people begin to exploit the exchange value of a good in the marketplace, the potential for ecological damage looms large.[87]

The point is that the globalization of trade encourages people everywhere to market "surplus" local resources and use the income to purchase manufactured goods or other things not available (or available only at greater cost) from the local economy. Indeed, international development is frequently based on an "export-led" development model. As described above, countries are encouraged to maximize their incomes by specializing in those crops or products for which they have a natural comparative advantage and use the income to import things they cannot produce at home (Canada produces lumber and wheat; Costa Rica, bananas).

The potential for massive ecological damage – including accelerated biodiversity loss – from trade is truly a modern problem. In pre-industrial times, trade was limited. Most countries and even smaller communities could produce most of their own limited material *needs*. However, the increasing sophistication and diversification of the globalizing economy means that virtually no region or country has the necessary population, human skills or resources to maintain the "good life" on its own. (Consider the explosion of high-tech consumer goods, many unheard of just a few decades ago – autos, computers, cell-phones, home entertainment systems, household appliances, etc. – that are now deemed necessities of modern life.) Most modern countries and regions are therefore essentially forced to trade and, naturally enough, the ecological effects are often greatest on biodiversity-rich developing countries. The latter have to export large quantities of resources to finance their imports of the expensive manufactured goods now required to satisfy their citizens' ever-rising material *wants*.

Both Low Prices *and* High Prices Can Be a Threat to Biodiversity

One result is that trade in agricultural and resource commodities has become a defining characteristic of global techno-industrial society. The problem for many resource-based communities and countries is that in an expanding, increasingly competitive global marketplace, the prices of many resource commodities have been stagnant or falling. (This is partly because there are often many competing suppliers of particular commodities but the few large multi-national trading conglomerates constitute a near-monopoly of buyers.) By contrast, the ever-increasing array of sophisticated manufactured products made from those resources command top dollar in world markets. Of course, for solvency, the value of exports must be at least equal to the value of exports – plus the extra cash needed to pay off the export development loan – but this is made more difficult by deteriorating terms of trade. Faced with heavy debt loads and falling prices, resource exporters must ship an increasing volume of unprocessed resources to finance their loans and pay for imported high-end manufactured goods and services. In many cases, despite rising harvest or depletion rates, economic margins continue to decline and resource exporters have reduced capacity to manage their natural capital stocks sustainably. In the short-term, low commodity prices resulting from unfavourable terms of trade and global competition may delight resource importers and ultimately consumers. However, low prices also encourage wasteful consumption that further accelerates natural capital depletion and biodiversity losses.

Ironically, biodiversity may also be threatened by economic behaviour induced by *rising* prices. The mere possibility of world trade exposes pockets of scarce resources everywhere to the largest possible market and a growing pool of wealthy consumers for whom price is no object. Competition among consumers may bid *up* the market price for highly valued species thus encouraging ever-greater harvest rates as local people respond to rising exchange values. One result is that wildlife poaching for trade is now said to be the world's second most important illegal economic activity after the trade in illicit drugs.

The economic boom in populous China provides several examples of this modern problem. Recent reports reveal that: "Thrilled by the wider choice of food that wealth brings, Chinese people are now consuming the country's beleaguered wildlife at rapid rate… Highly endangered species, such as the Tibetan antelope, called the chiru, have started to appear on Shanghai restaurant menus".[88] Moreover, the opening of trade between China and the countries of Southeast Asia is draining wildlife from the surrounding countries. When trade with China opened up, wildlife "harvesting" boomed in Vietnam. People found they could get high prices for certain animals – as much as $1000 for individuals of one species of turtle, *Cuora trifasciata*, the three-striped box turtle, believed in China to cure cancer. (As many as 12 million turtles may be sold in China every year.) While wildlife still commonly shows up on local restaurant menus in Vietnam, the effects of local commerce in game are nothing like the impact of trade with China. The trade has spread even to remote areas, where local people collect wildlife, then sell it to brokers, who in turn sell the animals to the China trade. This unregulated trade is having a noticeable impact on Vietnam's biodiversity.[89]

Even Canada's wildlife is being impacted by burgeoning global markets for illicit wildlife products. For example, the incidence of poaching on British Columbia's black bear population (along with other bear populations in the Pacific Northwest) has risen sharply in response to Chinese and other Asian markets demand for bear paws and gall bladders for "medicinal" purposes.

