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Goals and Conditions for a Sustainable World

A collection of papers by

John Cairns, Jr.

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Goals and Conditions for a Sustainable World

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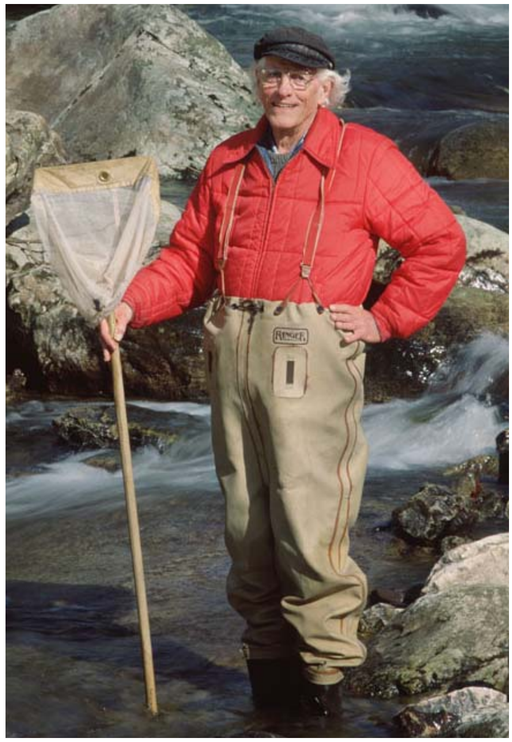

Cairns received the PhD and MS from the University of Pennsylvania, an AB from Swarthmore College, and completed a postdoctoral course in isotope methodology at Hahnemann Medical College, Philadelphia. He was Curator of Limnology at the Academy of Natural Sciences of Philadelphia for 18 years, and has taught at various universities and field stations. Professional certifications include Qualified Fishery Administrator by the American Fisheries Society, Senior Ecologist by the Ecological Society of America, and the Academy of Board Certified Environmental Professionals.

Among his honors are Member, National Academy of Sciences; Member, American Philosophical Society; Fellow, American Academy of Arts and Sciences; Fellow, American Association for the Advancement of Science; Foreign Member, Linnean Society of London; the Founder's Award of the Society for Environmental Toxicology and Chemistry; the United Nations Environmental Programme Medal; Fellow, Association for Women in Science; U.S. Presidential Commendation for Environmental Activities; the Icko Iben Award for Interdisciplinary Activities from the American Water Resources Association; Phi Beta Kappa; the B. Y. Morrison Medal (awarded at the Pacific Rim Conference of the American Chemical Society); Distinguished Service Award, American Institute of Biological Sciences; Superior Achievement Award, U.S. Environmental Protection Agency; the Charles B. Dudley Award for excellence in publications from the American Society for Testing and Materials; the Life Achievement Award in Science from the Commonwealth of Virginia and the Science Museum of Virginia; the American Fisheries Society Award of Excellence; Doctor of Science, State University of New York at Binghamton; Fellow, Virginia Academy of Sciences; Fellow, Eco-Ethics International Union; Twentieth Century Distinguished Service Award, Ninth Lukacs Symposium; 2001 Ruth Patrick Award for Environmental Problem Solving, American Society of Limnology and Oceanography; 2001 Sustained Achievement Award, Renewable Natural Resources Foundation. Cairns has served as both vice president and president of the American Microscopical Society, has served on 18 National Research Council committees, two as chair, is presently serving on 14 editorial boards, and has served on the Science Advisory Board of the International Joint Commission (U.S. and Canada) and on the USEPA Science Advisory Board. The author has been interested in sustainable use of the planet since 1948 when his mentor, Dr. Ruth Patrick, described it as "use without abuse of natural systems."

PREFACE

I am deeply grateful to Professor Otto Kinne and Inter-Research for this opportunity to share my ideas with colleagues over the entire globe. Neither the publishers nor I will receive any money for this book. We believe that the quest for sustainable use of the planet should involve all humankind, even if individuals cannot afford to purchase a book – in fact, particularly if this is the case. Sustainability requires an enduring global effort, so all must have hope for the future and for the quality of life their descendants will have. In order to achieve sustainability, human society must develop a mutualistic relationship with natural systems and with the species that inhabit them. Both human society and natural systems are dynamic and so must the relationship be.

The articles in this book represent preliminary steps in the transition from a homocentric to an ecocentric view; additional articles will be added when they become available. Because the articles were originally published in a diverse array of journals and books, some redundancy occurs because these concepts add to a newly developing field, and the common knowledge base of all professions and individuals needs to be expanded. The choice of a variety of journals for the original publications was deliberate because it was important to both determine the extent of shared knowledge about sustainability and to increase the amount shared. Except for the first article, from which the title of this book comes, it was difficult to decide what sequence the articles should follow. Sustainability is a multidimensional activity, so a linear arrangement seems inappropriate, although books must be produced this way. Doubtless, over large temporal and spatial spans, components will change in importance so the reader must select the order in which the articles are read. Since new articles will be added when available, it seems appropriate to add them to the end so they can be easily detected.

When I first became involved in studies of environmental pollution in 1948, it seemed reasonable to believe that providing evidence of the causes and consequences of pollution was all that was necessary. Most scientists have a touching belief that reason guided by evidence will prevail. However, with only one planet, it is not possible to carry out double-blind experiments with a high degree of confidence in the results as is often possible with reductionist science. Moreover, humankind's power over its environment has not been accompanied by a concomitant improvement in its ability to make rational use of the power or to implement compassion for future generations of our species and other life forms. Both are important to the quest for sustainable use of the planet.

There are a number of important issues not even addressed. Illustrative examples include: (1) Is it ethical for *Homo sapiens* to modify the planet so that one species can inhabit it indefinitely when other species are unlikely to have a comparable opportunity? (2) How should society cope with terrorists in a sustainability context? (3) How much should human society alter its practices and behaviors to protect the health and integrity of the planet's ecological life support system?

I now believe that global shared ethical values regarding natural systems is essential. As this is being written, six months after the events of 11 September, 2001, the quest for such ethical values seems utopian – arguably irrational. However, the consequences of not doing so are so appalling that the attempt must be made. Colleagues often ask me why I, a 78-year old, am so involved with the quest for sustainable use of the planet when I will not live to enjoy the benefits. A good question. For over half a century, I have worked to restore damaged ecosystems, knowing full well that the work could be ruined at any time. Restored ecosystems are not less vulnerable to degradation and destruction than natural systems unless human society becomes fully committed to cherish them. Since natural systems constitute the planet's ecological life support system, this could be viewed entirely as a matter of enlightened self interest. However, it should be more than that. The relationship should include empathy, compassion, equity, and fairness. I find constructive activities more satisfying than destructive activities and compassion more restful than rage. Even if natural systems cannot thank us or express gratitude, they will reward us by providing ecosystem services upon which human society depends for its survival.

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Colleagues who reviewed particular articles have been thanked in each one. Processing costs for assembling the disks were paid for by the Cairns Foundation. Permission to reproduce articles was granted from the following publishers: Kluwer Academic Publishers (two articles in *Hydrobiologia* and one article in *Journal of Aquatic Ecosystem Stress and Recovery*), Kluwer Academic/ Plenum Publishers (two articles in *Population and Environment*), *Environmental Health Perspectives* (two articles), The Parthenon Publishing Group Ltd (six articles in *International Journal of Sustainable Development and World Ecology*), The Social Contract Press (four articles in *The Social Contract*), Taylor & Francis (one article in *Quality Assurance*), Mary Ann Liebert, Inc. (one article in *Journal of Anti-Aging Medicine*), Association of Politics and the Life Sciences (one article in *Politics and the Life Sciences*), *Journal of Liberal Religion* (one article), Water Resources Publications, LLC (one chapter in *Advances in Water Monitoring Research*), International Society for Ecosystem Health, Blackwell Science (one article in *Ecosystem Health*), Elsevier (one article in *Aquatic Ecosystem Health and Management*). Permissions granted to reproduce future articles or book chapters after the book has been published will be noted in the individual articles when they are added.

DEDICATION

This book is dedicated to Darla Davis Donald, who has been my editorial assistant for 27 years. She has been extraordinarily dependable in all aspects of the publication process, including dealing with the numerous requirements from a variety of publishing houses, editing my writing for clarity and accuracy, carefully checking galley proofs, and keeping systematic and orderly files on all manuscripts. Despite the challenge of these numerous tasks, Darla has never let me miss a deadline. She has always given me assistance well beyond what I should ever have expected, and her quiet efficiency and organizational skills have made the most significant impact on my continuing to publish. I can only guess at what my publication record would be without her help. Although I thank Darla in every publication, this dedication to her is long overdue.

Article 1

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Commentaries

Defining Goals and Conditions for a Sustainable World

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I am indebted to E. Call for transcribing the dictation of the first draft and for including the many changes needed to produce the second draft and to D. Donald for editorial assistance in preparing the final draft for publication. P. H. Raven made some useful suggestions on an early draft and K..-H. Robèrt, P. Hawken, and J. Hagen provided useful assistance. My colleagues B. Wallace, A. Heath, B. R. Niederlehner, and J. Heckman provided useful comments on the second draft. Last, but far from least, I again thank those who launched the Natural Step Program and its U.S. offspring for the inspiration to give these matters more thought.

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Sustainable development is being approached component by component – socioeconomic, sustainable agriculture, transportation, forestry, energy use, cities, and the like – but, leaving a habitable planet for future generations will require the development of a widely shared paradigm. Further, the paradigm should be ecological from a scientific point of view. This development will be facilitated by a discussion of goals and those conditions necessary to meet them. The presently shared paradigm is that economic growth is the cure for all society's problems, such as poverty, overpopulation, environmental degradation, and the increasing gap between rich and poor. A paradigm shift from growth to sustainability might result either from suffering painful consequences of continuing to follow out-moded paradigms or by discussing what sort of ecosystems will be available to future generations. The purpose of this paper is to help initiate such a discussion.

Key words: conditions for sustainability, habitable planet, paradigm shift, sustainability goals, sustainable development.

Environ Health Perspect 105:1164-1170 (1997), http://ehis.niehs.nih.gov

Economist Kenneth Boulding *(1)* once stated "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist." Since that time, increasing attention has been paid to possible biophysical limits to the growth of human society. There are at least two ways to respond to limits: one is to deal with the consequences of exceeding limits as they are encountered; the other is to adjust behavior now to preempt the unpleasant consequences of exceeding limits to growth. The types of adjustments that may be necessary are the focus of the concept of sustainability.

The United Nations World Commission on Environment and Development Report *(2)*, commonly called the Brundtland Report after the woman who chaired the commission, is generally recognized as the document most responsible for the increased attention to the concept of sustainable development. Sustainable development is defined in the report as development that meets the needs of

Table 1. The four system conditions

System condition	This means:	Reason:	Question to ask:
1. Substances from Earth's crust must not systematically increase in the ecosphere	Fossil fuels, metals, and other minerals must not be extracted at a faster pace than their slow redeposit and reintegration into Earth's crust	Otherwise the concentration of substances in the ecosphere will increase and eventually reach limits – often unknown – beyond which irreversible changes occur	Does your organization systematically decrease its economic dependence on underground metals, fuels, and other minerals?
2. Substances produced by society must not systemically increase in the ecosphere	Substances must not be produced at a faster pace than they can be broken down and integrated into the cycles of nature or deposited into Earth's crust	Otherwise the concentration of substances in the ecosphere will increase and eventually reach limits – often unknown – beyond which irreversible changes occur	Does your organization systematically decrease its economic dependence on persistent unnatural substances?
3. The physical basis for productivity and diversity of nature must not be systematically diminished	We cannot harvest or manipulate ecosystems in such a way that productive capacity and diversity systematically diminish	Our health and prosperity depend on the capacity of nature to reconcentrate and restructure wastes into new resources	Does your organization systematically decrease its economic dependence on activities that encroach on productive parts of nature, e.g., over-fishing?
4. Fair and efficient use of resources with respect to meeting human needs	Basic human needs must be met with the most resource-efficient methods possible, and their satisfaction must take precedence over provision of luxuries	Humanity must prosper with a resource metabolism meeting system conditions 1-3. This is necessary in order to get the social stability and cooperation for achieving the changes in time	Does your organization systematically decrease its economic dependence on using an unnecessarily large amount of resources in relation to added human value?

Reproduced with permission from Robèrt and colleagues (3).

the present without compromising the ability of future generations to meet their own needs. More recently, Karl-Henrik Robèrt, Herman Daly, Paul Hawken, and John Holmberg *(3)* described a simple and accessible model of sustainability, which has been used by corporations and municipalities to guide choices towards those consistent with sustainability. This program, called the Natural Step Program, lists four conditions for sustainability (Table 1) that go beyond the Brundtland report. The Natural Step Program espouses "the need to re-examine the negotiable rules of our economic game so they conform to the non-negotiable rules of the biophysical world." The conditions (K-H. Robèrt, personal communication) are first-order principles for sustainability because 1) they are all necessary for sustainability, 2) they are sufficient for sustainability (i.e., cover the whole area), and 3) they do not overlap. Conditions 1-3 (Table 1) are ecological but severely economical in words, which is essential to reaching a consensus on first-order principles. The discussions will doubtless become more heated when the consequences of accepting a first-order principle are more explicitly stated. In addition, Paul G. Hawken has established a USA Natural Step Program, industries have taken note of sustainable development *(4)*, and the George and Cynthia Mitchell International Prize for Sustainable Development has been awarded for a number of years. The prize recognizes scientific, technical, or management contributions to sustainable development by individuals in the corporate setting or by individuals who have made corporate, sustainable development activities possible. This progress indicates that organizations may meet one or more conditions for sustainability, but these commendable efforts are hardly adequate for achieving sustainability at a planetary level. Not surprisingly, "thinkers" are often better known than "doers," but the latter are now beginning to receive some public recognition. However, a list of publications on sustainability is much more easily acquired than a list of organizations or regions practicing sustainability. Only one person is required to write an article on sustainability, but an organization, tribal unit, or society is needed to practice it.

The term sustainable development implies to many people that the present kinds of resource utilization, space allocation, and the like can be continued with only minor modifications. That is, society can indefinitely continue the loss of biodiversity and the further loss of old growth forests, groundwater aquifers, and ecological habitat. This misconception is one reason why the term sustainable use of the planet may be more appropriate than sustainable development, although initially less acceptable to policymakers. This same misconception is often why many, including myself, use the term sustainability instead of sustainable development. As the UNESCO-UNEP Environmental Newsletter *Connect (5)* notes

> Economic growth – until recently synonymous with development – was once presented as the panacea to the ills of humanity: from poverty and disease to over-population and environmental degradation. Even today there are those who firmly believe that it is the surest cure for ailing humanity.

Human society may have existed for over a million years (arguably as long as several million years) and, at the very least, for hundreds of thousands of years. For most of this time, humans were spread rather thinly across the planet, compared to present population levels and densities, and usually existed in tribal units or small societies. One notable feature of tribal life is that, when consequences surfaced from bad situations (e.g., food shortages), the suffering of the tribe was relatively equitably distributed. In a sense, sustainable use of the planet is an attempt to achieve equitable natural resource distribution over both large temporal and spatial spans *(6)*. One wonders whether compassion for individuals with little access to resources is a persuasive basis for equitable resource distribution for both present and future generations. Some suffering is inevitable, from earthquakes, hurricanes, and other climatic events, or from diverse susceptibility to cancer and other diseases that have dramatic effects on some individuals and not on others. In many human tribes, equitability apparently was achieved through mutual, voluntary sacrifice rather than government edicts, indicating that compassion sometimes has resulted in more equitable distribution of resources.

Illustrative Questions on Sustainability

Human society needs to ask a wide variety of questions about sustainability goals; the following is an illustrative list. Clearly, a comprehensive list is beyond the scope of this paper. Instead, it seems desirable to alert readers not familiar with sustainability issues to the breadth of the subject.

Are changes to assure sustainability really desirable? Most publications on sustainability assume that present lifestyles are highly successful and need only relatively modest tweaking (e.g., recycling) to be sustainable. However, what if the question of sustainability is studied in a systematic, orderly way and a dramatically different lifestyle becomes mandatory? Would society embrace sustainability and, more importantly, implement it? The sustainability initiative makes sense only if an extremely high priority is given to the well-being of future generations. Does the initiative also make sense if society does not always give as high a priority to the well-being of all humans presently alive in order to benefit future generations?

What are discussions of sustainability really trying to accomplish? Costanza *(7)* believes that discussing sustainability for infinite periods of time is inappropriate – all discussions of sustainability should have a particular time frame. Clearly, sustainability initiatives cannot exceed the life of the universe *(8)*. Perhaps the indigenous North American tribes who felt that no decision should be made unless it considered the next seven generations had it right. In fact, experience with money transfer systems, such as the U.S. Social Security system, has shown that some assumptions (in this case, the ratio of citizens contributing funds to those withdrawing funds) do not hold true for even seven generations.

The Natural Step Program lists conditions, meanings, reasons, and questions that should be asked for achieving sustainability. Acceptance of these conditions could be enhanced by stating what is being attempted and what condition must be in place to be successful. Some illustrative examples of my own are covered later in this discussion.

What should the scope and emphasis of a sustainability initiative be? This question is probably one of the biggest hurdles of the whole process. Clearly, countries such as Bermuda and, arguably, even Japan could not achieve sustainability in the near future without external resources because of their population density and the ratio of arable land per capita. Thus, such countries would require somewhat different sustainability scopes and emphases than Australia or Canada, which could possibly be entirely self-sufficient with internal resources. Furthermore, sustainability initiatives should have a strong local or regional component, in addition to sustainability initiatives for larger regions, countries, and, in fact, the entire planet. The People's Republic of China and the United States of America clearly would, at least initially, have different sustainability emphases and different scopes for each of these components.

The significant differences among geographic regions will necessitate lengthy discussions of any implementation of a sustainability initiative. Experiencing severe consequences will undoubtedly affect attitudes toward making sustainability conditions more socially and economically acceptable; however, informed self interest might reduce suffering if action is taken in time. Becoming doers clearly requires acceptance of a major new paradigm.

What program elements should a sustainability initiative contain? Program elements might be grouped by activities such as the timber industry, fisheries, agriculture, energy production, and the like. Considerable emphasis would also have to be given to ensuring that program components did not interact negatively or that program components, each attractive in isolation, would not be incompatible in concert. Also, components at the local, state, regional, national, and international levels must be compatible and not mutually exclusive at these geographic levels and at different levels of political organization. This situation emphasizes the importance of the dictum: every specialist should be able to talk professionally with those in other professions, and representatives from various regions should be able to communicate with each other.

Tentative Goals and Conditions for Sustainability

Thinkers and doers represent a striking dichotomy: some doers are unaware of thinkers, but are well aware of other doers; some thinkers are unaware of the degree to which implementation has occurred and the degree of correspondence to the theoretical models. Of course, this dichotomy is not absolute because some individuals are both thinkers and doers, but the dichotomy does exist to a surprising degree. Perhaps the following section, which attempts to link goals and conditions necessary to meet the goals, might bridge the gap between thinkers and doers.

The term condition is used here to follow the terminology of the Natural Step Program *(3)*. It does not describe existing conditions but, rather, refers to anticipated or qualifier conditions necessary to achieve sustainability.

Goal 1. To see that the machinery of nature has sufficient energy to deliver necessary ecosystem services.

Condition. Human society shall not co-opt so much of Earth's energy that ecosystems can neither furnish services nor endure for substantial periods of time.

Ecosystem services are defined as those functions of ecosystems that are necessary for human survival and welfare. A list of ecosystem services that was consolidated from many sources *(9-14)* is as follows:

- Capture of solar energy and conversion into food, fuel, and other raw materials
- Decomposition of organic wastes and sequestration of other wastes that cannot be broken down, such as heavy metals
- Maintenance of a gas balance in the atmosphere favorable to humans, i.e., storage of carbon dioxide and release of oxygen
- Recycling nutrients in forms useful for plant growth
- Storage, distribution, and regulation of freshwater
- Erosion control and sediment retention
- Generation of agricultural soils
- Control of pests by birds, bats, insects, etc.
- Pollination of crops
- Provision of a genetic library for development of new foods, drugs, building materials, and waste treatment processes through both Mendelian genetics and bioengineering
- Disturbance regulation, i.e., limiting destruction and disruption of other ecosystem services after expected disturbances such as fire, flood, hurricanes, and droughts
- Control of both microclimate and macroclimate
- Recreation and cultural amenities.

The structures of natural systems (i.e., forests, rivers, wetlands, oceans, etc.) can be thought of as natural capital or machinery. The functions of natural systems (i.e., photosynthesis, decomposition, etc.) can be thought of as interest. Without natural systems to capture sunlight, provide food and fiber, break down wastes, or distribute freshwater, human society could not survive. To the extent that human society destroys these ecosystem services, either by destroying the systems that provide them (the capital) or by impairing systems so they provide them less efficiently (reducing interest), sustainability is compromised. The combined value of these ecosystem services to human society has been estimated to be >$33 trillion per year (U.S. dollars) *(14)*.

Vitousek et al. *(15)* have hypothesized that human society is co-opting approximately 40% of the photosynthetic energy of Earth (i.e., that energy converted by plants from sunlight to forms such as carbohydrates that are more suitable for use by humans), which includes photosynthetic energy used for domesticated animals, gasohol, etc. At present, the percentage of the photosynthetic energy necessary for the machinery of nature to deliver the services essential for sustainability is unknown. At one time, human society used only a minuscule portion of the total; in fact, in the hunters and gatherers stage, society probably used far less than 1%. Energy is also extracted from rivers as hydroelectric power, which has a number of deleterious effects upon riverine ecosystems. The energy deprivation threshold at which the machinery of nature would break down is also unknown, but persuasive evidence indicates that some has already broken down. It would be prudent to have more robust information on various thresholds before developing a management strategy for sustainability that might give humans too large a share of Earth's energy.

Goal 2. To avoid poisoning or impairing the machinery of nature by altering both the structure and function of natural systems by means of toxicants.

Condition. Substances extracted from Earth's crust or synthesized from raw materials must not be concentrated or dispersed in ways harmful to the biosphere (e.g., metals, oil, or pesticides). This condition is essentially identical to system condition 1 in Table 1.

Humans and other species can have their functional capabilities impaired without actually causing death. In fact, medicine has moved from merely preventing symptoms of malfunction in humans to requiring evidence of robust health. Similar thinking should apply to natural systems.

Cairns et al. *(16)* have shown that ecological toxicity testing is still evolving despite notable advances during the last four decades. Human society has not yet developed effective predictive models for determining the effects of toxicants on ecosystem services, but the field of landscape ecotoxicology, once developed, should do so *(17)*. More important, more methods are being developed to improve protection and ultimately make ecosystem health a reality.

Goal 3. To ensure that ecosystem services, such as the maintenance of atmospheric gas balance, favorable to human and other life forms continue at their present or, preferably, better levels.

Condition 1. The physical and biological basis for the services provided by nature shall not be systematically diminished (e.g., overharvesting whales or fishery breeding stocks). This condition is similar to system condition 3 in Table 1.

In order to achieve sustainability, the life support system's integrity cannot be impaired. This requirement applies to both the technological life support system upon which human society is now dependent because of its distribution and density (urbanization) and the ecological component. The biotic impoverishment involving the loss of species in most parts of the planet will undoubtedly affect the delivery of ecosystem services, and some evidence exists that allows an estimate of the relationship between species diversity and the delivery of ecosystem services *(18-20)*. Although biotic impoverishment remains a major problem when consequences are likely to be severe (i.e., partial or total loss of life support functions), caution is required about further impairing the physical and biological basis for nature's services.

Condition 2. Artifacts created by human society may not systematically increase on the planet. This condition is similar to system condition 2 in Table 1.

Arguably, physical displacement of species and the ecosystems they inhabit, which is caused by urbanization, construction of interstate highways, surface mining, shopping malls, and a variety of other physical events, is a serious problem. Physical space is taken away from natural systems and perhaps, even worse, fragments the remainder. Small tracts support far fewer species than large tracts because not all species have the same home range. Some species, for example, must live in large forests – the spotted owl/old growth forest controversy in the Pacific Northwest in the

United States is a good example of how dependence on a certain type of ecosystem is common to many species.

Condition 3. A balance must exist between ecological destruction and repair.

Clearly, ecosystems cannot continue to be destroyed at the present rate with the expectation of having anything ecologically significant left by the end of the next century. Therefore, in order to achieve sustainability at some point, a balance must exist between ecological destruction and repair. Since the present rate of ecological destruction is unique in human history, now is the time to attempt achieving a balance while the quality of life is still reasonably high and some relatively pristine ecosystems are available to use as models. Of course, human error will always produce such destruction as accidental oil spills and other ecological catastrophes. In some cases, natural recovery will heal the damage; however, as sources of recolonizing species diminish and are more widely separated geographically, managed recovery or ecological restoration will be essential. The National Research Council *(21)* recommends beginning this process of restoration at a modest level for aquatic ecosystems.

Cairns *(22)* describes five options for human society regarding its relationship with the environment, only two (stabilize human population and exercise no-net-loss of ecosystem services, which would then maintain a status quo on ecosystem services per capita; and stabilize human population growth and restore ecosystems at a greater rate than destruction, which would improve ecosystem services per capita) of which are likely to result in sustainability. Both of these options would presently be regarded as visionary because they involve stabilizing the human population and level of affluence (which is not necessarily closely correlated with quality of life) and repairing ecosystems at the same rate as they are damaged or an even greater rate for a certain period of time.

Condition 4. Management strategies for sustainability must allow natural processes such as succession, evolution, predator/prey relationships, and the like to continue.