The increase in human depredation due to trade opportunities may push some slowly reproducing animals – and plants – closer to population or even species extinction. This is a particular danger if the species in question roams free in the unregulated global commons, accessible to any and all human hunters in pursuit of economic gain. McDaniel and Gowdy[8] describe several cases where prices, even in conventional markets, jeopardize or, at best, provide no protection to "open access" biological resources. In the contemporary case of Atlantic bluefin tuna, demand and market price have increased much faster than the costs of fishing, despite the declining stock. A single fresh bluefin fetches tens of thousands of dollars and the price of tuna just keeps rising. Fishers therefore actually have an escalating economic incentive to continue the hunt, possibly to the last fish.

By contrast, 19th century market prices for North American bison products and for the once super-abundant passenger pigeon rose only insignificantly as their respective populations plunged. Again, markets provided no incentive for conservation even toward the end. The passenger pigeon was extirpated and the few hundred bison that were saved owed their good fortune to the determined efforts of conservationists.

The historic human tendency to ravage the common pool for personal gain led Ophuls and Boyan[90] to observe that we may ultimately be propelled to the brink of ecological chaos "not so much by the evil acts of selfish people as by the everyday acts of ordinary people whose behavior is dominated, usually unconsciously, by the remorseless self-destructive logic of the commons." This reinforces our more general premise that conventional economic reasoning and behaviour reinforce humanity's inherent tendency toward unsustainability. Globalization simply takes humanity's historic conflict with non-human nature to a whole new level of intensity.

EPILOGUE: WHILE WE'RE SPECULATING…

This paper presents a bleak prognosis of prospects for sustainability and biodiversity conservation. The dynamics of the problem are complex but the basic argument is not hard to follow:

- Like all other species, *H. sapiens* has an innate biological imperative to expand into all available habitats. However, our capacity for language and technology make us more successful at this that any other large vertebrate.
- Humans have always had to use other species of animals and plants to survive. Indeed, we could not exist without biodiversity and other forms of "natural capital." Nevertheless:
- Human evolution has endowed us with no inhibitions against extirpating other species or destroying our own habitats. Consistent with this:
- Contemporary economic logic is based on a self-serving utilitarian ethic. All of this is problematic because:
- Material economic growth dissipates energy and material gradients (resources) found in nature. In effect, the economy feeds on the ecosphere.
- The human enterprise is an open growing subsystem of the materially closed non-growing ecosphere.
- The continuous growth of the human enterprise therefore necessarily compromises the integrity of the ecosphere, including biodiversity.
- We are unable to price biodiversity to reflect the full social value of its life-sustaining structure and functions. Markets are therefore incapable of signalling potentially disastrous ecological scarcity.
- In a growing economy, biodiversity is almost invariably traded-off in favour of economic considerations, this despite the fact that:
- Sustainability may depend on maintaining constant stocks of natural capital, including species, populations and ecosystems. Meanwhile:
- Our innate expansionist tendencies are currently being reinforced by the cultural myth of unlimited economic growth currently being abetted by globalization and trade.
- The rate of biodiversity loss is therefore increasing unchecked.

Even this bare-bones summary makes clear that an ever-expanding human economy is fundamentally incompatible with sustainability, particularly the conservation of biodiversity. It is also evident why, in many circumstances, efforts to price biodiversity in the public domain will provide little support for conservation. In any event, price signals in open markets may actually encourage the liquidation of even privately held stocks of "natural capital." In sum, contemporary economic logic and behaviour are simply unreliable allies in the quest for biodiversity conservation and sustainability.

The obvious conclusion is that achieving sustainability will require other than a strictly economic rationale. As McDaniel and Gowdy[8] argue: "Until we move from econocentric resource management to a policy whose [explicit] goal is the preservation of ecosystem integrity, biological resources will continue to be degraded". This argument recognizes that the only way biodiversity can be conserved is if we accord it trump status among moral principles.[91] Biodiversity must stand above all other considerations.

But this presents an immediate problem. As Randall[9] emphasizes: "Surely many would argue that enhancing the life prospects of the worst-off people has moral force at least as powerful as that of protecting biodiversity". In this light, "…pre-eminent value status for biodiversity…is unlikely to survive scrutiny, given the powerful appeal of many other candidates". Are we therefore condemned to a continuous loop, forced back to using faulty evaluation techniques to attempt "least-cost" trade-offs of biodiversity against human interests?

Perhaps for a time we are, but there is a potential way out. The world community would "merely" have to give up on population and economic growth before the pressures on biodiversity are irreversibly fatal. We have seen throughout this discussion that the bane of biodiversity is humanity's innate expansionism as now reflected in neoliberal growth economics. Remove this force and the tension between humans and the rest of nature disappears. Biodiversity would not have to trump other human interests – in the absence of growth pressure the two could coexist (as they still do in some places on the planet).[92] It would be relatively easy to establish a constant natural capital stocks rule. In most of the world, people are already living in remnant ecosystems but there is sufficient biodiversity left on Earth to stabilize the global system and perhaps begin the long-term restoration of biological integrity.

Giving up on growth should not be as difficult as it first appears. In most wealthy countries there is virtually no natural population growth and economic growth is a mere addiction, necessary to neither individual nor population health. Indeed, there is much evidence that human well-being is no longer correlated with income growth in the developed world and in some countries the relationship is negative.[93] Self-interested intelligent people would yield to these data and work to begin the transition to a steady-state economy.[94] Indeed, given present levels of wasteful consumption, steady-state levels of throughput could be substantially lower than current levels with no loss of life-quality. This would free up ecological space to meet the needs of the planet's worst-off and, over-time, reduce the pressure on biodiversity.

While we're contemplating revolutionary changes it wouldn't hurt to wonder whether modern humans can learn to love the non-human world, to come to feel in their bones that the violation of nature is a violation of self. Humans preserve only what they love (and they certainly do not normally subject the things they truly love to market forces). Even an acquired sense of biophilia would greatly reduce the economic pressures on biodiversity particularly if it were part of a generally more life-sustaining and spiritually satisfying life-style than most of us enjoy today.

There seems to be consensus that the human enterprise is currently unsustainable – the debate is about alternative paths to ecological security. Can we get away with fine-tuning the global economy or does the problem demand a more radical "paradigm shift"? David Pearce[10] once argued that the economic valuation approach to biodiversity "does not deny other rationales for [conservation]... Yet it may be unnecessary to resort to such moral arguments. Economic arguments alone could well be sufficient to justify a dramatic reduction in [biodiversity loss]". Well, perhaps in some situations, but not for long in a world committed to continuous material growth.

In these circumstances, we may well be justified in arguing that a shift to steady-state thinking[75,92] and ethics-based approaches are necessary,[95] and possibly even sufficient, for sustainability. This would not deny the economic rationale, yet, with a more balanced system of values, it might not be necessary to resort to crude economic analyses. Ethical and moral arguments alone would be sufficient to halt the arbitrary destruction of biodiversity. (And the question of how to commodify the living world would never come up.)

NOTES AND SOURCES

[1] For more on the topic of biodiversity, see Willison, Chapter 2.

[2] Nunes, PALD. and van den Bergh JCJM. Economic valuation of biodiversity: sense or nonsense? *Ecological Economics* 2001; 39: 203-222.

[3] Wilson, EO. The current state of biological diversity. In Wilson, EO. (ed.). *Biodiversity*. Washington, DC: National Academy Press; 1988.