The machinery of nature has adjusted over literally billions of years to continual change. Although the changes in species composition may be imperceptible within human time frames, they are often quite dramatic in geological time frames. Ecosystem function (and delivery of services) may be relatively stable with regard to turnover in species within an ecosystem if there is substantial redundancy within the ecosystem (i.e., replacement species with similar function). However, the rate of change and increasing fragmentation of ecosystems might well negate the advantages of functional redundancy. The resiliency of natural systems is sufficient to overcome these changes, which are often (no pun intended) glacially slow. However, human-initiated perturbations (such as persistent toxic chemicals with no natural counterparts, habitat fragmentation on a large scale, and a very high rate of species impoverishment) have developed with such rapidity that natural systems are unable to function as they normally would.

Goal 4. To devise a better balance in meeting short-term and long-term needs of human society.

Condition. Short-term human needs may not be met if doing so endangers the planet's ecological life support system.

The essence of sustainable use of the planet is to give a far higher priority to long-term needs than has been given in the history of human society. In essence, short-term needs might be denied or postponed if they endanger long-term needs. This is a difficult position to achieve and seems almost unthinkable in a society that insists on needs being met immediately. However, if some attention is not given to this issue, natural forces *(23,24)* will almost certainly adversely affect human society and deprive many individuals of perceived needs.

Sub-condition 1. If a world food shortage develops, grains will be shifted from domesticated animals to humans, rather than convert more natural systems to agriculture.

Converting more natural systems to agriculture is an example of placing short-term needs ahead of long-term needs. A recent article in *Scientific American (25)* recommended converting wasteland to agricultural use to solve China's food crisis. While not explicitly stated in the article, the impression is conveyed that wasteland is land not intensely used by human society, but clearly used by other species. Wasteland so defined is land going to waste in terms of human use, but it is not wasteland if other species and ecosystem services are valued. In short, the term wasteland would be inappropriate if this land were providing ecological services for society's life support system. For example, wetlands converted to agricultural purposes would no longer store flood waters and release them gradually into either surface waters or groundwater, thus changing both the amplitude and duration of flood peaks. This storage and release are definitely ecosystem services. However, this tyranny of small decisions – filling in a wetland here and there on a vast drainage basin – seems rational until the aggregate effect of a large number of small decisions is considered. California has eliminated approximately 91% of the wetlands that existed there in 1800 *(21)*, thus having an effect on the amplitude of flood waters in that state. This reduction is, of course, not the only reason for floods since creating impervious surfaces such as roads, roofs, shopping malls with large parking lots, and the like also changes runoff patterns, as does decreasing the ability of natural systems to transpire and absorb rainwater by losing topsoil and clear-cutting forests. Small decisions considered in isolation from other decisions may have effects too minor to measure and may seem inconsequential but, when taken in the aggregate, may have effects that can be measured and are accompanied by severe consequences.

Sub-condition 2. Society must not depend on yet undeveloped technologies to save it from the problems it has created.

This condition is also a part of balancing short- and long-term needs. Unquestionably, solutions to problems, particularly those involving development of new technologies, are often brought on by crises. The development of the atom bomb during the latter stages of World War II is a good example, or the U.S. space program, which was developed at a much faster rate after the former Soviet Union launched a spacecraft into orbit. Development of new technology does not inevitably follow a crisis; the AIDS crisis is one such example. Granted, some technological or medical solution to AIDS may be found through the use of advanced technology, but it will come too late to benefit many sufferers.

Goal 5. To ensure that most of Earth's population has the opportunity for a high quality life.

Condition. Human population over the long term must be stabilized at a point where adequate per capita resources are demonstrably available.

The U.S. Bureau of Land Management (BLM) has established limits to the density of cattle that may be grazed on BLM lands. These limits are, of course, not the same for every area because some areas have a higher carrying capacity than others. Nevertheless, in practice, carrying capacity is recognized for domesticated and semidomesticated animals, elevators, bridges, and wild animals such as deer and trout. However, society is not willing to admit that biophysical laws of nature apply to *Homo sapiens* in terms of resource utilization and carrying capacity. Quality of life is not high when the carrying capacity is at or above maximum. This problem can be observed in parking areas, where people must cruise the lot in search of empty space, or when a certain number of individuals are packed into an elevator, even if the number of people and their aggregate weight is within legal limits.

Sub-condition 1. When defining sustainable use of the planet, society can use quality of life as the primary criterion.

Alternatively, estimates can be made of how many people can be crammed on Earth at a subsistence level at any one period of time. Theoretically, sustainable use of the planet would be possible using either criterion, but the quality of life for an individual would be vastly different for each choice. Will quality or quantity be a primary condition for sustainable use of the planet?

Sub-condition 2. Human rights may not be met if the ecological life support system is endangered by doing so.

This condition is, again, part of the balancing act, that is, ignoring the needs of future generations by damaging their life support system in order to meet the needs of presently living persons. For example, destroying a unique ecological system to provide a power line right of way or yet another major highway will clearly be affirming that the need to reduce travel time for humans now living is more important than the need of future generations to have a robust ecological life support system and to enjoy its amenities and pleasures.

Sub-condition 3. The majority of people and countries on the planet must accept a single paradigm on sustainable use of the planet.

Getting most of the world, both countries and people, to accept a single paradigm seems an unachievable goal. However, this condition has already been met by the common acceptance of the economic growth paradigm. Arguably, the reluctance to relinquish the growth paradigm is the reason the term sustainable development has been used instead of the term sustainable use of the planet. At any rate, since a large portion of the planet, including all developed countries and most developing countries, at one time accepted the growth paradigm, and most still do, it is at least conceivable that an alternative paradigm could have comparable acceptance. Since the free market paradigm is still painfully under way in Russia and a number of other countries, this situation is an illustrative example of an occurring paradigm shift. Diamond *(26)* provides a plausible hypothesis [i.e., under certain conditions, a wide variety of cultural entities (in China) merged to a remarkable degree as a result of a shared paradigm] for achieving a shared paradigm from a sizable array of culturally different groups. As always, this change was achieved at a cost to a number of generations and cultures.

Sustainable use of the planet probably cannot be achieved with a mixture of traditional economic or ecological paradigms. The coexistence of a limits-to-growth paradigm and an unlimited growth paradigm does not seem viable. Further, environmental refugees are likely to increase as resources are overutilized or severely damaged (or both) in particular countries. Stemming the flow of environmental refugees (not to mention political and economic refugees) is likely to consume so much time and energy and be such a long-term management concern that the energy necessary for transition to sustainable use simply will not be available in time. It is disturbing that so much energy and resources are devoted to placing the blame rather than solving the environmental problem *(27)*. Instead of repairing environmental damage that occurred many years ago, society is engaged in endless legal battles to see if present property owners can be held accountable.

Goal 6. To avoid a human-induced episodic environmental catastrophe that would cause much human suffering.

Condition. When employing environmental management strategies about which the precise consequences are still somewhat uncertain, large protective safety margins (i.e., either slowing development or carrying it out extremely cautiously) are essential until the outcome has been better defined and the consequences have been determined to be acceptable and not of long-term sustainability significance.

The sun has a finite life span, even though it is probably in excess of a billion years, and the universe will not last forever *(8)*. Consequently, no sustainability initiative should be designed for an infinite period of time. In fact, glacial and interglacial cycles of approximately 100 thousand years are well documented, and management strategies for sustainable use of the planet would definitely have to be altered as a consequence of these events. A possibility also exists that Earth could be struck by objects from outer space that would cause dust clouds to change Earth's climate and a variety of other events will occur over which human society has no control. However, society can control many events. For example, greater protection can be given to the other species with which humans share the planet. At the very least, the rate of biotic impoverishment (i.e., extinction of species) could be substantially reduced. Development of sustainable management strategies is also complicated by not knowing when the rapid rate of extinction of species will stop. Some species may have enormous value to human society, but these values may not yet be known, or the species themselves may be unknown because inventories of much of Earth's biota are still inadequate. The problem is, of course, that short-term benefits accrue to those now living, who take risks with the planetary life support system, but the consequences of unwise decisions are likely to be endured mostly by future generations. Therefore, the type of development based on a frontier land use ethic, which is still all too present in human society globally, should be replaced by a maintenance ethic that would benefit both present and future generations.

Goal 7. To diminish the conflict between generations caused by U.S. Social Security and Medicare and elsewhere caused by the perception that future generations will lead impoverished lives because of present greed. (This goal is not identical to Goal 4 since long- and short-term goals may shift significantly as one ages.)

Condition. Older people must become deeply involved in sustainable use of the planet to demonstrate by deeds, not words, the older generation's concern for generations to follow.

As the number of workers decreases and retirees increase and Social Security and Medicare costs rise, the perception is that older people are maintaining their lifestyle at the expense of younger people. Developing a sustainable use policy is the best way to demonstrate with deeds, not words, a commitment to the future or succeeding generations. This development is a shared undertaking from which younger people will be the primary beneficiaries, even though the older people should take pride in this joint effort.

Goal 8. To reincorporate all waste from human society into natural systems without damaging their integrity.

Everything used by human society comes from natural systems. Although, in one view, human society is a part of all natural systems, in some ways it is apart from them. Society cannot afford to extract materials such as metals from Earth, use them, and then place them in long-term storage such as landfills and the like. Dangerous radioactive wastes and highly toxic chemicals cannot be accumulated in situations isolated from the web of life without further depriving both humans and other species of the use of this area of the planet.

Condition 1. Materials that cannot be safely reintroduced into natural systems should not be produced.

A substantial difference exits between artifacts created by human society, such as shopping malls, and radioactive wastes that require long-term storage. Difficulties in the United States in cleaning up hazardous waste sites highlight this dilemma. The uncertainties associated with effective long-term storage of hazardous wastes are daunting and not likely to be quickly resolved. The essence of sustainability is the benign, even beneficial, reincorporation of materials extracted from natural systems back into them. If this cannot be done with present methodology, such activities are incompatible with long-term sustainable use of the planet. This issue is not an unimportant detail in the quest for sustainability!

Condition 2. Assimilative capacity of natural systems shall not be exceeded.

Cairns *(28)* has defined assimilative capacity as the ability of an ecosystem to assimilate a substance without degrading the ecosystem or damaging its ecological integrity. Cairns *(29)* has defined ecological integrity as the maintenance of the structure and function characteristic of a locale. Meeting this condition requires that assimilative capacity be quantified and that human society adjust its waste disposal into natural systems so that they remain healthy and suitable for sustained use.

Condition 3. To develop robust predictive models regarding assimilative capacity, validate these models, and continually monitor them to ensure that previously established quality control conditions based on these two prior activities are being met at all times.

Natural systems are made up of both living and nonliving material, and it is a *sine qua non* that all living material varies. Therefore, assimilative capacity will vary within limits, and using it effectively requires attention to this characteristic. All living systems respond to the aggregate of the potentially stressing materials to which they are exposed, not to individual components in isolation from the others, although this can, at times, happen. Therefore, the monitoring and other activities must be at the system level in order to be congruent with decisions made at the system level.

Goal 9. To develop equity and fairness in resource distribution within human society and with other species with which it shares the planet.

Condition 1. A sufficient majority of humans must acknowledge the reality of equity and fairness so that there is an incentive to preserve the ecological life support system for sustainability.

This equity and fairness are best achieved at the grass roots level rather than by government coercion. Government may sometimes prevent gross damage, but fine tuning ecosystem health must be the mission of all society. As Pericles said "All honor to him who does more than the law requires."

Condition 2. Ethnic and racial strife, holy wars, wars over resources, and other extremely diverse political issues must be eliminated or restrained so that destructive energy can be rechanneled into constructive activities.

As Diamond *(30)* notes, humans genes are more than 98% identical to those of chimpanzees. The genetic differences between ethnic groups are less. Sustainable use of the planet will be best achieved if humans stop warring on their own and other species.

Goal 10. To develop a holistic sustainability initiative.

Condition. Each specific or targeted sustainability initiative (e.g., agriculture, transportation, energy, cities, fisheries, etc.) must not act as if it is the only "flower facing the sun!" It will be difficult to orchestrate these special interests but, otherwise, holistic sustainability will fail.

Ethics in Action or Inaction?

A substantial environmental ethic must be involved in any sustainability initiative. For example, Anglican Archbishop John Taylor *(31)* asked, "Is it immoral that the United States has to import over one half of its energy supply?" Similarly, he asks, "Is it reasonable that a child born in the United States or immigrating to it at an early age will probably consume 30 to 40 times the energy and natural resources per capita compared to the rest of the world, and possibly 200 times as much as some of the poorest underdeveloped countries?" One common belief among those few members of the general public who have given some casual thought to sustainable use of the planet is that, by minor changes in present practices, sustainability can be achieved without substantive behavioral change. However, much of the early literature on sustainable use of the planet indicates that a major paradigm shift and fundamental changes in human behavior, ethics, and lifestyles will be necessary. Stivers *(32)* espoused a new world that involved a radical change of attitudes and values. Birch and Rasmussen *(33)* argued that the most far-reaching change comes only with the combination of strong pressures and a compelling alternative vision.

Making no decisions that would compromise options for the next seven generations seems a sensible approach to formulating conditions for sustainable use of the planet. However, if a generation is 35 years, this span would cover 245 years, which is a long time for most human political groups. However, if each new generation were planning for the next seven, then it could adjust to climate changes, altered rainfall patterns, and other events not foreseen in the original plan. This plan might work equally effectively for a shorter number of generations, but seven seems an ideal number because it means that old growth forests, slow recharge rate groundwater aquifers, and other slowly renewing resources would get the protection they badly need for true sustainable use. The United Nations World Commission on Environment and Development *(2)* puts it more tactfully by stating that "sustainable development requires a change in the content of growth, to make it less material and energy-intensive and more equitable in its impact." Possibly this reasonable and moderate view was necessary so that the Commission would not be thought of as a group of environmental extremists. The *World Scientists Warning to Humanity*, signed by over 1,600 of the world's leading scientists, was much more blunt, as the title indicates *(34)*. Since this document was also signed by a number of the world's living Nobel laureates, one would have thought that this message would have received major front page attention in the world's newspapers, but it received very little attention and discussion in the news media as a whole. A similar statement by the officers of the Royal Society of London and the U.S. National Academy of Sciences *(35)* went virtually unnoticed. Orr and Ehrenfeld *(36)* feel that willful blindness has reached epidemic proportions and that nowhere is it more evident than in the U.S. Congress, which is denying outright the still growing mass of scientific evidence about the deterioration of Earth's vital signs while simultaneously attempting, often successfully, to dismantle environmental laws and regulations. However, there is a failure to distinguish denial from honest disagreement about matters of fact, logic, data, and evidence that is a routine and customary part of the scientific process. Orr and Ehrenfeld *(36)* feel that denial is the willful dismissal or distortion of fact, logic, and data in the service of ideology and self-interest. Although Ehrlich and Ehrlich *(37)* do not use the word denial, they do use the word betrayal and, unlike the comparatively short Orr and Ehrenfeld article *(36)*, have substantive illustrative examples to document their position.

These issues become extremely important because if denial and betrayal are the problems then more scientific evidence will not help. Kuhn *(38)* recognizes these issues when he states "a paradigm is a belief so strongly held that when contrary evidence appears the evidence is rejected." Even earlier, Dobzhansky *(39)* stated

> We like to believe that if we secure adequate data bearing on any scientific problem, then anybody with normal intelligence who takes the trouble to become acquainted with these data will necessarily arrive at the same conclusion regarding the problem in question. We like to speak of conclusions demonstrated, settled, proved and established. It appears, however, that no evidence is powerful enough to force acceptance of a conclusion that is emotionally distasteful.

One wonders what catastrophes human society must suffer before the major paradigm shift necessary to achieve sustainable use of the planet occurs. If the reasoned approach found in the publications of Robèrt and colleagues *[3,40]* is used, human society may be able to accomplish the transition gracefully.

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Article 2

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Eco-societal Restoration: Re-examining Human Society's Relationship with Natural Systems

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> We are all controlled by the world in which we live, and part of that world has been and will be constructed by men. The question is this: are we to be controlled by accidents, by tyrants, or by ourselves in effective cultural design?
>
> B. F. Skinner (1972)

HUMAN RELATIONSHIPS TO NATURE

Masters, Stewards, Coinhabitants, Blight

An almost incredibly wide range is present in the relationships people believe exist between themselves and natural systems. In earlier times, direct and intimate interactions between hunters and gatherers and the natural systems affected these attitudes. Currently, however, direct interactions with natural systems are quite limited for many of the world's people – more and more people live in cities and very few wild systems are left. Society's interactions with the remaining, intensively managed ecosystems are qualitatively less intimate in the present global economy: local crop failure does not inevitably lead to famine and incremental changes in air quality tend to affect only a small group of people directly. That is, society does not directly experience a personal dependence on natural systems for essential goods and services as in the past, and attitudes about the relationship between humans and nature are more dependent on various culturally transmitted beliefs about the nature of the world: scientific, political, religious, or philosophical.

Cultural Changes and Relationships to Nature

Even before the agricultural revolution, various human societies altered natural systems with fire, selective hunting of various species, and modest clearing of forests. During the agricultural revolution, land was cleared in ever-increasing amounts for the culture of specific crops valued by human society (Quinn 1992). The primary thrust of the agricultural revolution was to "tame" nature by clearing forests, draining swamps, and otherwise altering the landscape to enhance agricultural production. Additionally, when European settlers arrived in North America, they saw what appeared to be unlimited timber, soils of a considerable depth, and abundant game animals. Based on human perceptions (without the help of LANDSAT satellite data bases on land use or the like), wilderness and resources appeared unlimited. Some pioneers thought nothing of shooting buffalo just to extract the tongue for consumption and leaving the rest to rot. Even so, most of society's wastes of the early agricultural systems were easily reincorporated into natural systems. Further, abandoned agricultural land quickly reverted to natural systems comprised predominately of pioneering species which were ultimately replaced by other species if natural successional processes were permitted to occur. This rapid recolonization was possible because agricultural systems were fragmented rather than natural systems and sources of colonizing species always nearby. As the agricultural revolution proceeded, it was the natural systems that became more fragmented and, in some parts of the world, recolonization of the species inhabiting the area in the pre-agricultural era became increasingly scarce.

The industrial revolution was characterized by an exploding demand for fossil fuels, mineral and other natural resources, and by the production of waste materials not easily reincorporated into natural systems, which were introduced into natural systems as point source discharges rather than dispersed discharges. In the early days of the industrial revolution, waste discharges commonly came from a pipe into a river, although atmospheric pollution was also notable. Initially, because waste discharges into rivers were widely spaced and the industries were usually of relatively small size, rivers could recover from the damages through natural cleansing processes. As the wastes increased in both volume and frequency, natural assimilative capacity was exceeded.

The temporal and spatial scale of human-induced changes in natural systems and the magnitude of the disturbances have increased exponentially over time. Increases in human population densities and the increasing affluence of human populations contribute to the scale of disturbance. The consequence is that cumulative anthropogenic change has overwhelmed many repair mechanisms of natural systems. While previous generations could rely on natural systems to bounce back without human intervention, current generations cannot. Ecological restoration is needed to facilitate this process.

The Last Tree on Easter Island

Easter Island has always fascinated me. When it was discovered by the Dutch explorer Jakob Roggeveen in 1772, its Polynesian inhabitants had carved hundreds of statues, transported them several miles, and raised them to an upright position even though some weighed as much as 80 tons and were up to 37 feet tall. This had been accomplished by human effort, assisted only by rollers in the form of tree trunks and, of course, levers of the same material. Some statues had been abandoned en route to the display site, and others were discovered finished or partly finished in the original quarries. The peak population appears to have been approximately 7000 persons or over 150 people per square mile in ~1500 A.D. (Diamond 1994). By that time, about 1000 statues had been carved and ~324 erected.

Trees were important to this culture. It appears that Easter Island was covered by a forest when it was settled around 400 A.D. and that the Polynesians cleared the forests for agriculture, logs for canoes, and transport and leverage for the statues. The island is sufficiently small so that a survey of its resources could have been completed within a single life span. Furthermore, it is sufficiently remote (2300 miles west of Chile) that the unlikely prospects of depending on resources from outside the island must have been abundantly clear. Local ecological problems that accompanied deforestation in parts of the island must have also been evident over a course of time. But curiously, the same Easter Islanders who were sufficiently intelligent and organized to carry out the massive undertaking with the statues did not anticipate the ecological consequences of deforestation. It is difficult to believe they did not anticipate the possible consequences to their future when the last tree was cut down. Presumably, the energy and resources that went into producing the statues could have been diverted in part or in whole to sustainable living. Did they expect divine intervention as a consequence of having erected the statues?

The reduction of inhabitants on Easter Island to about one-third of its former population was all the more poignant because the means to build canoes for escape had disappeared with the last trees. One can fantasize an elaborate ritual to accompany the chopping down of the last tree. Surely, as trees became more and more scarce, the location of each was well known to the inhabitants, and, thus, the removal of the last one surely must have been accompanied by a ceremony of considerable magnitude. One troubling aspect of the account of Easter Island is that its society had all the information necessary to make the right ecological decision and failed to do so.

COEVOLUTION: RULES GOVERNING THE RELATIONSHIP

Although the term coevolution is most frequently applied to species pairs, it can be argued that human societies and natural systems are coevolving. A basic definition of coevolution is: the simultaneous development of adaptations in two or more populations, species, or other categories that interact so closely that each is a strong selective force on the other. Natural systems and human society certainly interact and shape each other. Natural systems have proven a strong selective force to human settlements through famine, disease, and natural disaster. Whole cultures, such as the statue builders on Easter Island, may have fallen through unsustainable practices. In turn, human society has proven a strong selective force to most ecosystems on earth – destroying a huge number of the earth's species and habitats. Human societies and natural systems shape each other, and benign changes enhance the survival of each partner.

Coevolution may be benign or hostile. Hostile coevolution might be characterized by the escalating pressures of pests (quite broadly and anthrocentrically defined) and the pest-control measures in which the only species not eradicated are the least desirable ones to human society (i.e., cockroaches, fruit flies, and Norway rats). Hostile coevolution may also involve strong and unpleasant selective forces on human societies, such as famine following increasingly frequent disease or pest-related failures in monocultural agriculture or pollution-related disease from exhausting the waste purification capacity of remaining natural systems. A benign coevolution would be one in which human cultural structures (e.g., economies, schools, and systems of belief) can sensitively respond to changes in ecosystem health. As a result, most of the earth's present species and habitats would survive, their ecological landscapes would be enlarged, and the landscapes, in turn, would continue to provide human society with ecosystem services such as water purification, carbon storage, waste processing, raw materials for genetic engineering and pharmaceuticals, etc. (Cairns, in press). Ecological restoration is a benign act of human society toward natural systems and facilitates benign coevolution. Ecological restoration is also an act of human self-interest because it increases the capacity of natural systems to provide ecosystem services.

SETTING SOCIETAL GOALS

What Does Human Society Need from Natural Systems?

Surely, human societies would choose to minimize harsh environmental selective pressures such as famine and disease. If the form of coevolution between natural systems and human society is to be guided toward a benign relationship, societies need to protect aggressively those ecosystem services that are essential to their own quality of life. Human society needs plants to capture sunlight and to provide food, building materials, and energy. Human society needs breathable air. Human society needs its waste products recycled. Human society needs potable water. Human society needs arable soils. These and other ecosystems services (e.g., Westman 1978) are essential to human quality of life and are provided by natural systems. Some ecosystem services are provided with no human intervention, while others are provided with minimal human effort compared to any human engineered alternatives. For example, the estimated cost of supplying ecosystem services to seven people in Biosphere 2 was $9 million per person per year (Avise 1994). The rest of human society depends on intact natural systems to provide these services. The ecological capital (forests, grasslands, wetlands, soils, biodiversity, etc.) must be preserved in order to continue to generate interest in the form of ecosystem services.

Two major factors presently governing human society's relationship with natural systems are: (1) a net gain of nearly 100 million people annually in the earth's population and (2) the desire of almost all of these individuals to improve the quality of life primarily by converting habitats occupied by other species for human use and concomitantly converting natural resources into goods and services for human society. This means that the land area that provides ecosystem services at the highest rates is declining at the same time that the number of humans sharing these services is increasing. The amount of ecosystem services per capita is plummeting.

Sustainability

Kuhn (1970) defines a paradigm as a belief so strongly held that, when contrary evidence appears, it is rejected. Human society's paradigm for its relationship with the environment has been that there will be no adverse consequences, even if the present rates of ecological damage continue to exceed the rates of repair or restoration. If enough contrary evidence appears, a paradigm shift will occur and a new operational model appear. We have recently witnessed some dramatic paradigm shifts in human society, such as the break up of the USSR, the fostering of private enterprise in the People's Republic of China, and the opening of the eastern block of nations in Europe to outside investments. In order for changes to occur, large numbers of citizens must be persuaded that there is a superior alternative to the present course of action. For a comparable shift to occur in human society's relationship with the environment, the average person must be convinced that either the present practices are unsuitable for long-term sustainable use of the planet or, alternatively, that a much higher quality of life is possible for a long period of time if human society's relationship with natural systems is re-examined.

Sustainability is a well articulated goal for management based on the explicit abandonment of the assumption that natural resources are limitless (World Commission on Environment and Development 1987, Lubchenco et al. 1991). The call for sustainability eschews the exhaustion of resources and waste sinks exclusively for short-term gain. Instead, it seems likely that, over the next million years, more humans will cumulatively inhabit the planet if ecological preservation and restoration are taken seriously than if they are not.

Science and Ethics in Setting Societal Goals

Both science and ethics are involved in making decisions on environmental management. Ideally, they are called into play sequentially (Suter 1993) – a subjective human perception of a problem leads to objective scientific investigation of the causes and possible management actions. Then, alternate actions and their projected costs and benefits are evaluated for effectiveness and consistency with other goals of society. As this process of impact assessment and management is applied to larger areas, longer time frames, more complex problems, and many interconnected problems, it becomes more difficult to distinguish ethical claims from scientific ones because the uncertainty inherent in scientific information increases with the scale of the environmental problem. A decision that seems to be empirically based to some scientists may seem to be based on ethics to others – because, while some professionals judge the uncertainty of the scientific data to be acceptable, others judge the uncertainty as excessive. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made. However, they are linked – acting with an intolerance of uncertainty often demands a high tolerance for risk.