[4] Keystone species may not be among the dominant or even obvious species in their ecosystems. The determining criterion of a keystone species (such as the sea otter in the inshore-marine kelp forests of western North America) is that their activities determine the structure of the entire community. They can usually be identified only by removal experiments. See Chapter 7, Keystone Species May be Essential to a Community, in Krebs, CJ. *The Message of Ecology*. New York: Harper and Row; 1988 (99-112).

[5] For more on fisheries collapses, see Hutchings, Chapter 6.

[6] Holling, CS. Resilience of Ecosystems: Local Surprise and Global Change. In Clark, W and Munn, T. (eds.), *Sustainable Development of the Biosphere.* Laxenburg, Austria: IIASA and Cambridge: Cambridge University Press; 1985.

[7] Ehrlich, PR and Daily G. Population Extinction and Saving Biodiversity. *Ambio* 1993; XXII (2-3): 64-68.

[8] McDaniel, C and Gowdy JM. Markets and biodiversity loss: some case studies and policy considerations. *International Hournal of Social Economics* 1998; 25 (10): 1454-1465.

[9] Randall, A. The Value of Biodiversity. *Ambio* 1991; 20 (2): 64-68.

[10] Pearce, D. Deforesting the Amazon: Toward an Economic Solution. *EcoDecision* 1991; 1 (1): 40-49.

[11] Eherenfeld, D. Why Put a Value on Biodiversity? Chapter 24 in Wilson, EO. (ed.). *Biodiversity*. Washington, DC: National Academy Press; 1988 (212-217).

[12] Classic early treatments of this subject include Stone, C. Should Trees Have Standing? Toward Legal Rights for Natural Objects. *45 Southern California Law Review 450; 1972* and Tribe, L. Ways Not to Think about Plastic Trees: New Foundations for Environmental Law. *83 Yale Law Journal 1315*; 1974. The ideal conditions for the contractarian approach are set out in Rawls, J. *A Theory of Justice.* Cambridge, MA: Harvard University Press; 1971.

[13] See Czech, Chapter 22.

[14] Montgomery, CA and Pollack, RA. Economics and Biodiversity: Weighing Benefits and Costs of Conservation. *Journal of Forestry* 1996 February; 34-38.

[15] See for example, Ponting, C. *A Green History of the World.* London: Sinclair-Stevenson; 1991.

[16] Diamond, J. *The Third Chimpanzee*. New York: HarperCollins Publishers; 1992. p 355.

[17] Rees, WE. Patch disturbance, Eco-Footprints, and Biological integrity: Revisiting the Limits to Growth. Chapter 8 in Pimentel D, Westra L, and Noss R, (eds.). *Ecological Integrity: Integrating Environment, Conservation and Health.* Washington, DC: Island Press; 2000.

[18] Pimm SL, Russell GJ, Gittleman JL, and Brooks TM. The Future of Biodiversity. *Science* 1995; 296: 347-350.

[19] See Chesworth, Chapter 3.

[20] SOHO theory posits that all living entities exist as self-organizing sub-systems within a loosely over-lapping hierarchy of such systems. The entire structure is termed a holarchy and each recognizable sub-system is a "holon," Holons (e.g., cells, individuals, ecosystems) may be self-producing but they are only quasi-independent. Each holon must draw on higher levels in the holarchy for resources and as sinks for waste. Holons are therefore "open" to both energy and material flows.

[21] See Willison, Chapter 2.

[22] Prigogine, I. *The End of Certainty: Time, Chaos and the New Laws of Nature.* New York: The Free Press; 1997. Chapter 2.

[23] Schrödinger, E. *What is Life: The Physical Aspect of the Living Cell.* Cambridge: Cambridge University Press; 1945.

[24] See, for example, Kay J and Regier H. Uncertainty, complexity, and ecological integrity. In Crabbé P, Holland A, Ryszkowski L, and Westra L, (eds.). *Implementing Ecological Integrity: Restoring Regional and Global Environment and Human Health*, NATO Science Series IV: Earth and Environmental Sciences, Vol 1. Dortrecht: Kluwer Academic Publishers; 2001.

[25] Schneider, ED and Kay, JJ. Complexity and Thermodynamics: Toward a New Ecology. *Futures* 1994; 26: 626-647. p. 364-365. See also: Schneider, ED and Kay, JJ, Order from Disorder: The Thermodynamics of Complexity in Biology. In Murphy, MP and. O'Neill, LAJ (eds.). *What is Life: The Next Fifty Years. Reflections on the Future of Biology.* Cambridge University Press; 1995. Nicholas Georgescu-Roegen famously pioneered the application of these thermodynamic concepts to the modern economy. See, for example, Georgescu-Roegan, N. The Entropy Law and the Economic Problem. *Distinguished Lecture Series no* 1. University of Alabama, Department of Economics. 1971; Georgescu-Roegen, N. *The Entropy Law and the Economic Process.* Cambridge: Harvard University Press; 1991.

[26] Ulanowicz, RE. Ecology, The Ascendent Perspective. New York: Columbia University Press; 1997.

[27] Luvall, JC and Holbo, HR . Measurements of short term thermal responses of coniferous forest canopies using thermal scanner data. *Remote Sens. Environ.* 1989; 27: 1-10.

[28] These coupled cloud-rain forest systems actually have the same long-wave temperature as mid-Canada in February, indicating prodigious essergy dissipating capacity!

[29] Daly, HE. Steady-state economics: concepts, questions, policies. *Gaia* 1992; 6: 333-338.

[30] Rees, WE. Consuming the Earth: The Biophysics of Sustainability. *Ecological Economics* 1999; 29: 23-27.

[31] Boltzmann, L. The second law of thermodynamics (orig. 1886). In *Ludwig Boltzmann, Theoretical Physics and Philosophical Problems*, McGinness B (ed.). New York: D Reidel; 1974. Boltzmann also said that "the struggle for existence of animal beings is… but a struggle for entropy…" which seems contradictory. But he went on: "…the products of the chemical kitchens [of plants] constitute the object of the animal world." These "products" are the result of photosynthetic net entropy production by plants.

[32] Lotka, AJ. Contribution to the Energetics of Evolution. *Proc. Natl. Acad. Sci.* 1922; 8: 147-155.

[33] For a thorough introduction, see: Hall, AS. *Maximum Power: The Ideas and Applications of HT Odum.* Niwot, CO: University Press of Colorado; 1995.

[34] Rees, WE. Globalization and Sustainability: Conflict or Convergence?" *Bulletin of Science, Technology and Society* 2002; 22 (4): 249-268.

[35] See Chesworth, Chapter 3.

[36] Price, D. Energy and Human Evolution. *Population and Environment* 1995; 16: 301-317; Duncan, RC. The Life Expectancy of Industrial Civilization: The Decline to Global Equilibrium. *Population and Environment* 1993; 14: 325-357.

[37] Pauly, D and Christensen V. Primary production required to sustain global fisheries. *Nature* 1995; 374: 255-257. Also see Hutchings, Chapter 6.

[38] Christensen V, Guénette S, Heymans J, Walters C, Watson R, Zeller D, and Pauly D. Hundred-year decline of North Atlantic predatory fishes. *Fish and Fisheries* 2003; 4: 1-24.

[39] Myers RA and Worm B. Rapid worldwide depletion of predatory fish communities. *Nature* 2003; 423: 280–283.

[40] Haberl, H. Human Appropriation of Net Primary Production as An Environmental Indicator: Implications for Sustainable Development. *Ambio* 1997; 26: 143-146.

[41] Vitousek, P, Ehrlich PR, Ehrlich AH, and Matson P. Human appropriation of the products of photosynthesis. *BioScience* 1986; 36: 368-374.