Science makes probabilistic statements about the nature of the world but does not tell us what we ought to do. Science helps to define problems and gather information about extent and severity and makes clearer the links between environmental change and human self-interest. The basic question of interest here is: Is human self-interest different from what is in the best interest of ecological integrity? An increased ability to measure those ecological functions which, in the aggregate, constitute the ecological life support system upon which human society depends would provide increasingly convincing evidence for the self-interest of restoring and conserving natural systems. While this information is essential to effective management action, this scientific information cannot set a goal.

Ethics, politics, and priorities are involved in setting goals. Is there a consensus about what society should do? Political action based on underlying ethical beliefs identifies consensus. In addition, there is never enough money to do all the ecological preservation and maintenance that would benefit human society over the long term. Ranking desirable goals and expediting some, while delaying others, is also a political process.

Environmental Literacy: Putting Information into the Hands of Decisionmakers

A relationship of human society to natural systems that would foster ecological restoration and maintenance would be encouraged by a dramatic increase in the level of environmental literacy in all citizens. However, current levels of environmental literacy seem woefully inadequate.

We recently had a symposium (Wallace et al. 1993) on environmental literacy at Virginia Polytechnic Institute and State University that was attended by approximately 300 persons. This is a rather poor attendance for an institution with over 25,000 students and over 6000 faculty and staff. When I asked one faculty member whose department has the word environment in the title why he had not attended, he said, “I already know about the environment.” Several students told me that they didn’t attend because they had been to Earth Day. I selected some extremely basic information from the various talks given at the symposium, and I feel sure that neither the faculty member nor the students have been exposed to these bits of knowledge. This is not a unique situation on my home campus, as evidenced by the Report on the University Colloquium on Environmental Research and Education (Blackburn 1992), which espouses going beyond single courses on environmental problems and including society’s indebtedness to the natural systems of the planet into all the courses in all the disciplines.

The concept of ecological literacy needs to be broadened; it is not enough to know that living things, including humans, interact with each other and their physical environments. Ecological literacy must extend to constraints and interactions between complex societies and their increasingly restructured environments. Both teaching and research should place a greater emphasis on improvement in environmental literacy in all disciplines. Disciplinary focus, as now understood, does not produce graduates skilled in helping society make the value judgments needed for preservation of ecological capital and sustainable long-term, nondegrading use of the planet’s natural resources. An uncharitable person might conclude that discipline specialization has made us increasingly ignorant of the factors important to a sustainable, long-term relationship between human society and natural systems. A high level of disciplinary literacy, as presently understood, has not provided a foundation for re-examining our relationship with natural systems.

In one attempt to see both the forest and the trees, educators recommend multidimensional literacy to broaden the perspective through which problems are viewed. Multidimensional literacy means understanding the place of one's own discipline among the other disciplines (Uno and Bybee 1994). In an environmental context, multidimensional literacy might be described as understanding the place of humans in natural systems and the effect of inappropriate actions upon long-term sustainable use of these systems.

Of course, multidimensional literacy is an ambitious undertaking. Williams (1994) feels that "the institutional barriers that discourage the seekers of broad perspectives are a minor problem compared to individual limitations. Just learning the bare necessities for a narrower specialty can be challenge enough for most people." This is indeed a crucial question for higher education: Should the narrow specialties dominate to the extent that students do not learn how to evaluate the workings of the world?

The problem is even more acute when the environmental literacy of the general, non-student population is considered. Media accounts of the environmental problems vary enormously in quality, and new approaches may be required to develop guidelines for communicating both risk and the uncertainty of scientific findings to the general public in a sensible, consistent, and contextual manner. Another acute problem is the early polarization of such reports. Part of the problem may be the hyperbole used at times to attract media attention to environmental problems. The ecologists who stated that Lake Erie was "dead" (when this was clearly not true) are as culpable as the present educational system.

Environmental Ethos

Human society's relationship with natural systems first and foremost should be based on an ethos, or set of guiding beliefs, which then must be implemented by both changes in individual and societal behavior and by the skilled gathering and use of scientific and engineering information as well as information from other disciplines such as economics and sociology. Environmental literacy and ethos are interacting processes in which each component influences the other. The first lecture in the Abel Wolman Distinguished Lecture Series (Leopold 1990) focused on ethos, equity, and fairness in utilization of water resources. Leopold (1990) states: "The ethos of which I speak is the unwritten gut feeling that the resources of the planet, and of the nation, are worthy of husbandry – indeed are essential to our long-term well being." Leopold's second concept was equity: "A dedication to fairness, a desire to consider various interests and treat them all with some measure of equality." It is possible that intelligence, guided by reason, can be used to develop a set of guiding beliefs, coupled with a sense of responsibility for human society's companion species.

Modifying Our Environment vs Modifying Our Behavior

We talk incessantly of managing the environment but rarely of managing human behavior, particularly at the individual level. Orr (1991) suggests that, despite the intent to extend human domination of natural systems to the maximum, the complexity of the earth and its life systems ensure that the planet can never be entirely managed. Instead, Orr suggests that what can be managed is human society, including human desires, economics, politics, and communities. He feels that it makes much more sense to reshape ourselves to fit a finite planet than to attempt to reshape the planet to fit our infinite wants.

Orr's point is well taken! The coevolutionary process, if it is to work well, must include some considerable effort on the part of human society to reshape its "needs" and expectations to fit the tolerance of natural systems for anthropogenic-induced stresses. Otherwise, these systems will ultimately adjust to these stresses in ways that society may consider "unsuitable," such as increased pesticide resistance or dominance of species not particularly favored by human society.

However, I am not as apprehensive about the term management as Orr is, since the concept of management can include maintenance of ecosystem health. If ecological management is directed toward achieving short-term goals of human society without regard to ecological integrity or health, then clearly the attempt will fail in the long term. But, management also includes human intervention to repair damaged ecosystems; i.e., restoration.

However, relying on behavioral changes to facilitate benign coevolution has its difficulties, even among environmental professionals. The World Scientists' Warning to Humanity (Union of Concerned Scientists 1992) seems to have had remarkably little effect. One of my colleagues wondered how many of the persons who, by signing the document, were agreeing that "The world is coming to an end if we continue our present practices" and then went back to their own specialized investigations. If the situation is, indeed, as serious as the signers of the declaration believe, shouldn't a very large percentage of them be devoting a substantial portion (e.g., over half) of their professional activities to resolving the important issues they identified? Granted, this would mean their leaving the area of specialization that may have brought them honor and awards and, possibly, the loss of extramural funding. If those issuing the warning have not changed their lifestyles dramatically, can the general public be expected to do so?

ECO-SOCIAL RESTORATION

Eco-societal restoration is the process of re-examining human society's relationship with natural systems so that repair and destruction are at least balanced and perhaps, ultimately, restorative practices will exceed destructive practices. Restoration ecology has only recently been accepted by mainstream science as a legitimate field, and non-scientists in a wide variety of places have undertaken ecological restoration projects. In addition, while hardly overwhelming, the news media are giving significant attention to restoration, and journals such as Scientific American have recently had articles by members of their editorial staff.

There are compelling reasons for carrying out ecological restoration.

1. Human society's practices are the best indication of its ethos or set of guiding beliefs. Ecological restoration is a positive statement of cooperation with natural systems. Preserving those systems still undamaged and protecting those restored would be an even more positive statement, especially if accompanied by major restorative efforts for presently damaged systems.
2. The ability to estimate the cost of restoration will be markedly improved as the number of projects increases. When the full cost of ecological restoration is better documented, it may well act as a deterrent to further damage because the dollar costs can be incorporated into comparisons of alternative actions. These full cost numbers will also enable the amount of money in restoration bonds to be determined with more precision.
3. Having restoration projects in each ecoregion, and preferably in each major area of the country, will provide demonstrations for local citizens, and this will vastly increase environmental literacy.
4. Very few people presently practice ecological restoration. While, in theory, any ecologist should be suited for restoring damaged ecosystems, most carry out their research on populations of a single species with infrequent attention to chemical/physical parameters (Harte et al. 1992). Addi-

tionally, ecological restoration involving society requires a far broader approach than the field of ecology as it is presently practiced.

5. Having a number of ecosystems that are being repaired will provide more natural resources of recolonizing species to other damaged ecosystems. These systems can also provide additional sources of recolonizing species where transport is necessary.

6. Since restoration to predisturbance condition is not often a viable option (Cairns 1989), creating naturalistic assemblages of plants and animals, consisting of species not necessarily there before the disturbance, will provide both scientific evidence and a number of case histories that both the general public and professionals can examine when making choices of restoration end points.

Is Ecological Restoration too Intimidating?

As Bradshaw (1983) notes, “The acid test of our understanding is not whether we can take ecosystems to bits on pieces of paper, however scientifically, but whether we can put them together in practice and make them work.” Almost certainly, none of us now living will survive long enough to determine whether ecology has passed this acid test. Perhaps, it is just as well, for the egos of ecologists, that the human life span is often shorter than even the assisted recovery time of many damaged ecosystems. On the other hand, one should not despair because, if the damage causing the stress is removed, natural recovery processes are extraordinarily effective if potential colonizing species have the opportunity to recolonize damaged areas by natural processes. A few of the problems might be that many sites contain residues of toxic materials, have lost their topsoil, and have no nearby sources of recolonizing species. In these instances, exotics will be a particular problem, although they will undoubtedly be a problem in nearly every ecological restoration project. We will never be certain whether assisted recovery (i.e., restoration by human society) will be ultimately more effective than natural recovery processes, although there is persuasive evidence that assisted recolonization, particularly vegetative, can accelerate the recovery process.

But perhaps, we have overdone our discussions on the complexity of natural systems – treating them like Swiss watches whose assembly requires extraordinary skill and training. It is essential to keep in mind that some ecological destruction is so gross that even the most primitive and simple-minded measures will produce a condition that is ecologically superior to the damaged condition. Professional ecologists may also be making a mistake in focusing on restoration to predisturbance condition, a problematic goal at best (e.g., Cairns 1989, National Research Council [NRC] 1992). A student in my course in restoration ecology at Rocky Mountain Biological Laboratory obtained grant funding while still an undergraduate to restore a coastal wetland in California, got matching funds for the grant money obtained, and got inmates from a local prison to help with the restoration, which apparently was so attractive that more volunteered than could be accommodated. She also generated much community support and interest in the project, and, while the outcome is yet uncertain, it seems quite likely that the restored system will be ecologically superior to the damaged system. This is not to say that anyone can set off on a restoration project unhampered by facts, but rather that a beginning can be made with a modest level of literacy in ecological restoration, coupled with strong motivation and organization.

Ethical Problems in Eco-societal Restoration

Does restoration ecology represent a new trend in human society’s relationship with natural systems, enhancing a benign coevolution? Or, are restoration ecologists merely running a group of environmental “body shops” that repair damaged ecosystems without appreciable effect on either rates of ecological destruction or on human society's set of guiding beliefs? At its worst, ecological restoration could be used as another justification for continued damage to natural systems. Furthermore, the rate of ecological destruction globally is so enormous that the comparatively few attempts to repair ecological damage are dwarfed by comparison. Indeed, there are some ethical problems associated with ecological restoration.

1. Most ecological restoration is carried out to repair damage caused by human mismanagement. If management is the disease, how can it be the cure? Noss (1985) has said "This is the irony of our age: 'hands-on' management is needed to restore 'hands-off' wilderness character."
2. Some mitigative restoration in carried out on relatively undamaged habitat of a different kind. For example, created wetlands may replace an upland forest, or an upland forest may be destroyed to produce a "replica" of the savannah that once occupied a particular area. Logically, this secondarily damaged habitat should be replaced by yet another mitigative action. Sacrificing a relatively undamaged habitat to provide mitigative habitat of another kind deserves more caution than it has been given.
3. At our current state of knowledge, restoration projects are likely to have unforseen outcomes. Ecological restoration carried out by the most skilled professionals will occasionally, perhaps frequently, omit some very important variables. Episodic events may occur at inconvenient times. Some of the unforeseen results may offset any ecological benefits likely to result from a particular restoration project.
4. Well-meaning restoration efforts may displace the species best able to tolerate anthropogenic stress. By attempting to return an ecosystem to its predisturbance condition, we may be hampering the evolution of a species capable of co-existing with human society. Attempts to manipulate the environment in such a way as to promote the success of one or two species may impede both the natural successional process and also exclude other species that would otherwise be there.
5. Similarly, if ecological restoration is carried out on an extremely large scale, human-dominated successional processes could become "the norm."
6. Finding sources of recolonizing species for damaged ecosystems is increasingly difficult. Should one remove them from quality ecosystems and risk damaging that ecosystem or use pioneer species or, worse yet, exotics with the hope that the more desirable species will eventually colonize naturally?

Reflections on Methods and Successes

Griffith et al. (1989) found that translocation of threatened and endangered species resulted in self-maintaining population only 46% of the time as compared to 86% success with game translocations. They also determined that a typical translocation involves six releases over a three-year period. These spaced releases are carried out so that animals have an opportunity to adjust to their surroundings, establish stable populations, and then gradually increase their numbers. Franklin (1993) suggests that, rather than focus on mega invertebrates and single species reintroductions, the time, money, and effort should be spent on saving ecosystems and all the biodiversity therein. However, as Orians (1993) notes, while preserving systems is a good idea, no legislation currently provides reliable protection for ecosystems and developing such legislation will be difficult, both scientifically and politically. As Burnham and Cilek (1994) note, there is a caveat in the Endangered Species Act indicating that critical habitat should be protected in addition to the individual species. This would provide an ecological/ecosystem umbrella covering many species. Franklin (1989) feels that no ecologically-sound restoration or ecosystem management can be developed without substantial changes in human society's thinking and practices.

The Kissimmee River restoration and other case histories serving as illustrations in the NRC report (1992) will encourage other areas to engaged in ecological restoration by providing evidence of capabilities for restoration. Whether the cost and effort involved will dissuade citizens from doing so remains to be seen. Evidence in books by Glantz (1988), the NRC (1993), Odum (1989), and Edwards and Regier (1990) show heightened concern.

The first step in re-evaluating human society's relationship with natural systems will be to quantify rates of ecological damage and repair. The establishment of bioregions in which such evidence is gathered would facilitate this process and simultaneously furnish local citizens with evidence that they can confirm personally. Additionally, since degrees of ecological damage or repair require considerable professional judgment, it will be necessary to establish a qualified "blue ribbon committee" of ecologists knowledgeable in determinations of both ecosystem health and degrees of ecological restoration. It would be advisable for these groups to use criteria and standards that are homogeneous as the differences between and among bioregions permit. A national "blue ribbon committee" could furnish both information and judgment to the regional committees. This group should be responsible for continually modifying and revising criteria and standards when enough new knowledge is available to justify revision from a scientific perspective.

Property Rights vs Landscape-Level Restoration

The NRC (1992) recommends ecological restoration at the landscape level whenever possible. The advantages of scale are readily apparent, especially when the hydrologic cycle is involved. However, restoration projects are often approached piecemeal. Part of this is due to fragmentation through assignment of government agencies to a portion of environmental management. As Leopold (1990) notes: "each agency acts as if it is the only flower facing the sun." Each government agency and most of human society is looking at ecosystems in terms of the uses that might be made of them, including alternative uses that threaten their existence. No organization is responsible for maintaining the integrated processes and relationships that collectively make an ecosystem what it is and make sustainable use possible.

Another formidable barrier to a landscape approach are the inevitable conflicts between environmental protection and property rights. The individual property owner with a small wetland is likely to be irate when told that filling, draining, or altering the wetland in major ways is illegal. This, the wonder sometimes says, is private property "and I will do as I wish with my property." However, private property rights are not sacred, even in societies with strong views on this subject. We accept limits on freedom that, on balance, will also protect our interests. All of us live not only on our private property but in a larger ecological landscape shared with others. So, a key question, at which environmental literacy, ethics, and human institutions such as law and economics interact, is: To what extent should we modify our individual, organizational, or national behavior and attitudes for the betterment of others of our individual species and for other species as well?

All zoning ordinances restrict property rights, and examples can be found in the news of cases where the proper balance between property rights and common good is delimited. Plans for constructing an incinerator for hazardous waste next to an elementary school predictably are met with fierce resistance. They are both in the same airshed, and unrestricted exercise of property rights on one property may unilaterally devalue the property rights of others in the same airshed. Helicopter flights in the Grand Canyon create noise that historically has never existed in the Canyon. If, hypothetically, a proposal were made to permit the construction of a fast food restaurant opposite the Vietnam War Memorial, a public outcry would be quite predictable.

There is, however, some justification for cautious optimism about the balance that will finally be struck. The NRC (1992) volume has a substantial number of case histories that demonstrate major changes in societal attitudes and practices with regard to natural systems. Janzen's (1988) biocultural restoration of the Guanacaste Dry Forest in Costa Rica has demonstrated such societal changes in behavior and practices in a country much less affluent than ours. Little (1994) describes a situation involving a small river and a small town where a group of local loggers, ranchers, miners, and homeowners collaborated in restoring the river. Although the article does not have much detail on private property rights vs landscape-level restoration, it is quite clear from the articles that much persuasion in the direction of landscape rehabilitation occurred. The heartening aspect of the article is that a group of permanent, full-time stream restorers are now applying the skills they learned on Wolf Creek to Clarks, Haskens, Spanish, and Red Clover Creeks.

After Restoration

Clearly, ecosystem restoration without concomitant ecosystem protection would be senseless (e.g., Woodwell 1994). To protect only restored ecosystem without protecting the unimpaired ecosystems would be equally senseless. So, how does one prevent restored ecosystems from being re-damaged? The only possible means is continual, direct surveillance and monitoring of ecosystem health and maintaining equal vigilance on proposed or actual activities that threaten ecosystem health. This requires a system of ecosystem guardians for each restored or undamaged ecosystem.

There were once river wardens in England who walked the rivers and protected them from harm. These were not highly trained academicians, but rather persons sensitive to abnormal changes in the complex, multivariate systems called rivers. Of course, nowadays no one can casually walk on a river bank or through a forest and detect parts per billion or trillion of a persistent toxic chemical. On the other hand, people can, even without instrumentation, often see changes even if they lack the analytical capabilities to determine the cause.

Ecosystem protection and restoration will require the collaboration of ordinary citizens who can be especially attentive to the actions and proposed actions of individuals and organization that might threaten the ecosystem. In addition, skilled professionals who can father the hard evidence necessary for policy and regulatory decisions are needed. Ehrlich (personal communication) has recommended that professional biologists tithe their time on projects beneficial to the general well-being of ecosystem and, consequently, human society. In the case of restoration and the maintenance of ecosystem health, this could well be extended to engineers, chemists, economists, sociologists, and almost any other discipline.

There are a number of scientific measurements, some well within the capabilities of highly motivated but relatively untrained individuals, that can furnish very useful information. The Save Our Streams program, administered by Trout Unlimited, provides one example. Regrettably, most of these measurements are at the population or community level with relatively few generally-accepted measurements of integrity or condition at the ecosystem or landscape level. Those that do exist tend to be experimental, require skilled professionals for reliable measurement and analysis, and are generally quite expensive.

In examining various measurements of ecosystem integrity, primarily for large river systems of the world, (Cairns, in review) suggests that examination of a selected list of practices and guiding beliefs of human society might accurately predict the general health and condition of the ecosystems in which these societies live. For example, if economic development is the highest value of a particular society, one would not expect ecosystems to fare well. If human society is not willing to modify its present behavior (e.g., living on floodplains and expecting engineering solutions for protection and wishing to move water where people are rather than people to where water is), it is quite likely that society will live in managed, rather than natural, ecosystems. This is not intended to denigrate scientific measurements of ecological integrity or to hamper further development in this area. It is rather to suggest that, since the fate of natural systems is in the hands of human society, the practices and guiding beliefs of this society be examined as a useful means of predicting the condition of ecosystems associated with that particular society.

The East Branch of the North Fork of the Feather River Coordinated Resource Management Group has, in eight years, restored 3000 acres of wetlands and 12 miles of severely degraded stream channel, built 20 check dams, and surveyed 1110 square miles of watershed. Biological improvements have been dramatic (Little 1994). Since all ecological restoration activities are necessary because citizens stand by while the systems are being damaged, what will prevent this particular restored hydrologic system from being damaged again? Almost certainly, no substantive new damage will occur while the memories of this magnificent restoration effort are still fresh. Also, there will be particular vigilance against recurrence of channelization and other assaults that caused the ecosystem to deteriorate and from which it was restored. However, in five or ten years when memories fade and the present children become adults, what is to prevent new types of damage from occurring incrementally so that, over the years in the aggregate, the new damage equals the old?

CONCLUDING STATEMENT

Logic suggests that the present rate of population growth and concomitant ecological destruction cannot continue indefinitely without severe effects on human quality of life. Either human society will re-examine its relationship with natural systems and alter society's impact upon them, or eventually natural processes will regulate human society's numbers and level of affluence. The first goal should almost certainly be to ensure that the rate of ecological damage does not exceed the rate of ecological repair or restoration. However, achieving a balance between destruction and repair merely increases the probability that things will get no worse unless the population continues to grow. Ensuring a net gain in quality ecosystems is a more desirable goal, especially if the human population size is stabilized or even decreased over the long term. These actions would enhance the accumulation of ecological capital such as old growth forests, top soil, and species through habitat improvement. The longer we wait to discuss and examine our relationship with natural systems, the less likely it will be that quality ecosystems will be available as models or species available to recolonize damaged ecosystems. There are examples only of what can be done to restore and protect natural systems. There are even more examples to justify pessimism concerning what will be done to damage natural ecosystems further. It is my hope that, during the lifetime of my students, the rate of ecosystem damage will be exceeded by the rate of ecosystem restoration and that there will be an overall net gain annually in ecological capital and robust aquatic ecosystems with an exemplary level of ecological integrity.

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Article 3

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Reviews & Commentaries

Restoration of Urban Waterways and Vacant Areas: The First Steps Toward Sustainability

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Increased population pressure and human activities have significantly altered the effectiveness of functions of ecosystems ("ecosystem services") at the local and regional scale. Of primary importance is the decrease in water quality due to urban storm water runoff. A number of communities have initiated restoration strategies to improve water quality standards. One such strategy is the incorporation of riparian walkways with native flora. As a result of such restoration efforts, habitats for native fauna have improved, and the number and diversity of wildlife have increased in urban settings. Restoration of urban habitats also provides social and economic benefits to the surrounding community. Efforts to mitigate the loss of ecological resources by restoring native habitats on lots that cannot be developed or on abandoned lots hold a high, unrealized potential. Habitat restoration not only provides natural diversions to urban surroundings, but also enlightens and educates individual citizens about the importance of balanced ecosystems and the role of humans within ecosystems. Education is the primary step toward creating ecologically sustainable communities.
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Most cities and towns have evolved along the banks and shores of waterways. Historically, the larger waterways functioned as major transportation corridors for humans as well as for other organisms. The numerous smaller waterways weaving through cities also functioned as sources of fresh water that provided food and habitat. Rapid urban expansion has dramatically changed the face of these waterways. Today, an estimated 93 million people reside in the coastal counties in the United States (*1*). Many water courses have been channeled, rerouted, paved over, transformed into storm sewers, or, in the case of wetlands, obliterated. Impervious surfaces, such as roofs, parking lots, roads, shopping malls, and industrial buildings, dramatically alter the flow of natural systems. Instead of percolating through the soil to groundwater aquifers or being transpired by vegetation, urban runoff shunted in abnormal patterns enters natural systems well beyond the urban areas from which the water originates. Additionally, the components of urban runoff, such as suspended solids, pesticides, nutrients, oil and grease, human and animal refuse, and pathogenic microorganisms, have significant impacts on the aquatic habitats they enter.

The National Research Council (*1*) estimates that approximately 85% of the 10 billion gallons per day of wastewater effluent discharged along the U.S. coasts enters bays and estuaries rather than open ocean. The ecological impacts of large-volume discharges into these slow-circulating habitats include sedimentation, anoxia, hypoxia resulting in aquatic plant die-back, and nuisance algal blooms, all of which adversely impact benthic populations such as shellfish. The Chesapeake Bay has seen dramatic declines in aquatic plant populations, which coincides with increased turbidity from agricultural and urban runoff. Aquatic plant communities are important nurseries that provide nutrients and shelter for molting crabs, juvenile fish, and shellfish, all of whose declines in the Chesapeake Bay are well documented. Residential, commercial, and industrial sites are all important contributors to urban runoff. Many of the contributing pollutants (such as refuse, oils, and solid materials) could easily be reduced with changes in urban lifestyle. With the water shortages we now face, particularly in the western United States, better management of water resources is mandatory. This can be accomplished while reacquainting urban dwellers with at least some of the attributes of natural systems.

The implementation of the 1972 Clean Water Act and its amendments in 1987 brought dramatic changes in point-source pollution, and society is only beginning to address the problems associated with nonpoint pollutants stemming from urban areas. Recognizing the importance of reducing nonpoint wastes, a number of creative and common-sense strategies have been developed. Unfortunately, no single “quick fix” or technology exists for reducing urban runoff, and a combination of innovative management policies and grassroots education is essential to improve water quality. Simple approaches, such as street sweeping and warnings posted on storm drains, may reduce urban pollutants, but to what extent is uncertain. In some cases, parking lot and gas station drains may be effectively retrofitted with oil and grit separators to remove hydrocarbons and heavy metals from storm water before its entry into storm sewers (*2*). San Francisco developed a combined sewer system in which all city water (including street runoff) is treated before its release (*3*).