[42] Tuxill, J. *Losing Strands in the web of Life: Vertebrate Declines and the Conservation of Biological Diversity.* Worldwatch Paper 141. Washington, DC: The Worldwatch Institute; 1998.

[43] McKee JK, Sciulli PW, Fooce CD & Waite TA. Forecasting global biodiversity threats associated with human population growth. *Biological Conservation* 2004; 115 (1): 161-164. Also see Willison, Chapter 2.

[44] Thomas, JA (and eight others). Comparative Losses of British butterflies, Birds, and Plants and the Global Extinction Crisis. *Science* 2004; 303: 1879-1881.

[45] Fowler, CW and Hobbs L. Is humanity sustainable? *Proceedings of the Royal Society of London, Series B: Biological Sciences* 2003; 270: 2579-2583.

[46] Hern, WM. Is human culture oncogenic for uncontrolled population growth and ecological destruction? *Human Evolution* 1997; 1-2: 97-105. See also: Hern WM. Why are there so many of us? Description and diagnosis of a planetary ecopathological process. *Population and Environment* 1990; 12: 9-39.

[47] Palmer M. (and twenty others). Ecology for a Crowded Planet. *Science* 2004; 304 (5675): 1251-1252.

[48] There is a good chance, however, that climate change, resource scarcity, systems collapses and geopolitical chaos will intervene well before the human population reaches such heady heights.

[49] University of Texas, Austin Press Release. *Extinction Rate Across the Globe Reaches Historic Proportions.* http://www.sciencedaily.com/releases/2002/01/020109074801.htm. 10 January 2002.

[50] Critics might argue that economic activity is not only dissipative in nature but that it also creates a good deal of order, a kind of order that many prefer to nature. This is true but misses an essential point: the creation of order by the human enterprise requires the transformation of available energy and matter extracted from the ecosphere. Since economic production involves thermodynamic processes that cannot be 100% efficient, the increased order of the human enterprise (the accumulation of manufactured capital) never fully compensates thermodynamically for the disordering of the ecosphere (the depletion of natural capital). In sum, negentropy production in the economy is always less than the negen-

tropy drawn from the ecosphere so the entropy of the total system increases. Continuous economic growth therefore continuously eats away at life-support structures and functions.

[51] Costanza, R. (and twelve others). The value of the world's ecosystem services and natural capital. *Nature* 1997; 387: 252-260.

[52] Pearce, D. *Valuing the Environment: Past Practice, Future Prospect*. CSERGE Working Paper PA 94-02. London: Centre for Social and Economic Research on the Global Environment, University College (London) and University of East Anglia; 1994.

[53] See Czech, Chapter 22.

[54] See Beder, Chapter 5.

[55] Rees, WE. How Should a Parasite Value its Host? *Ecological Economics* 1999; 25: 49-52.

[56] Vatn, A. and Bromley DW. Choices withouth prices without apologies. *Journal of Environmental Economics and Management* 1994; 26: 129-148.

[57] Randall, A. What Mainstream Economists Have to Say about the Value of Biodiversity. Chapter 25 in Wilson EO., (ed.). *Biodiversity*. Washington, DC: National Academy Press; 1988 (217-223).

[58] For more on attitudes and values, and ethics generally, also see Menon & Lavigne, Chapter 12; Lynn, Chapter 13; and Worcester, Chapter 17.

[59] Pearce D and Moran D. *The Economic Value of Biodiversity.* London: Earthscan Publications; 1994. p 30 and 32.

[60] Also see Beder, Chapter 5; especially her note 25 on neoliberalism, economic rationalism, and neoconservatism.

[61] For more on ecotourism, see Mugisha and Ajarova, Chapter 10; and Corkeron, Chapter 11.

[62] Fischhoff, B. Value Elicitation: Is There Anything in There? In Hechter M, Cooper L. Nadel L (eds.). *Values.* Palo Alto, CA: Stanford University Press; 1991.

[63] O'Neill, J. Managing Without Prices: The Monetary Valuation of Biodiversity. *Ambio* 1997; 26 (8): 546-550.

[64] Commoditization is an increasing problem for biodiversity conservation. It reflects the continuous pressure in modern consumer societies "to transform as much of the necessities and pleasures of life as possible into commercial commodities. [The latter] have replaced other forms of need satisfaction in the lives of most people. The more this happens, the more of the earth's resources are turned into commodities, and the more the waste products of consumption are pumped back into the biosphere". (Manno, JP. *Privileged Goods: Commoditization and Its Impact on Environment and Society.* Boca Raton: Lewis Publishers; 2000. p 13.)

[65] Lave, L. and Gruenspecht, H. Increasing the Efficiency and Effectiveness of Environmental Decisions: Benefit-Cost Analysis and Effluent Fees – A Critical Review. *Jour. Air Waste Management Assoc.* 1991; 41 (5): 680-693.

[66] The same criticism applies to various models advanced by economists for the valuation of biodiversity whose seeming analytic rigor and complexity obscures the models' excessive abstraction from real-world ecosystems. (See, for example Weitzman, ML. The Noah's Ark Problem. *Econometrica* 1998; 66 (6): 1279-1298).

[67] To put it another way, if the opportunity costs of conservation (the forgone benefits of development) exceed the perceived value of that which is conserved, development will proceed.

[68] Ecologist Garrett Hardin famously (and erroneously) labelled this "the tragedy of the commons" (Hardin, G. The Tragedy of the Commons. *Science* 1968; 162: 1243-1248.) It is now more accurately known as the "open access problem." (See Ophuls and Boyan, Note 90, for an excellent discussion.)

[69] For more on the bushmeat issue, see Eves, Chapter 9; Oates, Chapter 18; and Milner-Gulland, Chapter 20.

[70] Clark, CW. The Economics of Over-Exploitation. *Science* 1973; 181: 630-634.

[71] Clark, CW. Economic Biases Against Sustainable Development. Chapter 20 in Costanza, R. (ed.). *Ecological Economics: The Science & Management of Sustainability*. New York: Columbia University Press; 1991.

[72] In the extreme, starving farmers will consume their seed grain out of desperation to survive today, even at the expense of a harvest tomorrow. Poor people – and poor countries – have relatively high discount rates.

[73] For the basic argument, see Myers, N. Biodiversity and the Precautionary Principle. *Ambio* 1993; 22 (2-3): 74-79.

[74] For and update on "limits to growth", see Meadows, D., Randers, J. and Meadows, D. *Limits to Growth: The 30-year Update.* White River Junction, VT: Chelsea Green Publishing Company; 2004. 338 pp.

[75] Daly, HE. Steady State Economics (2nd ed.). Washington: Island Press; 1991. Also see Czech, Chapter 22.

[76] Costanza, R and Daly HE. Natural capital and sustainable development. *Conservation Biology* 1992; 1: 37-45. Daly, HE. Sustainable development: from concept and theory towards operational principles. Population and Development Review 1990 (special issue) Reprinted in: Daly, HE. *Steady State Economics* (2nd ed.). Washington: Island Press; 1991; Victor, PA, Hanna E, and Kubursi, A. How strong is weak sustainability? *Economie Appliquée* XLVIII (2): 75-94.

[77] Rees, WE. Achieving Sustainability: Reform or Transformation? *Journal of Planning Literature* 1995; 9 (4) 343-361.

[78] Pearce D., Markandya A and Barbier EB. *Blueprint for a Green Economy.* London: Earthscan Publications; 1989. p. 7.

[79] Norgaard, RB. The Rise of the Global Exchange Economy and the Loss of Biodiversity. In Wilson EO., (ed.). *Biodiversity*. Washington, DC: National Academy Press; 1988. p. 206-207.

[80] Becker, J. Why all the world feels China's growing pains. Independent Digital; 8 May 2004. http://news.independent.co.uk/world/asia/story.jsp?story=519237

[81] York, G. Myanmar mired in a deforestation crisis. Globe and Mail, 13 May 2004; p A14.