The construction of wetlands to alleviate storm water pulses as well as to improve water quality is becoming increasingly popular. Wetlands (either engineered or natural), with dense vegetation and wide, shallow basins, slow the entry of storm water by forcing it to flow through a longer course (decreasing water velocity) and remain in the basin for a longer period of time so that trapping sediments is possible. Trapped sediments containing nutrients (such as nitrogen and phosphorus) are then used by plants during growing seasons or are broken down through biological processes such as denitrification. Wetlands have been extremely successful in reducing high pollutant loads in storm water. Samples from a constructed wetland in Auckland, New Zealand, reflect an 80-97% decrease in sediment concentrations of lead, total phosphorus, and hydrocarbons (*4*). In addition to improving water quality, wetlands serve as an attractive habitat for waterfowl and provide important ecosystem functions (“ecosystem services”) to areas affected by urban development.

A number of cities are going beyond the banks of urban waterways to reduce urban runoff. Tucson, Arizona, is currently conducting a citywide storm water management study. This detailed analysis of the 59 watersheds in the city of Tucson is an effort to provide a long-range management plan for storm water quality and quantity. The plan promotes harvesting rain and grey water for landscape irrigation by private property owners and improved street and alley maintenance through increased street cleaning and waste removal. Tucson has a strict wash ordinance to protect washes from channeling and developing floodplains. Revegetation of disturbed floodplains and wash areas with native plant species is also encouraged. In other areas, Tucson has created an extensive set of linear parks along its two major waterways, the Santa Cruz and Rillito rivers. Areas that were once graded and devoid of other vegetation are now lush with native mesquite (*Prosopis* sp.), palo verde (*Cercidium* sp.), ocotillo (*Fouquiera splendens*), and numerous small herbaceous plants. As a result of this endeavor, the linear parks are not only heavily used by humans (hiking and biking) but by native fauna as well. It is not uncommon to see horned lizards (*Phrynosoma modestum*), road runners (*Geococcyx californianus*), coyotes, and numerous species of birds and rodents foraging among the plants adjacent to the walkways. In addition to reducing urban runoff, the restoration of such disturbed riparian areas increases the opportunity for public environmental education. Surrounding businesses and residential areas also tend to benefit economically from similarly restored areas. The recent restoration of a downtown creek in San Luis Obispo, California, raised property values and enlivened business activity (*5*).

Strategies to reduce urban runoff have wide-reaching effects on community lifestyles and result in subtle improvements in the ecological condition of native plant and animal communities residing within the city. Integrated with strategies to decrease urban runoff are opportunities for urban ecological restoration. Urban ecological restoration need not be limited to riparian areas or wetlands. Although traditionally perceived as a linear process, urban development can be quite circular. Clothes, newspapers, and milk cartons are recycled; why not abandoned stores and empty lots? What would happen in abandoned or perpetually vacant commercial areas and empty lots were restored to natural habitat parks? As suburban malls, shopping strips, and housing developments continue to expand away from the city center, the remaining abandoned and vacant areas are ripe with restoration opportunities. The restoration of abandoned or vacant urban areas with native plant species may provide similar societal, as well as ecological, benefits as the community gardens and parks of the 1960s and 1970s. Urban restoration has the added benefit of reducing the impact of urban runoff, which is both a major ecological and societal problem (*6*).

The restoration of abandoned or vacant urban landscapes with native flora provides one means of replenishing ecological capital (e.g., fossil water and biodiversity). Additionally, revegetating graded areas and removing deteriorating buildings reduces suspended solids entering urban storm sewers. A number of valuable ecosystems already exist in heavily urbanized areas (e.g., Central Park, New York, and Amsterdam Bos, Holland) which further legitimizes the practice of environmental restoration in urban settings. Holland has pioneered the ecological restoration concept of landscape planning on a significant scale (*7*). Amsterdam Bos is a large, man-made forest. Bijlmereer is a 1960s housing project located on the flat polders southeast of Amsterdam. In England, volunteers from youth organizations and the Conservation Corps created the Ecological Parks Trust on two acres of abandoned warehouses and docks along the south bank on the Thames (*8*). Restored areas in close proximity (e.g., multiple lots on a city residential block) may function as habitat for small mammals, reptiles, and birds. Agencies such as state Game and Fish Departments and the federal Fish and Wildlife Service are establishing urban wildlife branches to determine the number and diversity of animal species residing in urban areas. These agencies also identify potential urban landscapes that may provide ecologically valuable habitat to nonhuman residents. On a subtle scale, all of these steps in ecological restoration represent steps toward sustainable use at the level of the individual.

To continue the trend toward sustainable resource use, society must pay attention to its influence at the level of the individual; its control of the rate of loss of ecological capital; overharvesting of renewable resources and exhaustion of non-renewable resources; deterioration of environmental quality; and extinction of species. First, the environmental literacy of most societies must be dramatically improved (*9*). The presence of restored floodplains, riparian zones, created wetlands, and grey water harvesting expose citizens to the environment at an approachable level. Second, society must understand what sustainability means. In its simplest form, sustainable resource use meets present needs without compromising the ability of future generations to meet their own needs. In fulfilling these needs, society must focus on both technological development and ecosystem services (*10*). Ecosystem services are those functions of natural systems perceived to be of value to human society, such as maintenance of water quality. Third, as identified by the National Research Council (1), integrated management strategies that identify the cost and consequences of resource use must be implemented. To achieve this goal, society must form a clear vision of the future of its communities and develop strategies toward that vision. It is essential that ecosystem protection and restoration measures be incorporated into the daily lives of individuals to maintain natural resources. In doing so, sustainable use practices may be realized.

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Article 4

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Environmental Monitoring for Sustainable Use of the Planet

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Environmental monitoring is an activity that is essential to maintaining human quality-of-life. Since human society depends on ecosystems to provide breathable air, potable water, food, fiber, building materials, pharmaceuticals, and genes, it is simple self interest to monitor ecological capital and the rate at which the interest on this ecological capital in the form of ecosystem services is produced. By integrating the many existing environmental monitoring programs, making their methods compatible, making their spatial and temporal scales complementary, and making the products of these investigations readily available, an explosion in understanding of the relationships between human society and natural systems will be possible. The boundaries of each individual effort will be extended by this coordination, and the confidence in each finding will be magnified. These efforts will enhance the ability to demonstrate the intimate links between environmental condition and human quality-of-life and provide essential quality control for ecosystem services.

HUMAN DEPENDENCE ON ECOSYSTEM SERVICES

Natural systems provide services that are essential to human society (Westman, 1978). Those few functions of natural systems that have been widely recognized as beneficial to human society are called ecosystem services. If society's environmental literacy were sufficiently high, all functions of natural systems might be regarded as services. However, the benefits to human society of a few services provided by natural systems seem clear enough. Human society depends on (1) capture of solar energy and conversion into biomass, which is used for food, building materials, and fuel; (2) decomposition of wastes such as sewage; (3) regeneration of nutrients in forms essential to plant growth (e.g., nitrogen fixation); (4) storage, purification, and distribution of water (e.g., flood control, drinking water purification, transportation, etc.); (5) generation and maintenance of soils; (6) control of pests by insectivorous birds, bats, insects, etc.; (7) provision of a genetic library for development of new foods and drugs through both Mendelian genetics and bioengineering; (8) maintenance of breathable air; (9) control of both microclimate and macroclimate; (10) provision of buffering capacity to adapt to changes and recover from natural stresses such as flood, fire, pestilence; (11) pollination of plants, including agricultural crops, by insects, bats, etc.; and (12) aesthetic enrichment from vistas, recreation, inspiration.

Monitoring should have, as one of its primary objectives, the assurance that environmental quality control is adequate for these services to continue indefinitely. If monitoring and environmental quality control are not adequate, then sustainable use of the planet is impossible.

Quality control practices are well understood by members of industrial societies. Monitoring is common for the quality of blood given to patients in hospitals, for milk delivered to supermarkets, for gasoline used in cars, for bagels served on breakfast tables, and, of course, for beef made into burgers. Criteria have been determined for acceptable and unacceptable quality in these and other products. However, society is less used to setting similar quality control standards for complex multivariate systems that do not have clear cut boundaries such as ecosystems. Yet if sustainable use of the planet is a major goal, the quantity and quality of ecological capital and ecological interest must be determined so that future generations will inherit. If society depends on services provided by ecosystems, they should perform within certain boundary conditions. Going outside these conditions will affect the ecosystem's performance and, thus, the quality and quantity of their services. These concepts are challenging matters to define since society has not yet viewed its planet as an essential life support system. When this view has been considered, it has often been with poetic platitudes and much self righteousness. Society must recognize that its life support system is now both technological and ecological and that good management depends on optimizing the quality and quantity of both sets of services, without unnecessary sacrifice of either.

COEVOLUTION

While protecting ecosystem services seems a clear enough goal, complex interactions between human actions and environmental response occur (Cairns, 1994). Natural systems adjust to every action of human society – not always in the ways humans intended. The development of pesticide resistance is a key example. These changes in natural systems, in turn, require human society to adjust. Not only is the fate of ecosystems dependent on the actions of human society but the fate of human society is inextricably involved with the fate of ecosystems. In short, the dominance of human society over nature is not what it was once thought to be. The relationship is, in fact, more of a partnership. Each partner can benefit or harm the other. Such mutual modifications are analogous to the coevolutionary adjustments seen in pairs of species (e.g., hummingbirds and flowers).

However, the coevolutionary relationships that exist between species pairs are often accomplished by means of harsh penalties for those individuals or components that do not respond rapidly to changes in the other component. Thus, coevolution of human society and natural systems will be less unpleasant to humans if rapid information systems are developed to alert human society to needed changes.

A monitoring system can provide an early warning of deleterious change in ecosystems. However, this warning must be coupled with a sufficiently high appreciation for the dependence of human quality-of-life on ecosystem services. Without convincing links between environmental change and human quality-of-life, it will be impossible to influence human practices before the selective pressures of natural systems become too harsh. If environmental stewardship fails because of inadequate monitoring or the lack of will to take appropriate action, human society will suffer unpleasant consequences. Dobzhansky (1945) stated:

> We like to believe that if we secure adequate data bearing on a scientific problem, then anybody with normal intelligence who takes the trouble to become acquainted with these data will necessarily arrive at the same conclusion regarding the problem in question. We like to speak of conclusions demonstrated, settled, proved and established. It appears, however, that no evidence is powerful enough to force acceptance of a conclusion that is emotionally distasteful.

Assuming that human society has faith in the results of the monitoring data, will it have the courage to prevent unfortunate consequences, or wait until the consequences make action imperative?

This, I suggest, is the context in which environmental monitoring for regional, national, and global needs should now be viewed. Everyone must abandon the polarizing views of human society's relationship with natural systems and substitute a relationship of one system coevolving with another. Monitoring should furnish information suitable for making policy and management decisions to optimize the multivariate coevolutionary systems which, together, constitute society's life support system. Monitoring should also furnish information about the linkage between environmental condition and human quality-of-life.

TECHNOLOGICAL VS ECOSYSTEM SERVICES

In my earlier writings on biological monitoring (e.g., Cairns et al., 1970a;b; 1977; Cairns & Dickson, 1973), I envisioned an environmental quality control system that would permit use of nondegrading environmental assimilative capacity of societal waste, thereby protecting the integrity of natural systems but simultaneously taking advantage of their services. This would permit the coexistence of a technological society with natural systems and permit humans to enjoy both worlds (Cairns, 1996). In theory, this relationship of keeping technology sufficiently restrained so that it does not imperil natural systems is still possible, but the outcome is more uncertain than it was when biological and environmental monitoring was in its infancy.

Before the agricultural revolution, during the hunting gathering period, one could reasonably state that the life support system for humans was essentially ecological. Since the agricultural revolution and subsequently the industrial revolution, increasing numbers of people have become dependent on technological services to deliver food and energy and to treat waste materials. Catastrophic disruptions, such as earthquakes, hurricanes, floods, and the like, have shown how much even temporary disruptions of technological services can affect the well-being of human society, especially locally. Disruptions in ecosystem services are less obvious when they are incremental, or ameliorated by an overlay of technological services. For example, the loss in flood buffering capacity along the Mississippi River is a sorely lost ecosystem service, but is only experienced directly once every 100 years.

Significant numbers of people believe that technological fixes can be found for any and all environmental problems. However, current estimates of the cost to replace all ecological services by comparable technological services are sobering. Avise (1994) estimated that the cost of replacing ecosystem services by technology and/or managed ecosystems in Biosphere 2 was a staggering $9 million per person, per year. Achieving a balance between the provision of ecosystem and technological services will require both continual information about natural system condition and a willingness of human society to improve and, when necessary, restrain the delivery of technological services in order to prevent unacceptable levels of damage to the delivery of ecosystem services.

DEVELOPING ENVIRONMENTAL MONITORING POLICY OPTIONS

If human society acknowledges its dependence on an ecological life support system and simultaneously acknowledges that the system's capacity is finite and cannot indefinitely meet the demands of an ever-growing population, then five basic policy options for human society are possible (Cairns, 1993):

1. Continue environmental degradation and population increases until some sufficiently unpleasant selective pressure is exerted. Some would argue that there is already abundant evidence that crucial thresholds have been passed, but others deny this.

2. Develop a no-net-loss of ecosystem system services policy but do not attempt to regulate increases in population size or per capita level of affluence.
3. Exceed a no-net global, regional, or national loss of ecosystem services but permit both population and levels of affluence to continue to increase.
4. Stabilize human population with concomitant no-net-loss of production of ecosystem services. This is essentially the definition of sustainable use of the planet if one does not equate increased affluence with increased energy consumption and increased production of material goods. Perhaps a more accurate term than *affluence* is *net resources used per unit of product produced* so that recycling would then not increase demands on resources even though affluence would increase.
5. Stabilize human population and its demand on resources and exceed a no-net-loss of ecosystem services. This is the only scenario in which things are environmentally better than they are now are. Options 4 and 5 both permit sustainable use of the planet as it is generally interpreted; options 1, 2, and 3 almost certainly do not.

Regardless of the option chosen, environmental monitoring will be essential to see if the option is compatible with sustainable use and to see if the systems are functioning as expected. For example, it is possible that human society could still get sufficient ecosystem services with either half the ecosystem area or with a 50% decline in production of ecosystem services. If this is true, it is worth confirming. If it is not, the earliest possible warning would be highly desirable.

THE RISK-UNCERTAINTY PARADOX

Yet another consequence of the increasing scale of environmental problems is an increase in the uncertainty of the predictions of environmental outcome and consequences. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made in an environmental workshop. However, they are linked – acting with an intolerance of uncertainty often demands a high tolerance for risk. If the consequences are severe, one should be willing to act even in the face of high uncertainty. Impairment of ecosystem services certainly seems to fall in this category.

Traditional health and industrial monitoring systems produce both false positives and false negatives. In an environmental monitoring context, a false positive is a signal that some deterioration has occurred in the system when, in fact, it has not. A false negative is the absence of a signal when unacceptable changes in quality have occurred. The earlier use of sentinel species yielded false positive if the sentinel species was more sensitive to a particular toxicant than were the resident species and false negatives for some other toxicant for which the relative sensitivities were reversed. Reductions of errors can be accomplished by a better understanding of the system being monitored and by multiple lines of evidence. Integration of environmental monitoring programs will provide both. In addition, some attempt is being made to re-address the balance between false positive and false negative errors in risk assessments. Traditional scientific approaches control false positives at the expense of additional false negatives; this may be inappropriate in a risk assessment context (Shrader-Frechette, 1993).

ENVIRONMENTAL MONITORING FOR SUSTAINABLE USE

Developing a monitoring system so that ecosystem services essential to human society's well-being are maintained is quite a different activity than merely protecting natural systems for their own sake, although both activities are laudable. Acknowledging human society's dependence on ecosystem services and its vulnerability to their failure dramatically changes the perception of human society's relationship with natural systems from user and exploiter of these resources to one of mutual dependence. Unquestionably, human society has the capacity to destroy, within the next century, the ecological integrity of most global ecosystems as they now exist. It also has the capacity to preserve these global ecosystems if given appropriate monitoring information upon which to base decisions and the will to protect ecosystems out of enlightened self interest. A few illustrative changes in monitoring practices based on this new relationship follow.

1. Functional attributes will become much more important than they now are because they will be more practical endpoints for larger spatial and temporal scales. Structural and functional measurements alternate as one moves up a hierarchical scale, with each function contributing to the structures at the next higher hierarchical level. Since the scales relevant to various environmental problems are increasing and are becoming farther removed from the intrinsic time scale of individual human observation, functional measures may be more accessible and increasingly important as model structural changes are modeled at a scale inaccessible to individual human observation. Traditional structural attributes commonly used in monitoring efforts (i.e., critter counting) have been quite effective at the local level. But for larger temporal and spatial scales, ecosystem performance may be more important.
2. Also, as the scales relevant to environmental problems are increasing, endpoints characteristic of new levels of ecological organization become increasingly important (e.g., Cairns & Niederlehner, 1996). Populations and species are the customary level at which ecologists and biologists work (e.g., Harte et al., 1992), but landscapes may be a new focus. Considerable doubt exists about the robustness of extrapolations from one level of biological organization to another (e.g., Smith & Cairns, 1993).
3. As temporal and spatial scales expand, more "clients" will become involved and, inevitably, there will be real or perceived conflicts of interest. Integrated environmental management (Cairns et al., 1994) will be essential both to identify such situations before polarization occurs and to help resolve the conflicts over multiple use of finite resources before damage to the resources occurs.

Increasing awareness of human society's vulnerability to failure in either technological or ecological life support systems is a crucial component of this task. And just as quality control is essential to the reliable provision of technological services, biomonitoring is the key to quality control for reliable provision of ecological services. We all want the benefits of both ecological and technological systems for our descendants since we, ourselves, depend upon both. We can catch another plane, buy another car, or change our brand of shampoo if we think quality control is lacking, but we cannot change planets, at least not yet.

NOTES

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Article 5

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Sustainability, Ecosystem Services, and Health

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Key words: sustainable development, ecosystem services, ecosystem health, sustainability

SUMMARY

Sustainable development without regular delivery of services from the ecological component of Earth's life support system is presently impossible. Dependable delivery of these services over large temporal and spatial spans requires healthy ecosystems with unimpaired integrity. However, the conditions required for sustainable use of the planet's ecological life support systems have not received the attention necessary. Ecological resources as commodities (e.g., fisheries, timber) have received some attention, but those services (e.g., atmospheric gas balance) perceived as beneficial to human society have not. For example. we neither know how many can be eliminated and still serve as a life support system nor how much fragmentation will impair adequate delivery of services. The purpose of this manuscript is to initiate a discussion on these topics.

THE MANY INTERPRETATIONS OF SUSTAINABILITY

Thomas Jefferson, one of the early Presidents of the United States of America and a dominant political figure in my home state of Virginia, believed that each generation should pass the world on to the next generation in as good, or better, condition as it was received from the previous generation. This belief included not passing on financial burdens that were greater than the ones the present generation inherited. It is also clear that Jefferson meant this pronouncement ecologically as well, although some of the practices, such as clearing forest for agriculture, were regarded as improvements during his time, just as they are in much of the world today. Nevertheless, although Jefferson appears not to have used the term *sustainable development*, the concept was clearly in his mind. Lin Yuntang apparently had the same idea in his utopia when he proposed a tax on any children in excess of two per family. The most recent, widely publicized call for sustainable development was made in the 1987 report, entitled *Our Common Future*, by the World Commission on Environment and Development of the United Nations. This report is commonly referred to as 'The Brundtland Report' in honor of the chairperson, Dr. Gro Harlem Brundtland, then the Prime Minister of Norway. The World Commission defines sustainable development as '...development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1997). Weston (1995) states

> For most of us, development means progress or change for the better. Development involves maximizing the efficiency of resource allocation to meet needs – which is the dominant paradigm in economics at the present time. Thus, for most of us, sustainable development is, and should be, an economic concept.

The World Commission integrated the concept of sustainable development into the world's economy as follows:

> ... a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development ... institutional change to absorb the effects of human activities are consistent with future as well as present needs.

Development within ecological constraints was emphasized by the World Commission in its statement that 'Sustainable development can be pursued more easily when population size is stabilized at a level consistent with the productive capacity of the ecosystem'. Costanza (1996) states that 'a sustainable system is one that survives for some specified (non-infinite) time'. As Costanza notes, the problem is that a sustainable system can be identified only *after the fact*. As a consequence, what commonly pass for 'definitions of sustainability are actually *predictions* of what set of conditions will actually lead to a sustainable system'. Costanza (1996) also states that 'when one says a system has achieved sustainability, one does not mean an infinite lifespan, but rather a lifespan consistent with its time and space scale'. Costanza's introduction of a finite time span for sustainability of both economic and ecological systems is extremely important because the concept persuasively speculates that no one set of procedures, however well validated, will suffice indefinitely. Sustainability for finite periods requires monitoring (1) to confirm that necessary conditions are being met and (2) to validate the predictions or model.

Sustainability, in my opinion, requires human society to practice eight system-level conditions.

1. Artifacts created by human society may not systematically increase on the planet. Persistent toxic chemicals, parking lots (and other impervious surfaces that affect the hydrologic cycle), highways (and other artifacts that fragment ecosystems), and solid wastes are a few illustrative examples.
2. Substrates extracted from the earth's crust or synthesized from raw materials must not be concentrated or dispersed in ways harmful to the biosphere (e.g., metals or pesticides).
3. The physical and biological basis for the services provided by nature shall not be systematically diminished (e.g., overharvesting whales or fishery breeding stocks).
4. Short-term human 'needs' may not be met if doing so endangers the planet's ecological life support system.
5. There must be a balance between ecological destruction and repair.
6. Human society must not depend on yet undeveloped technologies to save it from the problems it has created.
7. Human society must not co-op so much of the energy captured by photosynthesis that the machinery of nature is unable to function normally.
8. If a world food shortage develops, grains will be shifted from domesticated animals to humans rather than convert more natural systems to agriculture.

The first four conditions just listed were developed as a result of correspondence with Peter H. Raven and Donald Aitken about the USA Step program. The original Step program, commonly called the Natural Step, was developed by Robért, Daily, Hawken, and Holmberg and was published in an undated, four-page document (source unidentified) entitled 'A Compass for Sustainable Development'. Some additional discussion may be found on this program on the internet ('The Natural Step's Progress'). My initial impulse was to state that the first four conditions were modified from the document produced by Robért and colleagues, but the conditions are so markedly altered that I hesitate to call them 'modified'. Unquestionably, the impetus to revise my thinking about conditions for sustainable development originated with the correspondence and documents just cited.

I have some serious reservations about my list in that conditions (1) and (7) mean that there can be no growth, which is exceedingly unlikely, even though desirable. Condition (5) requires a major change in present practices. For example, the American Electric Power Company wishes to establish a new 765-kv transmission line across the Appalachian Trail in my area of Virginia. The Appalachian Trail Club suggests that, if the new transmission line is approved, it should be accompanied by the elimination of one of the other power line trail crossings (Gordge, 1996). It is not clear whether present society will accept such elimination of old facilities, even though it may severely impair the prospects for sustainable use of the planet, but it does not include a no net loss of ecosystem condition. I am ambivalent about condition (6) because, very often, the impetus for development of a new technology is the result of a severe crisis or emergency. The most notable instance of such a rapid development of a new technology is the atom bomb during World War II. Some of the so-called miracle agricultural developments such as rice also had their impetus from clearcut needs for more food. On the other hand, dependence on new technologies did not save many of the passengers on the *Titanic*. Therefore, two problems surface with such an unqualified faith in the appearance of new technologies: (1) they may not appear in time, and (2) they may give a false sense of security with severe consequences. We may already be at or near the state postulated in condition (8).

There are also, to oversimplify the situation, two contrasting management approaches. Botkin (1990) advocates a proactive or 'take charge' model. He notes that nature is highly variable or inconstant, thus, providing no goals and guidelines for management practices at the level of uncertainty of most engineering models. In order to address this situation, he feels that human society must take complete charge of the planet, modifying or engineering it to whatever states human society decides are in its own interest. This takeover could be a dangerous situation if the information base is inadequate or the judgment unsound. On the other hand, Levins (1995) advocates an adaptive response model. This management approach is based on a statement once made by J.S. Haldane and quoted by Levins: 'The world is not only stranger than we imagine, but stranger than we *can* imagine'. Levins (1995) feels that 'The problem is not that Nature is inconstant and duplicitous, but that our minds and imaginations are inadequate to comprehend nature's complexity'. However, sound adaptive responses require a robust monitoring system and the willingness to alter human behavior and practices, sometimes on short notice. Ideally, this alteration should be instituted before ecosystems have suffered adverse consequences.

DEVELOPMENT AND SUSTAINABILITY

Unfortunately, for most of the planet, the term *development* has become associated with development for human habitation without recognition of human society's dependence on natural systems. While I have no quarrel with the way the term *development* is used in the publications already cited, I find, from asking ordinary citizens how they interpret the word, that it usually is associated with building highways, airports, tract housing, and the like. *Sustainable use of the planet* might be more appropriate terminology. But even if this is accepted, spatial and temporal scales must expand. Society's perspective is very short term indeed, as evidenced by the financial deficits that have accumulated in most countries and the breakdown of government services, such as health care, due to unanticipated demands or failure to take into account demographic changes and population increases. The cult of the individual has been taken too far because the aggregate impact of billions of individual decisions can be overwhelming. That is, in an era of scarce resources, individual perceptions of 'need' may thwart plans for long-term use.

In February 1995, a special component of the annual meeting of the American Association for the Advancement of Science (AAAS) suggested that Earth's resources of tillable land and petroleum energy are already strained beyond capacity. Continual rapid population growth plus increased affluence will obviously put more strains on this already overloaded system. Brown (1995) examines the long-range problem for the People's Republic of China, which is now importing food and is likely to do so for the near term future. The food shortages in North Korea have been well publicized, and other desperate shortages of food are obvious in parts of Africa and other continents. The AAAS meeting noted that the United States uses 470 000 000 acres of arable land to feed its 260 000 000 people, or about 1.8 acres per person. Until recently, the safety margin was sufficient for substantial export of food stuffs to other countries. As the AAAS meeting reported, when the population grows to 520 000 000, crop land may dwindle to 290 000 000 acres due to urbanization, erosion, and other highly probable factors. If this actually happens, only about one-half acre per capita will be available to produce food – certainly a far less comfortable margin than exists today. On the other hand, worldwide, the two-thirds acre per person now available may well be reduced to one-third acre per person, so the United States will still be better off by comparison. However, American agriculture depends heavily on oil, using about 140 gallons for every acre of corn, which is essentially using land to convert petroleum to food. Therefore, the energy and agricultural crises could well coincide during the first half of the next century. Ehrlich *et al.*, (1995) dramatically illustrate the race between human population increase and increases in agricultural productivity. Levins (1995) feels that, in the absence of complete prediction and control, an ecosystem manager is constrained to concentrate on fashioning a resilient culture and resilient ecosystems with an eye on what works in nature. Regrettably, numerous attacks have been launched on scientists who attempt to analyze such issues as population growth, desertification, food production, global warming, ozone depletion, acid rain, and the loss of biodiversity (Ehrlich, 1996).

CO-EVOLUTION AND SUSTAINABILITY

Cairns (1994, 1995) and Janzen (1984, 1988) believe that human society and natural systems are co-evolving and that human society should monitor what is happening in natural systems and respond so that the amenities and services of natural systems are not impaired but possibly improved. However, both the 'take charge' and the adaptive management responses are focused on human needs, and the basic question in sustainability is compassion for future generations and allocation of natural resources over large temporal and spatial spans (Cairns, 1995, 1996). The co-evolutionary relationship goes beyond Levins' fashioning of a resilient culture and resilient ecosystems in that it permits the existence of nonresilient ecosystems, which may well be furnishing important components to the ecological life support system. The primary disadvantage is the requirement that human society pay extremely close attention to the health and condition of natural systems, often making major behavioral changes to ensure that the systems are robust and not merely surviving. The idea of co-evolution offers considerably more security in that human society commits itself to meet certain conditions (e.g., the Step Program Toward Sustainability) and further commits to expanding these conditions if necessary.

RANDOM UNCONTROLLABLE EVENTS AND SUSTAINABILITY

On July 9, 1996, the Public Television Station in Roanoke, Virginia, broadcast a program on asteroids and other large extraterrestrial bodies hitting Earth (Public Television, 1996). In the program were some very interesting analyses of the number of times Earth's moon probably has been hit and some estimates of the number of times Earth has been hit by large bodies, including the one that may have caused the extinction of the dinosaurs. Recently, a sequence of asteroids hitting Jupiter was actually filmed, and speculation followed about the damage that might have resulted had the same group hit Earth instead. There was also some discussion about re-directing the so-called 'star wars' technology proposed during the presidency of Ronald Reagan in the United States to intercept, destroy, or deflect large extraterrestrial bodies on a course likely to intercept the Earth's orbit. Although present, rather inadequate information does not enable a robust prediction of the probability of an intercept of a very large body with Earth's orbit, recent investigation suggests that more large bodies exist than was previously estimated. The significance is, that however well planned, the realization of a sustainable future may be dramatically altered by events outside of society's control. This realization does not mean abandoning any planning for sustainable use of the planet but, rather, that the uncertainties involved in such planning are arguably dwarfed by the uncertainties of the type just described. One thing is certain: much human suffering will occur if the issue of sustainability is not addressed in a more systematic and orderly fashion, despite any inability to control the universe.

ETHOS, ETHICS, RELIGION, AND SUSTAINABILITY

Pronouncements such as the World Scientists' Warning to Humanity (1992) or the joint statement of the Royal Society of London and the U.S. National Academy of Sciences (1992) show that mainstream scientists are deeply concerned about the present state of the environment. When such pronouncements are made, they are either ignored by the news media or, alternatively, the media focus entirely on the sensational components without providing a basis for improved literacy among the general public. We are, after all, discussing the well being of our descendants, which is a sensational topic. Any progress in this area will require a synthesis of scientific information and predictive models with societal values. A mixture of ethics, ethos, and science will make many people uncomfortable, but scientific evidence is not needed if the consequences are unacceptable. For example, Baker (1996) notes, if citizens wish to take some action because they think it is the right thing to do, a conflict will not necessarily arise if everyone perceives that benefits will result from the action proposed. Leopold (1990) quotes Pericles, the Athenian General and respected leader, who spoke in 431 BC at the end of the first year of the Peloponnesian War to the assembled citizens concerning their strength, weakness, and prospects against the better prepared, military-minded Macedonians (I think this philosophy is the key to sustainable use of the planet): 'the ease in our private relations does not make us lawless as citizens'. Pericles noted that 'the chief safeguard is that citizens obey the customs and the laws whether they are actually on the statute book, or belong to that code which, though unwritten, yet cannot be broken without acknowledged disgrace'. [The original reference for this is Crawley (1951) in which the Pericles quotation was given by John H. Finley, Jr. in the introduction to Crawley's translation.]

Leopold defined *ethos* as a set of guiding beliefs of both government and citizens. The relevance of this concept to sustainability rests on the impossibly of writing laws so detailed and prescriptive that they handle every type of unexpected variability or episodic event. The current movement toward protecting the environment beyond the scope of existing or potential laws, covered so nicely by Baker (1966), is important. Science can never reduce uncertainty on the complex multivariate systems called ecosystems to the degree that would make explicit legislation possible, species by species, habitat by habitat, ecosystem by ecosystem, and landscape by landscape without going to ridiculous extremes. This situation does not invalidate the Step program or other attempts to establish conditions for sustainability. In order to protect ecosystems globally, some consensus must be reached on the broad, general conditions governing human society's relationship to the environment. Such a consensus is particularly important for the 'common grounds', such as the oceans and the gaseous envelope that surrounds Earth. Absent restraint in utilizing these two important components of the biosphere, sustainability will probably never be achieved.

PRIVATE PROPERTY AND SUSTAINABILITY

In addition to the common grounds theoretically shared by all nations and used as a waste dumping ground for many, issues are still in question that relate to sustainability within single political entities, particularly those that give some recognition of private property rights, which is now, arguably, extended to some degree to almost every free country in the world. The ability of corporations to use property under their control in any way they choose or for individuals to have the same prerogatives, if abused, could jeopardize any possibility of achieving sustainable use of the planet.

Given the current conflict in the United States between (a) private land owners who believe they should be able to use their land anyway they wish, (b) those who believe in a legal responsibility not to do anything that will have adverse effects on adjacent ecosystems or neighbors, and (c) a much smaller group who feels that endangered species on private property should be protected as vigorously as those on public property, a shared set of guiding beliefs seems virtually unattainable. With all of the ethnic conflict in the world, global industrial competition, budget deficits, and crime, giving attention to other species seems improbable, to some even laughable. Nevertheless, when the consequences of not changing behavior become more apparent, perhaps societal behavior will change. Additionally, the movement begun by some churches that maintains that science or laws are not needed 'to do the right thing' may be more effective than all the data on rates of loss of habitat and species. Geller (1994) thinks it is possible, through an actively caring model, to change human behavior substantially, which gives a rational basis for hope. The National Research Council (1991) (NRC) feels that an alteration in research priorities is necessary and lists critical research priorities for sustainable agriculture and natural resources management:

- overcoming institutional constraints on resource conservation;
- enhancing soil biological processes; managing soil properties;
- improving water resource management;
- matching crops to environments; and
- effectively incorporating social and cultural dimensions into research.

The NRC's conclusions (1991) apply quite well to resolving sustainability issues with only minor modifications to much of society's activities. The five major conclusions follow.

1. Major gaps still exist in the understanding of soil and water systems and processes, but more important are the gaps between what is known and what is applied.
2. Indigenous knowledge should always be assessed. It often can suggest promising research on ecosystem components and strategies, such as nitrogen fixing trees, nutrient accumulating species, and low input irrigation techniques. In some cases, indigenous knowledge can provide a platform for the integration of traditional and new technologies.

3. More effective links between the social and the natural science aspects of soil and water problems are needed. Social and economic contexts create constraints that can effectively limit the application of technical improvements unless such contexts are adequately understood and addressed.
4. More effective ways to use research resources for long-term, practical ends are needed. How can better feedback and communication be established between the field and the research institution so research can be focused on real, practical problems?
5. The weakest link in the research process is the dissemination of research findings to the farm or regional levels, with the great physical and human diversity that occurs. Greater effort is needed to develop better ways to communicate results.

The NRC (1991) notes that 'The search for ways to achieve sustainable agriculture and natural resource management will require changes in our traditional approach to problem solving'. Researchers must cross the boundaries of their individual disciplines and broaden their perspectives. The NRC feels that the change in vision is underway in various degrees throughout the research community, but that the pace of change is slow. With the population of the planet still growing, the pace must be accelerated toward sustainability.

DEVELOPING MANAGEMENT STRATEGIES FOR SUSTAINABILITY

While surprises occur, such as the asteroid damage mentioned earlier over which control is impossible but for which some degree of protection may be developed, other surprises may be due to excessive focus on one problem that blinds society to the existence of others. Colborn *et al.*, (1996) and Wapner (1995) note that preoccupation with human cancers induced by industrial chemicals caused many to overlook important events. Zeeman (1996) notes that a production in 1989 of approximately 5.9 trillion pounds of chemicals (the estimated U.S. manufacture and import of industrial chemicals only, not including pesticides, pharmaceuticals, and human and animal additives) is a mind-boggling amount but surely is an underestimate. Therefore, given the ubiquity and amounts of such chemical effects (other than hormone disruption and cancer, which remain undiagnosed at the present), surely other surprises will surface.

Despite these and other drawbacks to planning for sustainable use of the planet, human society would be wise to make plans and gather information that will enable the use of adaptive management strategies when new information indicates the plans should be adjusted.

EARTH'S LONG-RANGE CARRYING CAPACITY FOR HUMAN SOCIETY

As Daily and Ehrlich (1992) note:

> A sustainable process is one that can be maintained without interruption, weakening, or loss of valued qualities. Sustainability is a necessary and sufficient condition for a population to be at or below any carrying capacity. Implicit in the desire for sustainability is the moral conviction that the current generation should pass on its inheritance of natural wealth, not unchanged, but undiminished in potential to support future generations.

The term *carrying capacity* has been used by ecologists for years as 'the maximal population size of a given species that an area can support without reducing its ability to support the same species in the future'. Roughgarden (1979) notes that it is specifically 'a measure of the amount of renewable resources in the environment in units of the number of organisms these resources can support and is specified as *K* in the biological literature'. Daily and Ehrlich (1992) note that carrying capacity is a function of characteristics of both the area and the organisms, since a larger or richer area will have a higher carrying capacity than a smaller or impoverished area. Alternatively, a given area will be able to support a larger population of a species with a relatively low energetic requirement than a species at the same trophic level with high energetic requirements. I have been told off the record by a number of employees of the federal government, as well as of some states, that the use of the term *carrying capacity* is strongly discouraged. Certainly, it is difficult to find the term in governmental policy documents. Very likely, this prohibition is because an expanding economy, increasing per capita affluence, and increasing expansion of the industrial base in every political unit are thought to be the 'economic engine' that drives society. Ironically, this belief is strongly held in a society becoming increasingly health conscious where growth in poundage or size beyond a certain age is considered highly undesirable, although sometimes thinness and fitness are carried to extremes. Also, quality of life is arguably not improved by affluence beyond a certain level of adequate nourishment, housing, and education. Surely, cities might be better off taking care of the present inhabitants and improving their quality of life before further growth in population.

SUSTAINABILITY IN A CULTURAL CONTEXT

Clearly, sustainable use of the planet must take into consideration the way people are, rather than the way they should be. It is easier for a well-nourished person to reduce environmental impact than for a malnourished person to even consider it. Some recognition is already being given to the fact that strategies for sustainability must be designed, at least initially, for each culture. For example, the Association of University Leaders for a Sustainable Future (1996) discusses Professor Natalyap Tarasova's curriculum for sustainable development in the Russian context. Another organization is the Sustainability Education Center of the American Forum for Global Education (1020 Wall Street, Suite 2600, New York, NY 10005, USA). I have also been pleased to communicate with colleagues on sustainability in such diverse cultures as Finland, Malta, and the People's Republic of China. René Dubos' famous statement, 'think globally, act locally', certainly applies to this issue. On the other hand, exchanges of information about what each culture or political system is doing would be most advantageous. Some problems are shared with other cultures, and the present problems of industrially-developed societies presumably will ultimately be faced by societies where industrial development is still occurring. Most important, however, sustainability must be discussed globally, or at least in a landscape perspective, that transcends political systems where oceans, Earth's atmosphere, and transport of potentially toxic chemicals from one area to another are of concern (to mention a few illustrative examples). Another situation where multicultural approaches will be necessary is the issue of migratory birds and other organisms whose wintering grounds may be in South or Central America and the nesting grounds in the US and/or Canada. This range of considerations is one of the main reasons I prefer the term *sustainable use of the planet* instead of *sustainable development*, since the former explicitly mentions the planet in the sustainability context.

The prospects for sustainability will be enhanced if developed countries cease exporting inappropriate technologies to developing countries. Farvar and Milton (1972) discuss the inappropriate export of technology in international development. A number of interesting and illustrative case histories are given in that volume. What is needed now is the exchange of knowledge and technology for sustainable use of the planet and the collaboration of all cultures to protect the well being of future generations in human society.

If human society is willing to acknowledge its dependence on the life support services of natural systems, then it follows that the level of human accountability for the well being of other species and the ecosystems they inhabit would be much higher than if human society merely has respect for them. Furthermore, acknowledging dependence will almost certainly facilitate the development of societal norms of behavior that will lead to the acceptance of authority, not in the dictatorial sense but in the sense that certain norms must be enforced in order to achieve sustainability.

DETERMINATION OF HUMAN SOCIETY'S DEPENDENCE UPON ECOSYSTEM SERVICES

Undoubtedly, ecosystems furnish services such as the maintenance of the atmospheric gas balance and the control of the hydrologic cycle so as to reduce the damage of floods, etc. (Cairns, 1996; Westman, 1997). A number of crucial questions need to be answered for which no robust data exist.

1. To what degree do agricultural and other modified ecosystems, such as golf courses, substitute for the services provided by natural systems?
2. What level of ecosystem services (both quantitatively and qualitatively) is necessary for sustainable use of the planet?
3. How much seasonal variability and cyclic variability exist in the provision of ecosystem services?
4. To what degree do common grounds, such as oceans, provide ecosystem services of benefit to human society, and what organization should be responsible for their management?
5. How should human society pay for ensuring the delivery of ecosystem services (Cairns, in press)?
6. To what degree can technology substitute for the delivery of ecosystem services?
7. Does ecological restoration fully or only partially restore ecosystem services for both short and long term?

Cairns (1996) makes the case that human society is dependent upon both technological and ecosystem services and that overdevelopment of technological services can impair the delivery of ecosystem services. In short, for sustainable use of the planet, some sort of balance is necessary to maintain optimal levels of both types of services. The problem is that technological services are more clearly understood by human society than ecosystem services, although, arguably, dependence on ecosystem services is greater than the dependence on technological services since the former existed long before the latter and cannot be replaced by the latter. Since the reliable delivery of ecosystem services is essential to sustainable use of the planet for the foreseeable future, it would be prudent to expand the information base on them. For example, Cairns and Bidwell (1996) have described a situation identified by Professor J.R. Stauffer in Lake Malawi. There, schistosomiasis-bearing snails were kept under control by tilapia and, when this fish was overharvested, the snail population increased significantly as did the incidence of schistosomiasis. Society was not aware of the service until it disappeared. This situation may not be uncommon, and, thus, a robust list of ecosystem services may not be possible until the service is impaired and the results are evident or until the ecological interactions are better understood. Arguably, every ecosystem function is a service to human society, but society may not be aware of this because of the present level of ecological literacy. Developing a sound information base on ecosystem services may take decades, and, in the meantime, sustainable use of the planet will be less probable than it would be if a sound information base on ecosystems was available.

PRESERVING OR IMPROVING THE HUMAN CONDITION

Sustainable use of the planet for thousands of years will be impossible unless human society pays closer attention to the delivery of ecosystem services. Although no robust evidence is available on this, ecosystem services (those functions perceived as useful to human society) will be impaired if ecosystem health declines. Certainly, ill health generally impairs function in humans, and, while ecosystems are at a higher level of biological organization, they are composed of living species whose function is impaired when health deteriorates. Similarly, humans will not have robust health while living in impaired or badly damaged ecosystems. Although it is irritating or amusing to hear 'part-time environmentalists' intoning 'man is *a part* of nature rather than *apart* from nature' as they sit in a building surrounded by dramatically altered ecosystems, it is well to remember that the self-righteous statement is correct even if uttered by someone unaware of the irony of self-righteously making such a statement in that particular locale. Some illustrative, serious concerns regarding sustainability, ecosystem services, ecosystem health, and the human condition follow.

Governments make poor use of scientific information

Ford (1996) has written a thorough and detailed analysis of mad cow disease (BSE). This far-ranging book discusses the discontinuity between the available scientific information, the cautionary statements from scientists about uncertainties, and government pronouncements over a substantial period of time. Ford notes that, while the scientific findings have been methodically acquired, the official response has been hasty and ill considered. The British government's response to this particular situation, as well as the response of the European community, often uses selected quotes from the scientific literature intended to support the position being taken rather than to inform the public. Parallels of this are present in the United States as well, where the Union of Concerned Scientists (UCS) has over 1,500 scientists nationwide participating in the UCS's campaign to counter 'junk science' (Cole, 1996). Cole includes in her article some quotes that she refers to as 'junkspeak' from Congress, such as (1) representative Dana Rohrabacher (Republican-California), Chair of the Energy and Environment Subcommittee of the House Science Committee, on global climate change: 'Unproven at best and liberal claptrap at worst' (*Pittsburgh Post-Gazette*, September 25, 1995); (2) 'a politicized instead of a scientific concept' (cited in a *Washington Post* column by Jessica Mathews, January 29, 1996); (3) House Majority Whip Tom DeLay (Republican-Texas) on banning CRCs to reduce ozone depletion: 'The science underlying the CFC ban is debatable'; and (4) the agreement to end the use of CFCs is 'the result of a media scare' (*Washington Post*, October 27, 1996). Cole (1996) notes that the Nobel Prize in Chemistry had been awarded two weeks earlier to three scientists for their work on ozone depletion. These comments show that elected representatives are either unaware or choose to ignore the findings and deliberations of the scientific community published in peer-reviewed journals. Perhaps this situation is partly due to the scientific illiteracy of elected representatives, which in turn, is the result of a failure of the scientific community to democratize the process of science and its findings.

Is the general proposition that economic growth is good for the environment justified?

This claim is based on the assumption that an empirical relationship exists between per capita income and some measures of environmental quality (Arrow *et al.*, 1995). As Arrow *et al.* note, as income rises, environmental degradation increases up to a point, after which environmental quality improves; the relationship has 'an inverted U shape'. Harte (1996) notes that people have been talking about the U curve for years but have really not done much about it.

Is the carrying capacity of Earth for humans affected by fluctuations in the delivery of ecosystem services due to normal cyclical variability or pollution?

Fuentes-Quezada (1996) and Schindler (1996) discuss the relationship between economic growth and long-term carrying capacity for humans. Human society accepted its relationship with natural systems before the agricultural and industrial revolutions, but now the dependence is less clear, especially to many urban dwellers. Without a doubt, all strategies for sustainable use of the planet should incorporate economics as the ecology of human society with the further recognition that other species, especially those with non-human societies, have their own version of economics as well (Tullock, 1994). Some systems might be regarded, in this era when ecosystems free of human effects are arguably nonexistent, as those ecosystems unmanaged by human society even if they are affected by such things as acid rain, airborne pollution, and the like. Economists and ecologists should not be held responsible for the condition of the planet or the economics system since these are the result of individual choices of every human inhabitant of the planet.

HUMAN BEHAVIOR

Individuals and societies respond slowly or not at all to distant risks, especially if the uncertainty of the outcome is high. Compassion for humans now living and who are perceived as deprived almost always takes precedence over compassion for those yet to live. This aid to the deprived may give great satisfaction but is unlikely to result in sustainable use of the planet if compassion is used as a justification for environmental damage, such as over zealous use of pesticides, clearing of land unsuitable for agriculture, increasing population size far beyond carrying capacity, and the like.

Prophecy of future dangers are nearly always countered with either disbelief because the consequences are not yet visible or optimism that human ingenuity or technology will solve the problem. Cairns (1995) believes that serious thought should be given to resource allocation over large spatial and temporal scales.

THE THREE GUIDING PRINCIPLES OF SUSTAINABILITY

Arrow *et al.* (1995) have proposed three basic principles concerning economics and the environment.

1. All economic activity ultimately depends upon the environmental resource base.
2. The environmental resource base is finite.
3. Imprudent use of the environmental resource base may irreversibly reduce the capacity for generating material production in the future.

Regrettably, these and other guiding principles and conditions (such as the ones in the Step program mentioned earlier) will not influence human behavior if the general public and its representatives are misguided by inaccurate statements such as those in John Tierney's article 'The Optimists are Right' in the September 29, 1996, issue of the *New York Times*. Paul R. Ehrlich's response to this letter, dated October 4, 1996, to Mr. Jack Rosenthal (Editor of the *New York Times* magazine) maintains that Tierney's statement that the amount of food produced per person has been 'rising for centuries' is incorrect. Ehrlich notes that information on per capita food production prior to

1950 is scanty and unreliable, but the real picture is clearly one of fluctuation marked by numerous famines in which millions starved or migrated. Ehrlich notes that per capita production of grain ('the staple on which humanity depends directly or indirectly') has been declining globally since 1984, and absolute amounts have failed to rise since 1990. Ehrlich states, 'in deed, this year grain reserves have fallen to the lowest point in 35 years. Per capita yields of fishes from the sea are also declining, with 13 of 15 major fisheries seriously overfished'. Ehrlich notes that the book (1996) he and his spouse recently produced focuses entirely on such information and misquotes of science. The Ehrlichs call this anti-environmental movement response the 'brown lash' and are concerned that this will quell legitimate concern over the seriousness of environmental problems. As Orr (1994) notes, nothing less than the re-education of humankind will do. Orr quotes Vaclav Havel:

> We treat the fatal consequences of technology as though they were technical defect that could be remedied by technology alone. We are looking for an objective way out of the crisis of objectivism . . . We cannot devise, within the traditional modern attitudes to reality, a system that will eliminate all the disastrous consequences of the previous systems . . . We have to abandon the arrogant belief that the world is merely a puzzle to be solved, a machine with instructions for use waiting to discovered.

THE FUTURE HUMAN CONDITION

One of the most helpful books I have read in attempting to estimate the human condition in the next century and beyond is appropriately entitled *The Future Eaters* (Flannery, 1994). This volume is mostly about Australia, but with significant attention to New Zealand and other adjacent areas. The title is particularly arresting because somehow consuming the future of our descendants is more descriptive than merely stealing it from them.

Flannery's book notes that 'Fire, grass and kangaroos, and human inhabitants seem all dependent on each other for existence in Australia; for any one of these being wanting, the others could no longer continue'. Flannery also notes that, in Australia, the interdependence of people, flora, fauna, and fire is even more dramatic. He notes that the aboriginals appear to have had a substantive influence upon natural systems, but appear to have lived in harmony with them for roughly 60 000 years because they adjusted their behavior to meet the needs of the ecosystem and, more importantly, were sufficiently attentive to know what these needs were. The book has another attraction in that Australia is a relatively new country and, yet, is technologically advanced in many ways. Culturally, the Sidney Opera House is known the world over for its dramatic silhouette. The swiftness of these changes are dramatically documented in Flannery's book as he notes that roughly one quarter of the inhabitants of Australia were not born there and rarely does ancestry in that continent go back more than three generations, except for the aboriginal inhabitants.

Regrettably, most proponents of sustainable use of the planet appear to envision a steady state as the ultimate goal in human society's relationship with nature. However, Odum *et al.* (1995) note that a more realistic paradigm may be that nature pulses regularly to make a pulsing steady state. They note that people, scientists, and government are now beginning to recognize the limits of the biosphere and discuss sustainability in the context of managing growth so that the life-support carrying capacity of Earth is not exceeded. In this paradigm, a steady state is seen as a goal for sustainability, as well as the final result of self-organization in nature. This discussion (Odum *et al.*, 1995) is extremely important because sustainability viewed in the context of a pulsing paradigm for natural systems is quite different than a steady state that is achievable by both human society and natural systems as a result of self-organization. In the present view of sustainability, the dominating paradigm seems to be the quantity of people the planet can support indefinitely, which dominates most of the discussions of sustainability. However, as Mumford (1967) noted nearly three decades ago, immense human benefits may be curtailed by a one-sided emphasis on quantity – hence, the idea that quality in control of quantity is the great lesson of biological evolution. In the question of sustainability, attention must be given to the quality of an ecosystem, which is arguably more important than the quantity. A large quantity of something of poor quality may not be the best way to approach sustainability.

Discussions are just now beginning to explore the interfaces between science, engineering, policymaking, and the general public. These interfaces must also be considered between traditional market economics and a new developing field of nonmarket ecosystem services, which must somehow be incorporated into the present economic system (Cairns, in press).

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Article 6

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What Sustainability Is Not!