[82] Lieth, J. Chapter in T. Schrecker and J. Dalgleish, (eds.). *Growth, Trade And Environmental Values.* Westminster Institute for Ethics and Human Values; London, Ontario: 1994.

[83] That trade acts to increase (local) carrying capacity depends on the fact that each trading region is an open system. However, the world as a whole is effectively closed which

turns things around in ecological terms. Non-renewable resources (e.g., petroleum) imported by and consumed in region “a” are no longer available for future consumption in the exporting region “b.” The terms of trade may also lead to the depletion of self-producing resources throughout the trading network (see below). Hence, while exchange can result in a short-term increase in the human population and material standards in each trading region, it also increases global consumption and waste generation. In short, trade tends to accelerate resource dissipation everywhere. It follows from the second law that continuous trade-induced growth of the human enterprise must eventually lead to a *decrease* in global carrying capacity.

[84] I ignore here a significant *economic* problem. The free flow of capital among nations undermines the theory of comparative advantage that confers the presumed universal benefits of trade. Rather than staying home and specializing in those goods for which the domestic economy has a comparative advantage, capital flows out across the world in search of the absolute advantage represented by low-cost labour. China thus becomes the world’s manufacturing centre as firms in the developed world “outsource” production at the expense of their domestic employees and economies.

[85] Richards, P. *Indigenous Agricultural Revolution: Ecology and food Production in West Africa*. Boulder, Colo: Westview Press; 1985.

[86] Perry D., Amaranthus M., Borchers J., Borchers S., and Brainerd R. Bootstrapping in ecosystems. *BioScience* 1989; 39 (4): 230-237.

[87] For example, consumption by Canadians alone would have had only a marginal impact on the Northern Cod stocks under their jurisdiction or on the volume of Canada’s old-growth forests. Both resources are now greatly trade-depleted – indeed, the industrial cod fishery collapsed in the early 1990s and has remained suspended for over a decade.

[88] Hu Pan. Wealthy Chinese Eating Wildlife into Extinction. *Environment News Service* 2000. 31 January 2000.

[89] Newsletter, Washington: American Museum of Natural History (Center for Biodiversity Conservation). Fall 2000.

[90] Ophuls, W. and Boyan AS. Jr,. *Ecology and the Politics of Scarcity Revisited: The Unraveling of the American Dream*. New York: W.H. Freeman and Company; 1992. p. 199.

[91] For more on the subject of ethics, see Lynn, Chapter 13.

[92] To illustrate, consider contemporary British Columbia, Canada. The province is wealthy, resource rich and enjoys a low average population density compared to most other places on in the developed world. British Columbia boasts one of the world’s largest sockeye salmon runs in the Fraser, its greatest river. The Fraser also has enormous potential as a source of hydro-electricity. The potential annual economic value of the energy (particularly for export) is in the hundreds of millions of dollars, vastly more than the economic value of the salmon. Yet any politician who seriously proposed developing that power would face a political storm. The people of BC identify with the salmon; at this stage in the development of the region, they implicitly value the integrity of the salmon run more than the wealth that would be derived from power development. However, excessive population or demand growth, or severe energy shortages in North America, would force a choice between salmon and development of the river and the salmon would almost certainly be sacrificed before the perceived greater need for more energy.

[93] Lane, R. *The Loss of Happiness in Market Democracies.* New Haven: Yale University Press; 2000.

[94] See Czech, Chapter 22.

[95] See Lynn, Chapter 13.

A Triptych of Limerick

On this once verdant planet called Earth
Of big-brained folk there’s no dearth
But they talk conservation
Without reservation
While trashing the place of their birth.

The GDPs up in the zillions
While life forms die off by the millions
There’s just one conclusion
The money’s illusion
(And there’s too many people by billions!)

At its meeting in old County Clare
The IFAW did loudly declare
That a world sustainable
Is not attainable
If there’s no wildlife there.

William E. Rees, 2004