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Keywords: sustainable development, sustainability backlash, anti-industry, anti-technology, environmental extremists, private property

SUMMARY

In the span of years of seminars and lectures I have given on sustainable use of the planet, sustainable development, leaving a habitable planet for our descendants, and similar titles, a small but exceedingly vocal group has attempted, during the discussion period or the talk itself, to link sustainability with environmental extremism. Almost without exception, objections to sustainability have been without foundation. The most common accusations are that sustainability is: (1) a subterfuge to protect endangered species, (2) anti-technology, (3) anti-industry, (4) anti-humans, (5) anti-private property, and (6) anti-change. Consequently, stating what sustainability is not is often helpful, and repetition of it may be necessary, depending on the depth of the misunderstanding in the audience. This discussion covers some, but far from all, common objections to sustainability. As sustainability has become better understood, attempts to associate it with environmental extremism should have diminished. However, no reduction in these misunderstandings has occurred, and, if anything, the intensity may have increased slightly. Generally, only a small percentage of audiences appear to be emotional about sustainability, and stating what sustainability is not may not change their opinion or even silence their opposition. However, other members of the audience may be informed by stating what sustainability is not.

OBJECTIONS TO SUSTAINABLE DEVELOPMENT

During the past three years, I have given seminars, talks, keynote addresses, mini-courses, and the like on sustainable development. Audience age usually ranges from high school students to retirees. Occupations of those employed or previously employed range from blue collar service workers to industrial executives, and from modestly educated to highly educated. Despite the diversity in age, occupations and interests, the reoccurrence of at least some objections to sustainability, as perceived, is always startling.

An illustrative list of objections to sustainable development follows.

Sustainability initiatives are a thinly masked initiative to protect endangered species

The spotted owl of the Pacific Northwest is the most commonly used example in the United States of protecting an endangered species. Surprisingly, objections are often raised by people who have never seen a spotted owl or, in some cases, even been to the Pacific Northwest. This example is mentioned in these seminars even though no particular endangered species is being discussed. The spotted owl seems to be the icon of the fear that protecting endangered species and the habitat they require will result in loss of jobs and will adversely affect wage earners who are dependent on the lumbering industry for their income. A similar argument is used in areas that depend on the tobacco industry – taking certain health risks is preferable, to at least some people, than the option of finding an alternative agricultural economy or even retraining workers for a different occupation. Consequently, the argument becomes a question of sacrificing humans to protect owls (or other endangered species), and emotions intensify.

Given the widespread nature of the accusation that endangered species are more important than jobs, it is desirable to point out that sustainable use of the planet is in the enlightened self-interest of all humans, particularly those interested in the well-being of future generations. The charge is frequently voiced that the endangered species is unnecessary and that the loss of it would hardly be noticed. The planet did get along quite well without the spotted owl for millions of years and, in fact, did so equally well for long periods of time without *Homo sapiens.* This fact leads to the assertion that sustainability focuses on life-support systems and prudent use of resources, not on individual species. In addition, the habitat occupied by the endangered species may furnish useful ecosystem services that contribute to sustainability, so the primary sustainability objective is not the protection of the spotted owl or other endangered species but the protection of the habitat and the services it offers. The Natural Step program maintains: 'We need to re-examine the negotiable rules of our economic game so they conform to the non-negotiable rules of the biophysical world' (Robèrt *et al*., 1996).

Sustainability is anti-technology

This objection forgets that sustainability goals and conditions will require a technological revolution and a major paradigm shift in technological development. Hawken (1993, 1997) describes many technological innovations that will be necessary to facilitate this shift. Furthermore, consulting firms, such as Roy F. Weston, Inc. (e.g., Weston, 1995), have produced publications on this subject, and such firms as Mitsubishi have produced videotapes that depict technological innovations undertaken by that organization to foster sustainable use of the planet. Clearly, both individuals and companies are investing great amounts of time, energy, and money into developing technologies suitable for sustainable use of the planet. Sustainability is fostering technological changes and is not seeking to curtail technology but use it effectively.

Sustainability is anti-industry

Industry has invested a great deal of time in sustainability thus far. A large number of Swedish industries have endorsed the Natural Step Program (Robèrt *et al*., 1996), which has living sustainably as its objective, and Tibbs (1992) envisions hybrid industrial/ecological systems. The Mitsubishi videotape mentioned earlier devotes considerable time to both the continual reuse of plastics and the industrial transformation of garbage and other societal wastes so that they may be reintroduced into ecosystems in a way that will make ecosystems thrive. Consequently, industry has an enormous stake in sustainability.

The technological and ecological components of human society's life-support system must work together to reduce the risk of the technological component damaging the services delivered by the ecological component. In fact, rather than a 'them' versus 'us' polarization of industry and those interested in sustainability, a synergistic cooperation must exist. That is, in order for sustainable development to occur, some degree of unanimity must be reached on the goals and the conditions. Applications will necessarily be different in developing and developed countries. However, none in the global marketplace should be isolated from the rest of the world because the environmental effects, such as acid rain and ozone holes, transcend political boundaries.

Sustainability puts natural systems ahead of humans

If sustainability is considered on large temporal and spatial scales, then more humans can occupy the planet over the next century, or even millennium, than would be possible if the ecological life support system is pushed beyond its endurance. Anyone even partially literate in toxicology realizes that humans cannot kill every species on the planet without killing themselves. Indeed, disappearance of any species indicates unfavorable conditions for life in general, whether the conditions be toxicological or physical. Therefore, humans are inevitably affected by any condition that affects large numbers of other living creatures, and it is in enlightened, human self-interest to protect the natural systems upon whose services human society depends.

However, some people believe that technology can solve every ecological problem (even though the problems are often caused by technology), and others believe that human ingenuity, intelligence, and technology free humans from the harsh biophysical laws (natural laws) that restrict other species. This argument is difficult to counter because of remarkable advances in science and technology over the last 200 years. On the other hand, these advances have also created new problems that did not exist 200 years ago, which have not yet been solved (for example, safe long-term storage of radioactive waste). Present storage technologies may be ‘safe’, but persuasive evidence indicates that the safety has not yet been adequately validated. Basically, this mind-set is a version of ‘trust us’, ‘the check is in the mail’, and ‘the persons who created the problems can also solve them’. Certainly, these options are not always true. Technology often advances faster than changes in social behavior evidenced by the fact that, in an era when weapons of mass destruction exist in incredible quantities, some governments and political leaders still act in ways that are generally viewed as irresponsible and self-serving. Reversing severe ecological damage in time frames of relevance to human society (that is, to avoid major suffering) is not possible, and only one major mistake is required to cause severe societal disequilibrium. One of the goals of sustainability is to avoid such an unfortunate situation, both for present and future generations.

Moral reasons exist for protecting natural systems and the organisms that inhabit them. Sustainability does not address these ethical issues, except indirectly to the degree of leaving a habitable planet for future generations. Further, humans hope that their descendants will have at least the same opportunities to enjoy natural systems that they had. Persons now living cannot imagine future circumstances or what the value system of future generations will be. Sustainability initiatives do not attempt to address these issues, but rather to leave ecological and societal capital in place for present and future generations so as not to restrict any options.

Sustainability is anti-private property

This contentious issue is probably best examined by repeating the old saying ‘your right to swing your fist wherever you choose ends where my nose begins’. A social contract diminishes the opportunities for an individual to do serious harm to other individuals in society while exercising freedom of choice. Members of society voluntarily relinquish certain individual rights clearly perceived as harmful so that their lives are not disrupted by inappropriate actions of others. Stated more crudely, individuals make a social contract to avoid damaging behavior with the understanding that society will coerce all of its members by imposing consequences for inappropriate behavior.

The situation becomes more complicated when private property is involved because people feel that they own the property and should be able to do whatever they wish with it. However, the same principle applies – a social contract requires that individual behavior must be restrained if such behavior endangers either the freedom or the property of others. Some residential areas even extend this principle to the aesthetic, where hanging laundry outdoors is considered inappropriate and antenna towers for ham radio operators are not permitted. A general, social contract is essential if one moves from one part of a country to another and wants to assume that certain protections are in place.

Sustainability merely modifies the social contract, i.e., general consent to protect future generations from the actions of present generations that will jeopardize their opportunities for living a comparable life. Sustainability, therefore, is not anti-private property but merely seeks, with common consent of society in general, to ensure that future generations have a habitable planet and at least the same opportunities as present generations.

The problem with all social contracts is that the perception of an individual action may be that it causes no harm – for example, filling in a one-acre wetland in a drainage basin that extends from the Canadian border to the Gulf of Mexico. But, filling in thousands of acres reduces storage of flood waters. The exhaust from a single automobile can hardly be measured any distance from the exhaust pipe. However, the exhausts from millions of automobiles have a dramatic effect within the limits of a city, especially when there is a temperature inversion or some other factor that keeps the air confined to the city as if it were covered with a dome. When an individual fights restraint either on individual behavior (such as speed limits) or on use of private property, the question is often not just whether a particular type of behavior is irresponsible. If only one person were acting this way, it might not be; however, the question becomes: what if everybody acted this irresponsibly? Sustainability is merely a social contract with large temporal and geographic spans, not different in principle from any other social contract.

Sustainability is anti-change

The Brundtland Report (United Nations World Commission on Environment and Development, 1987) states that major societal changes will be essential in order to achieve sustainability. Rather than being anti-change, advocates of sustainability want to cease present activities that are not sustainable and change them to ones that are. Therefore, people against sustainability could be considered anti-change, and those for sustainability are pro-change (at least where non-sustainable activities and behaviors are concerned).

THE EVOLUTION/SUSTAINABILITY PARADOX

The evolutionary process is continually producing new forms, most of which are no better suited to present environments than existing organisms, but a notable few are. Sustainability is essentially an attempt to ensure favorable conditions for one species, *Homo sapiens,* over large temporal and spatial spans. Many other species compete with humans for a wide variety of resources; the most successful in the competition will have a greater fitness than other species. From a human perspective, this situation will lead to some destabilization. Sustainable development and its other descriptors acknowledge that humans are dependent on natural systems, but the question of how competition from other species is handled has not been addressed adequately. Certainly, not all interactions with other species will be benevolent and might even require drastic measures. This complex issue will probably prevent sustainable development from being the steady state perceived by most persons. In addition, general goals and conditions can endure if they are continually modified, but prescriptive rules and regulations for sustainability applied too bureaucratically will not suffice.

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Article 7

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Malthus Revisited: Sustainability and the Denial of Limits

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A wrongdoer is often a man who has left something undone,
not always someone who has done something.
— Marcus Aurelius

All man's troubles arise from the fact
that we do not know what we are
and do not agree on what we want to be.
— Vercors (Jean Bruller),
You Shall Know Them (1953)

Abstract

In the bicentennial year of Malthus' seminal paper, human society is still debating whether the evidence of biophysical limits on population growth (which applies to other species) also applies to *Homo sapiens.* In terms of evolutionary or geological time, 200 years is a trivial span to test such a hypothesis. Human ingenuity and technology appear to invalidate Malthus' hypothesis, although the present living conditions of at least 2 billion people support Malthus' idea. However, the emerging debate on sustainable development or sustainable use of the planet has again raised questions about whether infinite growth in any species can occur on a finite planet. No other habitable planets are known and, even if they are discovered, shipping 95 million people annually to another location might exhaust Earth's resources more quickly than sustaining the population here. As many others have noted, human society is engaged in a global experiment with no "control" planet. Unlike changing from an airplane that may be in poor condition, humans do not have the option of catching another planet. This paper analyzes some of the issues raised by Malthus in a sustainability context.

What Hasn't Changed in the Last 200 Years?

(1) Human society still views complex, interactive systems in terms of special interest components (i.e., those of obvious interest personally or to an applicable group). The failure in this view is not realizing that affecting the components affects the system, and the system affects the components and, ultimately, human society.

(2) Human society looks for single connections rather than patterns. Those who look at patterns are disregarded because the short-term uncertainty is usually higher than for simple, even limited, multiple connections.

(3) Human society rarely acknowledges the programmatic futility of single interest, lobby- (i.e., money-) dominated politics.

(4) A touching but dangerous belief is that problems caused by technology can be solved by more technology, rather than by changes in societal behavior.

What Has Changed in the Last 200 Years?

(1) The power of individuals, especially terrorists, to place the social order in disequilibrium has vastly increased and is becoming worse.

(2) Ecological capital (e.g., old growth forests, etc.) has decreased dramatically. The per capita decrease is even more dramatic due to increased numbers of humans.

(3) Economic and, arguably, ecological disparities for individuals have markedly increased, thus providing disincentives for the average human to work for the common good.

(4) Natural systems are highly manipulated parts of industrial society. As Holmberg and Robèrt (draft) state: "The industrial society can be said to be a highly manipulated part of the natural ecosystem, but its dependence on, and influence on, the natural ecosystems are determined by the same basic laws of nature that are in operation in nature itself."

Uncertainties Associated with Human Society's Largest Experiment

As Schneider and Londer (1984) note, climate both influences and is influenced by life on Earth – the two appear to have coevolved. Unquestionably, the interactions are intricate and profound. Persuasive evidence also indicates that human society and natural systems are coevolving (e.g., Janzen, 1984; Cairns, 1994, 1997a). Cairns (1996) notes that this type of coevolution can be either hostile or benign (the relationship leading to sustainability). The harmonious aspects of coevolution in natural systems are often the result of harsh penalties exacted on those individuals or components that do not respond adequately or with sufficient rapidity to alterations in other components. In more blunt terms, global experiments with climate and ecological life support systems can result in extremely harsh penalties to human society. If significant uncertainties about the outcomes of various courses of action (such as crossing an ecological threshold without realizing it or relying on human ingenuity and technology to replace all exhausted resources) are in error, human society may cease to exist as it is now known.

Non-renewable resources, such as fossil fuels, are being exhausted at a substantial rate, as are renewable resources/ecological capital such as topsoil, old growth forests, and fossil water. Population is still increasing despite birth rates that are less than replacement rates in some parts of the world, and the disparity in per capita resource use and living standards is increasing at the individual and national levels as well. Equitability and fairness for the entire planet's human population will be resource-use intensive, and efforts to increase standards of living for the billions now deprived will almost certainly be a final blow to Earth's ecological life support system.

The Uncertainty/Risk Paradox

The absence of certainty is not synonymous with the absence of risk. The statement is platitudinous, but 200 years of inaction since Malthus' seminal publication indicates that this statement is not commonplace for a number of societies. The December 1997 Climate Summit in Kyoto, Japan, indicates a reluctance by human societies to accept that their unwillingness to change their behavior does not suspend consequences of biophysical (i.e., natural) laws. The next "Kyoto Summit," whenever and wherever it is held, will almost certainly be convened to discuss ways to minimize the consequences of climate change. At the same time of the 1997 summit, news services were carrying news accounts that increased ultraviolet radiation from depletion of the protective ozone layer may be responsible for the demise of salamanders and other amphibians. Even before such evidence became available, amphibians were suffering despite the uncertainty/risk dilemma, even 200 years after Malthus' publication.

One of the major consequences of the increasing temporal, spatial, and intensity scales of environmental problems is an increase in the uncertainty of the predictions of environmental outcome and consequences. Tolerance of scientific uncertainty and tolerance of risk are both appropriate subjects for debate before decisions are made that will affect environmental health and condition. However, they are linked – acting with an intolerance of uncertainty usually demands a high tolerance for risk. If the consequences of inaction are likely to be severe, even though not certain, one should be willing to act even in the face of high uncertainty.

Cairns (1992) notes a vast difference between the response to perceived personal risk as opposed to risk to ecosystems. Chemicals may kill a few people and take a few years off the lives of others, but the collapse of Earth's life support systems may kill billions, or at best, cause billions to suffer. In an interesting article in *Science* (January 19, 1990), asbestos abatement costs versus the National Institutes of Health (NIH) budget were covered, as well as asbestos risks in the perspective of other hazards, such as long-term smoking, home accidents, motor vehicle accidents, high school football, and the like. For some reason, a chemophobia exists for both certain chemicals and the perceived risks from them, however improbable according to the evidence. These fears are greater than the much more probable, though not certain, risks from the collapse of Earth's life support systems. Human society will not be able to address crucial societal problems until it comes to grips with the uncertainty/risk paradox and realizes that uncertainty does not permit it to evade the laws of nature (nor do economic and social needs).

Rights versus Responsibilities

In order to avoid the suffering predicted by Malthus, human society would either have: (1) to practice mutually agreed coercion to limit population size and utilization of resources to fit the planet's carrying capacity or (2) to depend on an enlightened citizenry with sufficient compassion for future generations and other species to impose these restrictions voluntarily. However, a strong distrust of government and an increasingly vocal, militant stress on perceived individual rights exist at present. In his forthcoming book *You're Driving Me Crazy*, Scott Geller (personal communication) gives much attention to aggressive automobile driving. This situation is just one of many examples of decreased civility and lack of concern for others. To offset this trend, Geller (1994, 1996) espouses an "actively caring model," which stresses the positive benefits of appropriate behavior rather than the dire consequences of inappropriate behavior.

In the United States, and likely in other countries as well, many grandparents are caring for their grandchildren because the grandparents feel more responsibility for these children than the actual parents. Many others of the same age as the grandparents or younger have had adult children return to their home so that these adult children can continue the lifestyle they previously enjoyed, without earning enough money to do so on their own. These adult children feel they have a "right" to these services, whether it means asking someone else to care for children they have produced but are incapable of caring for, or whether it is a lifestyle to which they have become accustomed but which they are incapable of achieving on their own. The reason for introducing these depressing circumstances is to illustrate the point that some people feel an intense responsibility and others are almost polar opposites, despite being members of the same extended family. Given the shocking display of irresponsibility of large segments of society, even when their own offspring or close family members are involved, is it realistic to expect a feeling of responsibility for passing on a habitable planet to future generations? In addition, is it reasonable to expect those so insistent on the exercise of their own perceived "rights" (to the extent that they neglect or ignore the rights of blood relatives) to show restraint that will permit future generations of their own species and other species to survive or, better yet, thrive? Ecologist Kinne (1997) feels that modern societies are preparing the scene for suicide by destroying the basis of life on Earth. Wilson (1993) expresses a similar view in a *New York Times* Sunday magazine supplement.

One wonders how Malthus would analyze the present situation, except that he might state that there is no "right" to survive, either as individuals or societies! The opportunity to survive exists if human society pays careful attention to the biophysical laws of nature. However, this acknowledgment is only the first step. Ehrlich (1997) discusses what professional ecologists should be doing about the world's plunge toward ecocatastrophe. He notes that increasing numbers of ecologists are beginning to understand that the major thrust in saving the world will occur in the realm of the social sciences – especially in ecological economics. This scenario will mean venturing into areas that make most ecologists, and scientists in general, exceedingly uncomfortable. However, Wilson (1998a) believes that now is the time for the "hard" sciences and the social sciences to come together. Not too long ago, an applied ecologist was considered a second-rate citizen by the theoretical ecologists. This hierarchy still exists, and there are vestiges of this relationship remaining to this day.

What in the 1990s Would Surprise Malthus?

Leopold (1966), who effectively expressed the joy of ecology, was acutely aware of its pain, as shown by the statement:

> *One of the penalties of an ecological education is that one lives alone in a world of wounds... An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise.*

Ehrlich (1997) recounts personal observations of wounds developing in healthy ecosystems in numerous and widely scattered portions of the planet. Malthus was primarily concerned with the ability of *Homo sapiens* to produce offspring well beyond the replacement rate, even in his era, and about the limitations of resources, particularly food, on a finite planet. He was not concerned, nor was there then reason to be, about the dramatic assault on the environment that has caused the present problems of biotic impoverishment, fragmentation of habitat, ozone holes, global warming, and loss of topsoil well beyond the replacement rate.

How would Malthus feel about these situations in the bicentennial year of his remarkable article? Clearly, sustainable use of the planet was on his mind but, of course, the current phrase "sustainable development" was not. The following are a few of the issues I think would have startled Malthus if he had available a fast-forward time machine permitting access to 1998.

(1) *Even 200 years later, the basic issue is still being debated – are there too many people with too high expectations for a finite planet?*

Despite extensive analyses of the ethical problems (Hardin, 1972, 1993) and population issues (Ehrlich, 1968; Ehrlich and Ehrlich, 1996; Ehrlich et al., 1995) involved, most people are either unaware of the problem or are in a state of denial (Orr and Ehrenfeld, 1995).

(2) *The degree of isolation still continues in the academic disciplines.*

While scientists are more numerous today than in Malthus' time, they are more isolated from each other and far more specialized. The reductionist approach has certainly accomplished much, but the resulting isolation of the disciplines has resulted in a paucity of synthesis of how the world works.

(3) *A global economy makes resource depletion possible.*

The existence of a global economy makes resource depletion in an area far removed from one's living space quite possible. Thus, Australian forests may supply Japan; the Arabian Peninsula and other areas far distant from the United States supply some of its oil; and many nations deplete ocean resources, which are "common grounds," except, of course, for the areas adjacent to particular nations and claimed by them.

(4) *Some nations have achieved a birth rate below replacement level (e.g., Italy, at 1.35 or so children per woman) and others are still far above replacement rate (e.g., Nigeria).*

Zero population growth is possible, but not universal. I am ambivalent about whether Malthus would be surprised by the legal and illegal immigration into such countries as the United States and Canada. He would probably be surprised that individuals from developing countries could so easily colonize developed countries, given the territoriality of most nations and individuals. For a "nation of immigrants" such as the United States, there is a lack of awareness regarding the effect this will have on long-range demographics (e.g., Lutton and Tanton, 1994), and there is a sympathy for immigrants since American ancestors were in this category.

(5) *Malthus would probably be astonished that, with an environmental crisis unprecedented in human history and a human population far larger than even at the beginning of the century, there is so much "business as usual" in the academic community, which might be expected to address these issues more vigorously.*

Harold Mooney, once President of the Ecological Society of America, is quoted by Ehrlich (1997) as stating (to Ehrlich) that one could read an entire year of the journal *Ecology* and not be made aware that an ecological crisis exists. How can ordinary citizens be expected to believe in an ecological crisis if the ecological journals do not proclaim this continually? In recent years, the Ecological Society of America has begun producing a second journal, *Ecological Applications,* which does indicate the existence of an environmental crisis. Is this enough? If there is, in fact, a severe ecological crisis (and I believe there is), it should be proclaimed in every professional journal of ecology as an indication that ecologists have shifted their priorities. The public perceives academics as studying questions and issues that are important for scholarly reasons, but which may be shockingly irrelevant to "real world problems." If scientists were making everyone aware of the ecological situation, Lubchenco (1997) would not have had to exhort the entire scientific community to mount "a more effective, interdisciplinary ... effort on the environment." Lubchenco asks scientists to redirect their efforts and form a new social contract to this end. Presumably, the effort would include all those who signed the World Scientists' Warning to Humanity (Union of Concerned Scientists, 1992), even though they are not allocating a large amount of their professional time addressing environmental issues, but rather continue in almost complete absorption with their area of specialization. Since over 1600 scientists signed the warning, I am assuming that at least a substantial number of them, arguably even a majority, are still primarily preoccupied with the specialized area of research that resulted in a "world-class" status.

(6) *Companies and, frequently, individuals externalize the costs of doing business and, thus, reap a disproportionate share of benefit, while disseminating the cost throughout society or substantial portions of society.*

Hardin's (1968) classic paper is arguably the most concise and effective examination of this problem of cost shifting. More recently, Hawken (1993), a businessman deeply concerned about environmental problems, described the situation very effectively:

> *The more able a company is to externalize its cost of doing business and to be ruthless in its practices, the greater return on capital it may achieve in the short term. While this is not always the case, it is true often enough to substantiate the point that the growth of money and the enhancement of human welfare are not coincident.*

(7) *Many people still believe that the planet has enough resources to last indefinitely if human ingenuity and technology are coupled with economic development and allowed to proceed unhampered by environmental activists.*

Malthus clearly believed in limits and would almost certainly be appalled by both human society's indifference to limits and, even more troublesome, denial that they exist. Rohe (1997) eloquently reaffirms a finite planet and a world of limits. He admits as unknown how many people the planet can accommodate – but maintains that limits exist. The central hypothesis of the Reverend Malthus was the question "Will human numbers eventually outstrip the carrying capacity of the landmass?" The Carrying Capacity Network (CCN), a non-profit organization in Washington, D.C., defines carrying capacity as "the number of individuals who can be supported without degrading the physical, ecological, cultural, and social environment, i.e., without reducing the ability of the environment to sustain the desired quality of life over the long term." Although phrased somewhat differently, this definition is the goal of sustainable development (e.g., World Commission on Environment and Development, 1987), sustainable use of the planet (e.g., Cairns, 1997b,c), or leaving a habitable planet for future generations. The United States has seen, in just two centuries, the fallacy of maintaining the illusion of unending, inexhaustible resources. Has this obviously naive faith of the frontier society merely been replaced by a faith in unlimited, inexhaustible human creativity and technology, or is there something more?

Orr and Ehrenfeld (1995) believe that willful blindness to the ecological/environmental crisis has reached epidemic proportions. Ehrlich and Ehrlich (1996) observe a betrayal of science and reason and have coined the term "brownlash" to describe the propaganda campaign designed to create skeptics who believe that ecologists (or anyone else) are unnecessarily taking the threat of deteriorating life support systems seriously. Ehrlich (1997) notes a major effort in the United States, both within the government and without, to roll back regulations for environmental protection.

An equally daunting obstacle hinders the attainment of sustainability. Durant and Durant (1968) surmise from their study of history that a large gap in per capita income between the wealthy and the poor always demands a redistribution of wealth, either by revolution or government action. Quite clearly, if mechanisms needed to attain sustainability are perceived as creating more hardship for the poor, who vastly outnumber the wealthy, this faction of society will, at the very least, be hesitant to support sustainable use of the planet because they will not view it as being beneficial to either them or their descendants. Since Malthus was attacked for his views in his lifetime, he probably would not be surprised by the shifting defense tactics designed to avoid admitting there are limits.

Denial of Limits

Malthus would find the denial of limits stronger in 1998 than 200 years ago. The frontiers of the planet are essentially gone – certainly those that would be hospitable to long-term human residence. Population growth on the planet in the last 200 years has followed Malthus' expectations. Almost certainly, the view of Earth from outer space, Sagan's (1994) *Pale Blue Dot,* put an end to the idea of unlimited space and resources for most rational people. True, the oceans are viewed as an unexplored frontier, but they are not as easily colonized by humans as the relatively uninhabited parts of Earth were in Malthus' time. Some also claim that resources are available on the moon, but the difficulties in summer 1997 with the MIR space station indicate that utilizing these resources will not be easy and may not be cost effective. Even if the oceans could be colonized and resources could be obtained from the moon, human capacity for reproduction would still, in a few hundred years at the most, encounter a new set of limits.

In Malthus' time, the ecological collapse of ancient civilizations (e.g., Diamond, 1994, 1997) was not as well known as today. Monitoring of environmental condition, while not all it could be, is enough to provide warnings of serious declines in ecosystem quality. A number of studies have been provided in the literature on resource depletion and overutilization (Postel et al., 1996; Carson, 1962; Hardin, 1968, 1993). Without question, the opportunity to become environmentally literate is far greater than it was in Malthus' time. Despite this, the acknowledgment of limits seems to be no greater.

Wilson (1993) feels that humans are smart enough and have time enough to avoid an environmental catastrophe of civilization-threatening dimensions. However, he acknowledges that the technical problems are sufficiently formidable to require a redirection of much of science and technology, and that the ethical issues are so basic as to force a reconsideration of the human self-image as species. People who write on the environmental crisis, sustainability, and ecological limits must be optimistic about what human society could do, or why bother to publish on this subject? Most, however, are apprehensive about what human society will do. It seems inescapable, given the conditions of poverty and hunger today, that a large part of humanity will suffer even more in the future because of the glacial slowness of social change. The longer the recognition of limits is postponed, the greater the suffering and societal disruption will be.

Ecological restoration partially reverses the damage to a naturalistic assemblage of plants and animals, but it can only occur while the species exist to recolonize the damaged area. Biotic impoverishment is now occurring at a much greater rate than in Malthus' time, and, if it is not now at a crisis level (there is persuasive evidence that it is), it soon will be. The next three to five decades will tell whether restoration ecology is merely a "body and fender shop" that repairs damaged ecosystems at an inadequate rate or whether restoration ecology is one of the keys to sustainable use of the planet.

Waiting Until the Last Day

Hardin (1993) gives a marvelous illustration of exponential growth – starting with a single lily pad of a specific size in a pond of a specific size and a specific rate of increase. When will the pond be half covered with lily pads? This growth will be accomplished on the 29th day, assuming a daily doubling rate. The pond will be fully covered with lily pads on the 30th day, or the next day. The pond's carrying capacity for lily pads, which was only half reached on the 29th day, was fully reached on the 30th day. After the 30th day, half the lily pads produced would suffer seriously because of lack of room, or all the pads would have less surface area to share in collecting photosynthetic energy. These two conditions presumably would result in a declined quality of life for lily pads or, in fact, for the entire plant. Not mentioned in Hardin's example, but quite obvious to an ecologist with his background, is the detrimental effect upon other members of the pond's community of having even half the pond covered with lily pads. Photosynthetic organisms would be deprived of sunlight; organisms eating these would be deprived of nourishment; the pond would be deprived of oxygen produced by organisms such as algae; and nutrient and energy transfer systems would be dramatically altered.

Malthus identified the problem of carrying capacity over 200 years ago when Earth was far short of reaching these limits. Limits have been expanded by increasing the amount of agricultural land (thus depriving other species of their habitat) and by technological advances, but these increases do not mean that limits have disappeared, but only that their effects have been postponed. When a population with exponential growth crosses a threshold, it usually does so with amazing rapidity, as in the lily pad example.

Why Malthus' Message is Still Not Received Loud and Clear

Either empirical evidence, plausible speculation about how the situation can be relieved, statements that if the free market economy were given a chance the problem would not exist, or outright denial that there is a problem exist on every issue that appears to illustrate the existence of limits. A selection of illustrative examples follow.

(1) *The world is running out of food*.

Brown (1995) has an extensive and relatively recent analysis of the food situation in China. In contrast, Prosterman et al. (1996), in *Scientific American*, asserted that China's food problems could be met if three conditions were implemented. One of these concerned agricultural development of "waste" land. Presumably, this land is now in ecosystems undeveloped by humans, but which furnish services benefitting humans. Such a condition is a short-term, unsustainable solution to a long-range problem. The surprising consequences of exponential growth are not the sole province of population biologists, but results of unbridled growth have been in folktales and the like for centuries. Meadows et al. (1993) use an old Persian legend about an astute courtier who gave a splendid chessboard to his king. The courtier suggested that in exchange the king give him one grain of rice for the first square on the board, two grains for the second square, four grains for the third, etc. Marveling at his good fortune, the king agreed and ordered rice to be brought from the storehouses. The fourth square on the chessboard required 8 grains, the tenth took 512 grains, the fifteenth 16,384, and the twenty-first square gave the courtier more than a million grains of rice. By the time the counting had reached the fortieth square, a million's million grains of rice had to be piled up. The payment could never have continued to the sixty-fourth square because it would have taken more rice than was then available. Given the ubiquity of both folktales and peer-reviewed scientific literature, it is difficult to understand how oblivious policymakers remain regarding the consequences of exponential growth.

(2) *Homo sapiens is not exempt from the iron biophysical laws of nature that limit other species*.

An obituary of recently-deceased optimistic economist Julian Simon (Anon., 1998) notes that he "challenged the popular (and still widely held) view that there were limits to growth; in particular that the earth's natural resources were becoming so scarce that they would become even costlier." Simon (Myers and Simon, 1994) also stated that "we now have in our hands the technology to feed, clothe, and supply energy for the next seven billion years." If human ingenuity, creativity, and technology free human society from limiting factors that affect other species, clearly Malthus was wrong. It seems premature to have so much faith in human ingenuity while "poverty, misery, vice, selfishness, famine, disease, and war" (Malthus as quoted by Himmelfarb, 1998) are in the news frequently. To this list, one might add: terrorism, AIDS, worldwide economic problems, climate change, biological/chemical warfare agents, and aggressive drivers.

(3) *Human society is in ecological denial*.

Orr and Ehrenfeld (1995) believe that human society is in a state of denial about ecological problems. Since denial exists in many forms these days, one more addition to the list is not surprising.

(4) *Society's approach to multidimensional problems is compartmentalized and fragmented*.

Leopold (1990) notes that each government agency often acts as if it were "the only flower facing the sun." Regrettably, the same accusation all too often applies to academic disciplines (e.g. Cairns, 1993). Even a holistic problem such as sustainable use of the planet is fragmented into sustainable-energy, -transportation, -agriculture, and the like. Wilson's (1998a, in press) consilience (literally "leaping together") of a presently fragmented system provides persuasive grounds for optimism.

Perceived Societal versus Personal Risk

A number of possible explanations could be given for the general views on societal risk. The first is the fatalistic view that could be expressed: if one is sailing on the Titanic, one might as well go first class.

A second view is that "everyone else is doing it," why should I suffer? This perspective is especially true in societies where irresponsible, but sexually active, persons have children without being able to support them. Society is then placed in the regrettable position of protecting the child from suffering. In some areas, competition for control is leading groups to increase their own population in the hope of freeing themselves from domination by some other cultural or ethnic group.

The third view relates to the use of credit cards – gratification is immediate and consequences are postponed, although not for long. A number of other views of societal risk are possible, but these three are highly probable and not mutually exclusive.

The matter becomes more puzzling where individual risk is concerned. Geographer Charles M. Good (personal communication) is studying the incidence of sexually transmitted diseases (STDs) in Africa and in Southeast Asia. He finds that even when the risks are apparent, risky behavior continues. Many inhabitants of more developed countries continue to smoke cigarettes despite mounting evidence about the consequences. If individuals ignore warnings about personal risk, are they likely to pay much attention to Malthus?

Virtual Reality Graveyards

On December 22, 1997, the English language broadcast from Radio Japan carried a fascinating news item that space for burial could be acquired on the Internet. The Japanese respect and honor their ancestors and their final resting place, but burial sites in Japan are becoming extraordinarily expensive and, even then, difficult to acquire because of the aging population, the large size of Japan's population, and shortage of space. Apparently, the Internet offers the ability to call up an image of the gravestone and grave site, together with a biographical sketch of the ancestor. One can also have one's own Internet tombstone, apparently the names of the living color-coded differently from the names of the deceased. Additionally, the caring rituals, such as cleaning, leaving flowers, and other marks of respect, could be carried out on the Internet as in traditional graveyards on traditional gravestones. Furthermore, the burial site could be visited at any time, regardless of time of day, inclement weather, or amount of time available. One wonders whether the computer screen can produce the same aura evoked by real tombs and real graveyards and whether the location in one's home will have the same effect as a particular geographic location with real burial sites. Japan and other Asian countries have already led the way in producing virtual reality pets, and one wonders whether the relationship of humans with nature will suffer the same transformation. The difference, however, is that human society may revere and respect its ancestors, may cherish its pets, but it is dependent on natural systems and their services. A computer screen may substitute, to some degree, in the emotional part of the relationship (although even this is questionable), but not in terms of the biophysical services provided. If human society cannot provide space for its deceased ancestors, held in much respect, is it likely that space for living individuals of other species will get serious attention if human society does not admit an interdependent relationship with these other species?

Economists

As a regular viewer of Reukyser's *Wall Street Week in Review* on public television, I am frequently reminded that economists are often far off target; however, as Reukyser himself notes, this shortcoming does not seem to diminish their following appreciably. A healthy economy is necessary, and the general public seems to accept this claim universally. However, comparable statements about the well-being of ecosystems and their influence on human society are rarely made and generally not believed by the general public. Both economics and ecology have their share of individuals who, according to the ancient Chinese saying, "watch the sky from the bottom of the well" – referring to those having a very limited outlook or who are narrow-minded. As Wilson (1998b) notes, scientists often learn what they need to know in their specialized area, often remaining poorly informed about the rest of the system they inhabit. Doubtless, every profession has its share of highly specialized persons who are remarkably well informed about a very narrow area. Their research is often unintelligible to people in their own general field, except for a few kindred spirits. Most professionals are extremely reluctant to venture outside their area of high competence, either because the other areas are, in their view, less important or because they fear being less well informed and, thus, vulnerable to criticism. Certainly, making connections with other parts of their profession, other parts of science, and even, for some, with the rest of the world they live in is considered professionally risky and, therefore, unacceptable.

Ecologists

Although the field of ecology as a formally recognized entity did not exist in Malthus' time, his writings have enormous ecological implications. Since ecology is a scientific field, it seems appropriate to examine Malthus' model with a scientific perspective – namely, an organized systematic enterprise that gathers knowledge about the world and condenses the knowledge into testable hypotheses and principles. Wilson (1998b) concisely states that some diagnostic features of science are useful in distinguishing it from pseudoscience.

(1) *Repeatability*.

Numerous instances have been documented of population crashes (resulting from exceeding carrying capacity) for other species. Diamond (1994) and Ehrlich and Ehrlich (1990) cite cases for human society also. Of course, at the global level, repeatability is out of the question – no control series of planets is available for testing, as would be necessary for many scientific experiments. However, microcosms and mesocosms can be used for some experiments. Island biography is especially instructive, which is why Diamond's writings are so persuasive.

(2) *Economy*.

Certainly Malthus attempted to synthesize information into a form that is both simple and aesthetically most pleasing by using mathematics that could be followed by almost any literate person. Although his concept did not take into account the mechanization of agriculture and other components of the agricultural revolution, it was not invalidated by them.

(3) *Mensuration*.

Mensuration is the feasibility of being properly measured, using universally accepted scales. Since Malthus' time, particularly in the last century, the ability to study human population dynamics has improved enormously, and the numbers are rarely disputed. The consequences of the rate of growth, rather than the actual numbers themselves, remain in dispute. Sewage treatment systems have become overloaded, water supply is short, schools are overcrowded, transportation systems are clogged, and cost of land for housing in populous areas has risen. The only way to ignore such consequences is to assert that the carrying capacity for humans is unlimited, even though biophysical laws show that limits exist for other species.

(4) *Heuristics.*

Heuristics is the ability to stimulate additional research often in unpredictable new directions that, in turn, provides additional tests of the original hypothesis. The quest for goals and conditions that will facilitate sustainable use of the planet (which has received increased attention over the last decade) is one such new "direction." However, the effort is in such early developmental stages that it lacks substantive implementation for providing evidence of robust analysis because of too many fragmented viewpoints (e.g., discrete initiatives for sustainable energy, sustainable agriculture, sustainable transportation, sustainable cities, and the like).

(5) *Consilience*.

The explanations of different phenomena most likely to survive are those that can be connected and proved consistent with one another. This area is the least satisfactory and, arguably, the most crucial feature. Regrettably, as temporal and spatial scales and the level of complexity increase, the degree of uncertainty also increases appreciably. This scenario leads to challenges of experimental error, faulty science, political views masquerading as science, and the like. The fact that uncertainty exists about the consequences of particular courses of action does not mean that human society is free of risks until the uncertainties are diminished! Waiting for reduction in uncertainty could produce risks that, with 20/20 hindsight, would be clearly unacceptable. This area is probably the core of the population problem resolution. Any one who is intolerant of uncertainty must necessarily have a high tolerance for risk because the two are connected. Those who dispute Malthus focus on the uncertainty and minimize the risk. However, ignoring risk does not eliminate it, as human society has demonstrated over and over again. Perhaps this acknowledgment is why the film *Titanic* is so popular – it shows clearly the consequences of denial of risk.

Conclusion

If humans are not exempt from the biophysical laws that limit other species, and they seriously impair the planet's ecological life support system beyond repair, then Malthus will be proven right at great cost to human society. Ecosystems are difficult to restore when many of the species that inhabited them have been driven to extinction. Even if Malthus is proven wrong, staying within ecologically sound limits will lead to the kind of life-quality life that most people want. The rise in eco-tourism and other related activities (e.g., bird watching) indicate that many humans derive great satisfaction from a close relationship with natural systems. At the very least, human society should wait for more persuasive evidence that it is exempt from natural laws before committing itself irreversibly acting on the belief that it is so exempt. This stance requires paying more than token attention to limits of ecosystem abuse on a finite planet.

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Article 8

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The Zen of Sustainable Use of the Planet: Steps on the Path to Enlightenment

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At its best, the quest for sustainable use of the planet aspires to a harmonious relationship between human society and natural systems. At its worst, sustainable use is an assertion that human ingenuity and technology can free humankind from biophysical constraints and its dependence upon ecological life support systems. Although science guided by reason is essential to reaching informed decisions on sustainability, it must be accompanied by a new ethos, or set of guiding beliefs. Science can never reduce uncertainty on the complex multivariate systems called ecosystems to the degree that explicit legislation would be possible to protect the components on a species by species, habitat by habitat, ecosystem by ecosystem, and landscape by landscape basis without going to ridiculous extremes. This circumstance does not, however, invalidate attempting to define conditions appropriate to achieving sustainability. Some consensus must be reached on the broad, general conditions governing human society's relationship to the environment. A shared ethos would promote sustainable use and reduce the possibility of harsh penalties exacted upon species that do not respond adequately to alteration in their environment.

> *For a successful technology,*
> *reality must take precedence over public relations,*
> *for Nature cannot be fooled.*
>
> Feynman (1988)

INTRODUCTION

Sustainable use of the planet will require that the two components of human society's life support system – technological and ecological – be in balance (Cairns, 1996). Holmberg et al. (1996) state the situation superbly: "A long-term sustainable society must have stable physical relations with the ecosphere. This implies sustainable materials exchange between the society and the ecosphere as well as limitations on society's manipulation of nature." At present, persuasive signs indicate that the technological system is damaging the integrity of the ecological life support system (Cairns, 1997). By monitoring the condition or health of both systems, a benign coevolution of human society and natural systems would be possible (Cairns, 1994; 1995). However, sustainable use of the planet will require environmental management on unprecedented temporal and spatial scales.

The attainment of sustainability faces considerable obstacles. A societal distrust of scientific evidence has arisen that ranges from a belief that science does not differ from other ways of knowing to a total misunderstanding of how science works. Also, one common belief is that quality of life is more closely associated with consumption or affluence than with environmental quality, and, consequently, that a maintenance of affluence is to be preferred over the maintenance of natural systems. This false choice arises from human society's failure to recognize its dependence on natural systems for essential ecological services, such as maintenance of breathable air, drinkable water, the capture of energy from sunlight, and the provision of arable soils (e.g., Daily, 1997).

Possibly, the same human ingenuity that people have relied on to solve local resource limitations could also be used to develop an environmental ethos that will enable humans to conserve the ecological capital (old growth forests, species diversity, topsoil, fossil water, and the like) upon which they now depend. Humankind has survived thus far by meeting short-term emergencies as they occurred. However, humans supposedly can be distinguished from other species by their awareness of the transience of individual lives and their own mortality. Extending this awareness to the possibility of human extinction might be enlightening.

Wilson (1993) asks "Is humanity suicidal?":

> The human species is, in a word, an environmental hazard. It is possible that intelligence in the wrong kind of species was foreordained to be a fatal combination for the biosphere. Perhaps a law of evolution is that intelligence usually extinguishes itself.

If human society destroys, by its own actions, the living components of Earth that maintain an environmental state favorable to human survival, human society hastens its own extinction. Protection of these ecological services extends the time that the human species can survive on Earth. By regulating the use of ecosystem services to a rate that does not destroy the ability of natural systems to produce them, more humans will live better lives over time. Towards this end, a number of steps can be undertaken.

STEP 1: DEFINE TERMS AND BE INTOLERANT OF PURPOSEFUL OBFUSCATION

Terminology surrounding sustainability should be consistent. Not surprisingly, some people interpret the goal of sustainable development as sustaining the current rate of growth (meaning more or bigger). This interpretation conflicts with the definition of *sustainable development* given by The World Commission on Environment and Development of the United Nations (1987): "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition clearly discourages the sacrifice of natural systems, which have developed over centuries, for short-term perceptions of economic gain. Another United Nations Commission (UNESCO-UNEP, 1996) has attempted to further reduce the impression that development means growth in quantity rather than growth in quality by stating:

> Economic growth – until recently synonymous with development – was once presented as the panacea to the ills of humanity: from poverty and disease to over-population and environmental degradation. Even today there are those who firmly believe that it is the surest cure for ailing humanity.

A plea for consistency in terminology is the result of frustration with the staggering array of definitions used by governmental agencies and those groups hoping to influence them. In many cases, a cynical person must assume that choices of terms were based on a desire to obscure rather than enlighten.

While one's instinct is to turn to the educational system to correct this confusion, Barzun (1986) notes that often the damage does not come from the illiterate and ignorant, but rather from the educated and pretentious. His splendid book, which has insightful comments on errors and confusions, points out the hidden emotions and social attitudes that lead to jargon, pedantry, and "highfalutin" terminology. Diamond (1997) furnishes an example from a major scientific journal:

> The table of contents gives the title: `Activation of SAPK/JNK by TNF Receptor 1 Through a Noncytotoxic TRAF2-Dependent Pathway.' In that entire title the word noncytotoxic is my sole clue as to the subject of the article. ...Since I have been a professional biologist for 39 years and my research fields include cell biology, I am much more likely to be the article's intended reader than most other scientists. ...I went on to read the rest of the short report, but in the end I still didn't know what it was about.

Fragmentation of academic specialization and identity politics also obfuscate the debate on sustainability. As Gordon (1997) notes, identity politics (emphasis on ethnicity, gender, and other attributes of personal identity) is increasing the professional fragmentation caused by academic specialization. Although Gordon is focusing on history, similar transformation is occurring in other disciplines as well. This fragmentation also appears in governmental organizations which, as Leopold (1990) notes, often act "as if each were the only flower facing the sun." Of course, formidable obstacles inhibit transcending disciplinary boundaries (e.g., Cairns, 1993). Increasingly, societies throughout the planet are fragmenting into special ethnic, interest, or other groups. Responsibility for the "common ground" – air, water, and land – suffers when each group is fighting for highly focused self-interests.

I have not successfully resolved this problem of misleading terms even on a personal level – when writing about sustainability, I have been repeatedly told by reviewers to use the term *sustainable development* rather than my preference for the terms *sustainable use* or *sustainability*. One can attempt to diminish the damage only by stating as clearly as possible exactly what one means by sustainable development, usually using such descriptions as "leaving a habitable planet for our children."

This argument about terms is not trivial. Orr and Ehrenfeld (1995) believe that human society is in a state of denial about its ecological situation and that the deliberate choice of words that enables it to avoid confronting the problem directly is part of this mind-set. I have been told that some federal agencies with environmental responsibilities go so far as to prohibit the use of the term "carrying capacity," – a fairly common and generally accepted ecological term, but one which is key to the debate about sustainability. The policymakers are not prepared to refute assertions that infinite expansion is possible on a finite planet.

Economist Kenneth Boulding (1966), who was one of the first to use the term *spaceship Earth*, once stated, "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist." However, his is still a minority view, even though it is shared by the officers of the Royal Society of London and the U.S. National Academy of Sciences (1992) as well as the over 1600 scientists and Nobel laureates who signed the Union of Concerned Scientists Warning (1992). In contrast, Simon (1994) states, "We now have in our hands ... the technology to feed, clothe, and supply energy to an every growing population for the next 7 billion years." Leakey and Lewin (1995) ask: What are the human and ecological costs of Simon being wrong?

For some reason, individuals have no trouble recognizing limits for elevators, the number of people who can comfortably sit in a car, or the ideal number of astronauts or cosmonauts in a space capsule, but they discard normal limitations when it comes to their planet. Is this because the consequences of inappropriate behavior are not likely to occur immediately? Alternatively, is there a failure to recognize that the space a human occupies is not the space required to support its lifestyle, particularly if the lifestyle is as resource intensive as in the United States and other developed countries? Finally, the possibility at least exists that human society realizes that growth limits exist, but it remains in a state of denial.

Developing robust policies on sustainability requires a free and open discussion of all relevant issues, not an attempt to censor terminology or avoid contentious subjects. The possibility that sustainability will require changes in societal and individual behavior should not elicit avoidance behavior where language is used as a barrier, rather than a means, to understanding.

STEP 2: REFOCUS THE DEBATE ABOUT SUSTAINABILITY

How can questions about the existence of ultimate limits to growth on a finite planet be anything other than frivolous? Given the fixed nature of inputs, growth has limits. Human society should acknowledge both ultimate biophysical limits to human actions and, in the same breath, acknowledge powerful cultural and technological modifications to ultimate carrying capacity. So while debates about the existence of limits are frivolous, debates about where these limits are and how they can be and should be influenced culturally and technologically are not.

Has human society already exceeded its carrying capacity? The debate continues as a billion or more people go to bed hungry daily. Further, another billion people are not living a lifestyle that would be acceptable to most Americans. Attempts to stabilize the world population to reduce environmental impact have met with fierce resistance. Although some countries have a birth rate below estimated replacement levels, immigration cancels out these demographic shifts in reproductive behavior (Hardin, 1995). Moreover, the possibility of moving undercuts the incentive to live sustainably within the local environment. Larger family size or continued high fertility is a predictable result of ecological release (Abernethy, 1993; 1996).

Technology has repeatedly raised local carrying capacity through provision of greater and more reliable supplies of such basic environmental services as potable water and food. While technology is capable of raising human carrying capacity per unit area to the global level, this advancement has not occurred. Political constraints mean that food in one location does not prevent starvation in another. Moreover, relocation of foodstuffs might not be advisable because of the threat of shifting responsibility to an anonymous, distant provider. Regrettably, as the tragedy of the commons shows (Hardin, 1968), common resources are not always equitably shared.

Additionally, in focusing on the most pressing demands such as food, technology often sacrifices other ecological services essential to human quality of life. The introduction of the potato in Ireland certainly raised the carrying capacity in the short term. However, this situation sacrificed the biological diversity that buffers ecosystems from expected periodic disease outbreaks and 2 million Irish died of starvation. Certainly, more technology was developed to address the problem, but a continued pattern of disaster and reactive development of technology is unthinkable. Also, the closer to the limits that human society operates, the more unpleasant surprises it can expect.

Proactive responses require both protection of all ecological services and the anticipatory development of sustainable technologies.

Cultural practices, especially affluence, also clearly affect carrying capacity. The potential impact of cultural practices on carrying capacity is often illustrated with an example about food pyramids. The food pyramids of terrestrial and marine ecosystems differ. On land, only 10% of the calories contained in food end up as growth in the animal that eats it. This means that, each time the energy captured from the sun by plants is transferred from one animal to the next, 90% of the energy is lost. In the marine ecosystem, efficiency seems to be better; about 15%. For that reason, seven levels can be maintained. Planktonic algae are at the bottom. Codfish are at the fifth level, seals at the sixth, and polar bears at the seventh. Some idea of the magnitude of losses involved as calories are passed up this long chain (instead of obtained directly from plants) can be gathered from this calculation: If the entire world's grain crop (corn, wheat, rice, etc.) were fed into the marine pyramid, it would support a standing population of no more than 100,000 polar bears. The planet could support more people at this level of grain consumption only because humans are largely herbivores (Bruce Wallace, personal communication). However, populations often shift to a meat or mixed diet as soon as this is affordable; China and other Asian countries have done this.

Living lower on the food chain decreases the number of acres required to feed the human population. In turn, reduced agricultural pressures on land would allow more space for other species. Reduction of agricultural acres would, simultaneously, decrease the overall use of pesticides and reduce the amount of water used for irrigation, thereby permitting a more normal hydrologic cycle. In addition, if unneeded farmland were revegetated appropriately and permanently, the amount of particulate matter deposited in rivers, reservoirs, lakes, and streams would be reduced.

An economist colleague once stated: "We do not want to make the rich poor; on the contrary, we want to make the poor rich." However, the attrition rate from plant to animal food sets a clear biophysical limit to how many people can be supported on a meat diet – at most, 15% of the number that can be supported on a plant diet.

STEP 3: REEXAMINE THE CULTURAL BIASES AGAINST SUSTAINABILITY

Redefining "The Good Life" Independent of Advertisers

Societies in which prestige or status continue to be determined by consumption of energy and material goods will be less amenable to sustainable practices and may be less satisfied as well. In the documentary "Affluenza," John De Graaf and Vivia Boe define affluenza as "an unhappy condition of overload, debt, anxiety, and waste resulting from the dogged pursuit of more" (as quoted by Walljasper, 1997). De Graaf and Boe have a serious message for the individual – voluntary simplicity in living will not only help improve the possibility of living sustainably on the planet, but it will also improve personal well-being by eliminating the side effects of overspending: headaches, low back pain, heart palpitations, unexplained aches and pains, hyperacidity, depression, anxiety, and sleeplessness.

An additional restraint on sustainability comes from an excessive individualism when there is concomitant deemphasis on community. In stable, non-growing communities, community spirit is immense. The North American Plains Indians were intermittently nomadic and could not transport huge amounts of material goods per capita. Prestige and status in that society was focused on the "coup stick" on which one could make a notch for each act that was thought to contribute to the well-being and success of the tribe. Today's American society might not approve of all of the criteria used then, but the coup stick did focus on the integrity and well-being of the group rather than on the individual whose actions were, nevertheless, honored by the tribe. Actions enhancing general well-being determined individual status. However, in modern American society, the emphasis is much more likely to be on individual rights than on action for the common good. This situation is another problem of misuse of the commons because of no control over community membership or growth.

A Sense of Ecological Place

People in intimate contact with the natural world develop a sense of ecological place. And, when people develop a sense of ecological place, then responsibility, respect, and esteem for natural systems and the species that inhabit them follow. When I served as chair of the National Research Council (1992) committee on ecological restoration, the committee visited a number of restored or partially restored sites. One of the most impressive benefits of serving on this committee was to encounter firsthand the justifiable pride and satisfaction of the people in the results of the ecological restorations being undertaken. These restored areas were an ecological place of which people could be proud. An intimate relationship with ecosystems is fundamental. I can also feel enormous satisfaction in Janzen's (1988) restoration of the Guanacaste dry forest in Costa Rica, though my sense of accomplishment will be orders of magnitude stronger if I am personally involved in the restoration effort and have witnessed the ecological improvements that occur. Personal involvement undoubtedly gives a strong sense of esteem for natural systems.

Both urbanization and the unprecedented growth and mobility of much of human society today present formidable barriers to the development of a sense of ecological place. It is not unusual for a person in the United States to have lived in eight or ten biologically distinct ecoregions during the course of a lifetime. Furthermore, a country such as the United States, with large numbers of immigrants from a variety of different cultures, has the difficulty of establishing a sense of community and shared goals. Pride in diversity must be complemented by a sense of unity in preserving common goods such a ecological services from water, soil, air, and other species.

Developing an Ethos

The venerated Athenian leader Pericles focused on an *ethos* or set of guiding beliefs. He noted that the safeguard of freedom is the fact that citizens obey the customs and the laws "whether they are actually on the statute book, or belong to that code which, though unwritten, yet cannot be broken without acknowledged disgrace" (as quoted in Crawley, 1951 and Finley 1951a,b). Underwriting these guiding beliefs are assumptions of *fairness*, *equity*, and the *common good* (emphasis mine). Components of an environmental ethos include valuing other species and constraining individual entitlements or rights by concern for the common good.

In current American culture, people have renewed the search for a purpose larger than themselves. The local National Public Radio station devoted (on August 8, 1997) an entire hour to the reinvigorated search for spirituality, not only in this country, but globally. Ironically, the next day, there was a news item about Gettysburg National Historic Park. Developers wish to erect a shopping mall on the site just outside park boundaries in an area that was dedicated to treating the wounded from both sides of this intense conflict of the Civil War. Along with the standard justifications for development (jobs, stimulation of the economy, progress) was the incredible claim that construction of a shopping mall and its satellite business would honor the dead! Such a bizarre interpretation of the word *honor* seems to confirm that American society has lost its sense of the sacred.

However, some people still hold natural systems sacred and respect them more than some of the economic values with which the present culture has become obsessed (e.g., Pooley, 1997). The collective efforts of people interested in protecting ecosystems make me feel optimistic about what we can do to develop sustainable use of the planet, although I am not yet optimistic about what we will do.

STEP 4: VISUALIZE SUSTAINABILITY

Industrial Wastes Must Be Made Valuable to Ecosystems

As Hawken (1993) notes, while nature's wastes are used by something (e.g., dung by the African dung beetle), business wastes have no value to other species or organisms and may be fatal to them. However, industrial wastes can be modified to be more amenable to cycling. The idea of industrial ecology or industrial symbiosis is to model industrial systems after the cycles apparent in natural systems. Materials are not extracted, produced, used, and thrown away. Instead, they are cycled. The example often cited is the Danish port city of Kalundborg (Hawken 1993, Tibbs 1992, Charles 1997). In this small city, the industries act as if they are a series or a web linking the "metabolism" of one company with that of the others. For example, the "waste" energy in the form of spent steam from a power plant is used to heat the town, to warm fermentation vats for a pharmaceutical company, and to warm water for aquaculture. The spent steam does not become an environmentally harmful waste discharge.

One of the industrial executives emphasized an important feature of their work: this design was done in a relatively small place with sizable industries where the executives and managers could easily get to know each other and develop a working plan (Hawken, 1993). Discussion on the radio report (Charles, 1997) clearly noted that this extraordinarily successful model, which has been operational for a significant number of years, has not been copied elsewhere because of the lack of a comparable sense of connectedness or community. In fact, the discussion noted that the U.S. Environmental Protection Agency had tried to establish similar industrial metabolic exchanges, thus far without success. As Tibbs (1992) notes, the cooperative synergy at Kalundborg was not specifically required by regulation and all exchanges, trades, and interactions were negotiated independently. Furthermore, in some cases, price was a factor but, in others, it was the installation of an infrastructure as a result of what might be regarded as an economic subsidy by the unit generating the waste.

I believe the Natural Step program (Robèrt et al., undated) is capable of producing results anywhere in the world similar to those in Kalundborg. Two papers (Holmberg and Robèrt, submitted; Holmberg et al., 1996) provide much useful detail on the rationale behind the system conditions and the socioeconomic principles for a sustainable society. (Information may be obtained from the Natural Step Foundation, Slottsbacken 6,111 30 Stockholm, Sweden.)

Fifty years of experience with environmental problems persuades me that successful solutions are likely to be local. Much of the above discussion also suggests this. Serving on the National Research Council (1992) Committee that produced a volume on restoring aquatic ecosystems, which includes a large number of case histories, very firmly reinforced my belief in local solutions. On the other hand, I am equally persuaded that a global consensus on a set of guiding beliefs must be developed for sustainable use of the planet because many of the problems are not contained within political boundaries or even modest ecological boundaries. Cairns (1997) outlines some of the goals and conditions upon which it seems essential to reach a consensus. One of the strengths of the Natural Step Program is the degree to which a consensus has been achieved in Sweden between industry, environmental action groups, political groups, and the like. Hawken (1993), Tibbs (1992), and Cairns (1997) suggest some ways in which human society might pay for ecosystem services. All of the suggestions suffer from the need to persuade human society to pay for what has, up to now, been regarded as "free goods," i.e., natural services that the present economic system essentially ignores (e.g., Costanza et al., 1997).

Reuse Must Be as Important as Assembly in Design of Products

Hawken (1993) notes the success of the German government in placing the problem of package waste back on the creators of that packaging. Given a choice of meeting a goal of 80% recycling or a 30-cent surtax on all packages, companies joined together to form a private corporation that is soon expected to serve 90% of the German market.

Disassembly must include not only how things will be taken apart, but what new products can be made from the disassembled components. BMW has built a pilot disassembly plant to recycle its older cars. Hitachi has planned for the disassembly of refrigerators so that re-incorporation into other industrial products will be facilitated, and it also plans on reusing plastics a substantial number of times. Hawken (1993) suggests that an ecologically sound society will come from the grassroots up, not from the top down:

> Sustainability means that your service or product does not compete in the marketplace in terms of its superior image, power, speed, packaging, etc. Instead, your business must deliver clothing, objects, food, or services to the customer in a way that reduces consumption, energy use, distribution cost, economic concentration, soil erosion, atmospheric pollution, and other forms of environmental damage.

Clearly, such steps will decrease energy costs, the amount of solid waste in landfills, and extraction of materials from natural systems. The crucial question is whether human society will be guided by the economies of nature, which does not make its resources readily available on demand to most species. The economics of nature are also characterized by systematic recycling and reuse and maintaining an inventory of ecological capital.

WAR AND SUSTAINABILITY

Clearly, the prospects for sustainable use of the planet are not enhanced by war, which is a tremendous drain on resources and usually results in damaged infrastructures and communication systems and large numbers of human refugees. The Tofflers (1993) note that, while all countries seek to protect their citizens and need energy, food, capital, and access to sea and air transport for this purpose, their needs diverge beyond that. As a consequence, radically different conceptions of national interests are devised.

One focus of the Tofflers is the clash between cultures – the first wave is agarian, the second wave is industrial, and the third wave is information and innovation. Culture clashes between the simultaneously existing three cultural waves are as important in sustainable use of the planet as they are in war. Somehow the clash between the different cultures must be resolved for sustainability. The solution of raising all developing countries to present-day developed country materialism and energy use is also clearly not the solution since the planet's ecological systems would not take this.

CONCLUSIONS

The beginning of the next century is a period during which society will almost certainly determine whether current behaviors are ecologically sound and whether they will enable humans to avoid constraints on their species that apply to the other 30 million or more species on the planet. Almost certainly, the social impetus towards sustainability will be the result of the desire to prevent the chaos that would result if human ingenuity and technology are unable to keep up with simultaneous population growth and destruction of ecological capital. There is no robust evidence that human ingenuity and technology can, in the next century, replace billions of years of ecological evolution with a superior system of human design. On the contrary, experiences such as those in Biosphere II (Avise, 1994) point out that human engineering is not yet ready to provide the services that natural systems now provide. On the other hand, much can be done with present technology which, coupled with the acceptance of a new paradigm, might well make sustainable use of the planet more probable.

The quest for sustainable use of the planet is based on acceptance of a world of limits. This is more easily appreciated in local, known environments, which is another reason that solutions must be local to be effective. Present knowledge does not yet permit the estimation of a precise level of people and affluence that can be maintained without compromising the ability of future generations to lead a quality life. However, the evidence for limits is persuasive. Should we stake our descendant's future on the denial of the existence of limits by persons with far less evidence to support their beliefs? Decades ago, this denial might have been attributed to indifference. But, is there such a thing as aggressive indifference? Now, those who call attention to ecological destruction, pollution, population problems, and the like are vigorously attacked. Science itself is being disparaged (Ehrlich & Ehrlich, 1996). However, there is hope that the human species will cherish its planet and try to keep it habitable for future generations of all species. The behavioral and social changes to do this may be traumatic, but they will be less than the aggregate suffering and loss if they are not done. This type of thinking is the essence of the quest for sustainability.

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Article 9

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Estimating the Risks Associated with Implementing Goals and Conditions for Global Sustainability

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Key words: sustainability, risk analysis, sustainable development, sustainable use

SUMMARY
For those persuaded that present societal behaviour and individual behaviour are unsustainable, the risks of continuing the present course of action seem loud and clear. However, any new undertaking has uncertainties, which includes hidden risks as well as the risks associated with any major paradigm shift as yet untried. This paper provides a preliminary examination of some of the risks and focuses on the need of examining sustainable use of the planet more carefully in terms of risks and uncertainty of outcomes. A shift to sustainability will be greatly improved by an examination of the risks associated with any paradigm shift, since no undertaking has zero risk.

SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT – WHAT ARE THEY?
Sustainability and sustainable development are topics of great interest and considerable discussion among politicians, business leaders, policymakers, scientists, and economists, as well as the general public. However, the two terms are not necessarily synonymous. The term *sustainable development*, first used in the 1980s by the United Nations (UN) World Commission on Environment and Development (WCED, 1987), has been defined by Weston (1995a) as ‘process of change that meets the needs of the present without compromising the ability of future generations to meet their own needs’. No generalized agreement appears to exist on the definition of ‘without compromising’. Cairns (1997a) argues that society as a whole believes that sustainable development can be accomplished with only minor modifications to present lifestyles and interrelationships with the environment. Cairns (1996) also describes how the term ‘development’ has negative connotations for the lay public, and he suggests alternative terminology. Raven *et al*. (1998) define *sustainability* as ‘the ability of the environment to function indefinitely without going into a decline from the overuse of natural systems that maintain life’. However, Costanza *et al*. (1997) believe that sustainability can only be achieved in a finite time span; this concept is reinforced by Cairns (1997b), who submits that sustainability for such finite periods will require monitoring to confirm that prescribed conditions are being attained and to validate predictions or models. Use of the term *sustainability* or the term *sustainable use of the planet* is preferable to the term *sustainable development*.

Weston (1995a) lists several factors that have driven the call for sustainable use of the planet, including increasing population densities, increasing rates of per capita resource utilization, overharvesting of renewable resources and exhaustion of nonrenewable resources, species extinction, environmental quality degradation, and increased disparity in living standards. All these factors place additional pressures on ecosystem services.

ECOSYSTEM SERVICES AND THEIR ECONOMIC RELATIONSHIP TO SUSTAINABILITY

Ecosystem services encompass a diverse and broad set of resources that are provided from biotic and abiotic sources. Such services, summarized by Westman (1978), Daily (1997), and Cairns (1997a,c), may include (but are most definitely not limited to) fisheries, forests, photosynthetic trapping of energy, decomposition of organic matter, biogeochemical cycling, maintenance of the oxygen-carbon dioxide gas balance, crop pollination, natural pest control, and recreation and aesthetic functions. Maintenance of such services is imperative to continued human and biosphere survival. Impairment of several of these ecosystem services on a widespread level may have severe ramifications that undoubtedly would adversely affect human society as it is now known. However, the study of these ecosystem services on a widespread scale is truly in its infancy. Obviously, additional research is warranted if humankind is to understand such services on widespread spatial and temporal scales and predict what effects regional stresses may have upon them. Unfortunately, such research is unlikely to be funded at a sufficient level in the current political and economic climates. In addition, funds continue to be wasted on carrying out research on risks of relatively minor significance. It is an interesting oddity that, while many people are indeed very concerned with the risks posed by local hazardous waste sites and nuclear plants, relatively few are truly concerned with the potential risk to future generations that may occur from climate change, human population increases, endocrine disrupters (Colborn *et al*., 1996), worldwide degradation of arable soils, and the loss of biodiversity from species extinction and habitat destruction.

If sustainability of the planet is to continue gaining political and financial support, it must be related to economic principles, including supply and demand and cost-benefit analysis. Cairns (1997a) describes the structures of natural systems, such as forests and rivers, as natural capital (in economic terms) while the functions of these structures may be thought of as interest on the capital. It is obvious that ecosystem services provide benefits to humankind in such a manner that life as it is now known could not continue without such 'free' services. However, ecosystem services could be associated with costs if these services were somehow provided by the public or private sectors. As such, estimates have been made of the economic value of these ecosystem services. Costanza *et al*. (1997) have estimated the mean combined value of these services in excess of $33 trillion per year, far in excess of the gross national product of the United States, or even the world.

Conventional economic analysis usually postulates that there is never a shortage of anything – only a price. If unsold items accumulate, the price must have been too high. If buyers cannot find what they want, the price must be too low. However, Tullock (1994) has described quite different economic systems for non-human societies. Such societies have existed longer than human society and, arguably, are more congruent with the biophysical laws of nature. Consequences of inappropriate behaviour may be judged as too harsh on individual humans. Human society is often reluctant to apply supply and demand reasoning to the labour market, as evidenced by the minimum wage debate in the United States. Perhaps it is a mistake to do so for natural systems as well. Natural resources cannot often be replaced by substituting another resource. For example, economists believe in exhausting a resource if another marketable resource is available and obtainable. However, if the original resource is a fishery stock and the stock is harvested to extinction and not replaceable, then irreversible biological harm has occurred regardless of the associated economic theory. Such harvesting is occurring today as overfishing and pollution take their tolls on ocean fisheries.

If human intelligence, ingenuity, creativity, and technology exempt the human species from the biophysical laws of nature that, if violated, result in severe penalties for all other species, perhaps the human species can also ignore carrying capacity and resource limitations. Among other assumptions, this exemption would require that a technological solution be available for every serious problem created by technology. No robust information on large spatial or temporal spans supports exemptionalism or technological solutions for problems created by technology. Even if human society were not dependent on ecosystem services, the ecosystems would serve as a backup system in case technology fails. Since human society is dependent on ecosystems as a life support system, they deserve better management.

POPULATION INCREASE AND ITS EFFECT ON SUSTAINABILITY

Unfortunately, demands placed on these ecosystem services have and will continue to increase in future decades. At the time that Ehrlich (1968) wrote *The Population Bomb*, the world contained an estimated 3.5 billion people. Demographers at the Population Reference Bureau forecast that the world's population will reach 6 billion in April of 1999, an increase of just over 70% in slightly more than 30 years. Interestingly, an estimate of 6 billion individuals by the year 2000 is the same as was predicted by the UN Population Division in 1958. With the vast majority of the world's population (as well as its increase) existing in developing countries, it is painfully obvious that controlling the population increase must and should be a major priority in any sustainability paradigm. Until the issue of an ever-increasing demand upon limited resources is addressed, sustainability is likely to remain more of an idea than a practiced concept.

According to Poindexter (1997), no nation in the last 100 years has moved from a less developed status into a developed status until the country had achieved a total fertility rate (tfr) of 2.3. Nations begin to improve and develop as their tfr approaches 2.5, but do not truly enter the developed status until a tfr of 2.1 or lower is achieved. Poindexter describes a UN report that compares the countries of Brazil and Japan from 1963 to 1985. Both Brazil and Japan experienced similar growth in gross national product (GNP) and, in 1975, had a per capita GNP of $900 and $1400, respectively. However, by 1985, Brazil's per capita GNP had only risen to $2000 while Japan's had jumped to $16 000. According to Poindexter, this disparity was attributed by the UN to the population growth rate in Brazil. At present, innovative public education in Brazil has dropped its tfr from 3.4 in 1989 to 2.3 in 1996.

GOALS AND CONDITIONS FOR SUSTAINABILITY

Accepting the premise that more and more demand will be placed on limited natural resources and other ecosystem services, Cairns (1997a) proposes two responses to such limits: (1) deal with the consequences as they become evident, or (2) adjust societal behaviour immediately so as to preempt the undesirable consequences of exceeding these limits. Sustainability is rapidly moving from the conceptual phase toward implementation. An excellent example of the implementation of sustainability is the Natural Step Program (see Cairns, 1997a), which lists conditions, meanings, reasons, and questions for the private or public sector to use when evaluating its own environmental stewardship.

Cairns (1997a) proposes several goals and conditions for sustainability and uses the terminology of the Natural Step Program for the term *condition* – anticipated or qualifier conditions that are necessary to achieve sustainability. The proposed goals and associated conditions (Cairns, 1997a) are summarized in Table 1.

THE RISK-UNCERTAINTY PARADOX

Yet another consequence of the increasing scale of environmental problems is an increase in the uncertainty of the predictions of environmental outcome and consequences. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made. However, they are linked – acting with an intolerance of uncertainty often demands a high tolerance for risk. If the consequences are severe, one should be willing to act even in the face of high uncertainty. Impairment of ecosystem services certainly seems to fall in this category.

Traditional health and industrial monitoring systems produce both false positives and false negatives. In an environmental monitoring context, a false positive is a signal that some deterioration has occurred in the system when, in fact, it has not. A false negative is the absence of a signal when unacceptable changes in quality have occurred. The earlier use of sentinel species yielded false positives if the sentinel species was more sensitive to a particular toxicant than were the resident species and false negatives for some other toxicant for which the relative sensitivities were reversed. Reductions of errors can be accomplished by a better understanding of the system being monitored and by multiple lines of evidence. Integration of environmental monitoring programmes will provide both. In addition, some attempt is being made to re-address the balance between false positives and false negative errors in risk assessments. Traditional scientific approaches control false positives at the expense of additional false negatives; this may be inappropriate in a risk assessment context (Schrader-Frechette, 1993).

The absence of certainty is not synonymous with the absence of risk. Rapidly emerging environmental issues will have a direct impact on industry despite the common view that technological and ecological systems are not interdependent. As Tibbs (1992) notes, the emerging environmental challenge requires a technical and management approach capable of addressing problems of global scope. The question is: will management strategies based on risk assessment be undertaken only after the damage is so great that even a fool can see it (to paraphrase Homer's comment in *The Iliad*) or will preventative management practices for sustainability be put in place? Tibbs (1992) states:

> Effective defense against uncertainty will be based on the recognition of a key principle. The ultimate driver of the global environmental crisis is industrialization, which means significant, systemic industrial change will be unavoidable if society is to eliminate the root causes of environmental damage. The resulting program of business change will have to be based in a far-sighted conceptual framework if it is to ensure the long-term viability of industrialization, and implementation will need to begin soon.

Hawken (1993), Tibbs (1992), Cairns (1996), Holmberg *et al*. (1996), and Robèrt *et al*. (1997) base sustainability strategies on the assumption of need for both technological and ecological components of human society's life support system.

ESTIMATING RISKS ASSOCIATED WITH IMPLEMENTING GOALS AND CONDITIONS

Assessing the risk associated with the implementation of goals and conditions for global sustainability is an extremely nebulous and difficult concept at this time. Conventional risk assessments,

Table 1 Goals and conditions for a sustainable world (after Cairns, 1997a)

Goals	*Condition(s)*
To ensure that the machinery of nature has sufficient energy to deliver required ecosystem services (Goal 1)	Human society shall not co-opt so much of Earth's energy that ecosystems can neither furnish services nor endure for substantial periods of time
To avoid poisoning or impairing the machinery of nature by altering both the structure and function of natural systems by means of toxicants (Goal 2)	Substances extracted from Earth's crust or synthesized from raw materials must not be concentrated or dispersed in ways harmful to the biosphere
To ensure that ecosystem services continue at their present or, preferably, improved levels (Goal 3)	The physical and biological basis for the services provided by nature shall not be systematically diminished. Artifacts created by human society may not systematically increase on Earth. A balance must exist between ecological destruction and repair. Finally, management strategies for sustainability must allow natural processes to continue
To devise a better balance in meeting short- term and long-term needs of human society (Goal 4)	Short-term human needs may not be met if doing so endangers the planet's ecological support system
To ensure that most of Earth's population has the opportunity for a high quality life (Goal 5)	Human population over the long term must be stabilized at a point where adequate per capita resources are demonstrably available
To avoid a human-induced episodic environmental catastrophe that would cause much human suffering (Goal 6)	Large protective margins are essential when employing environmental management strategies where results are uncertain
To diminish the conflict between generations caused by the perception that future generations will lead impoverished lives because of present greed (Goal 7)	Older people must become deeply involvedin sustainable use of the planet by deeds and not words
To reincorporate all waste from human society into natural systems without damaging their integrity (Goal 8)	To reincorporate all waste from human society into natural systems without damaging their integrity. Materials that cannot be safely reintroduced into natural systems should not be produced. Assimilative capacity of natural systems shall not be exceeded
To develop equity and fairness in resource distribution within human society and with other species with which it shares the planet (Goal 9)	Humans must acknowledge the reality of equity and fairness so that there is an incentive to preserve the ecological life support system for sustainability
To develop a holistic sustainability initiative (Goal 10)	Each specific initiative must not act as if it is the only 'flower facing the sun'. It will be difficult to ensure cooperation, but otherwise holistic sustainability will indeed fail

both human and ecological, tend to concentrate on specific instances of risk from a specific stressor in both a spatial and temporal context. Endpoints tend to be specific, well-documented cellular or physiological responses (human/ecological assessments) or, at best, population and community responses (ecological assessments). Such endpoints are indeed useful for the spatiotemporal and regulatory requirements of those assessments. However, applying modern risk assessment paradigms on the global scale that is required will need a reassessment of current paradigms and the scales addressed by them. In addition, quantifying probability as well as uncertainty of the risk estimate will undoubtedly require continued development of the tools of risk assessment.

As described by Weston (1995b), people often attempt, in the race to 'do something', to solve a problem without understanding its philosophical and technical elements. This strategy often leads to failure, miscommunication, and delay in real progress. Weston believes that all events on Earth should be recognized as a transaction in natural economics. While some criticize the attempt to unite economic theory and risk assessment, such a union provides a set of tools that are well understood by the business and political communities. While this union of diverse fields is only in its infancy and is far from perfect, a better understanding of each discipline by practitioners of the other is the only way that risk assessment paradigms can be refined to incorporate the endpoints and spatiotemporal scales necessary for examining risk from implementation of the goals necessary to ensure global sustainability.

The use of cost-benefit analysis will be imperative to the success of implementing the goals and conditions needed. Although the estimate of the current economic value of the 17 biomes examined by Costanza *et al*. (1997) does contain significant uncertainty, as acknowledged by the authors, the value of $16-54 trillion with a mean of $33 trillion relates ecosystem services in a context understandable by politicians, businessmen, and policymakers. As a point of comparison, the total global gross national product is only about $18 trillion. Additional research will undoubtedly refine this estimate of the value of ecosystem services and lead to the development of models that will estimate risk to a particular ecosystem service if demands of public and private sectors are not significantly modified.

RISKS ASSOCIATED WITH IMPLEMENTATION

The optimistic economist Julian Simon (Myers and Simon, 1994) states that 'we now have in our hands the technology to feed, clothe, and supply energy for the next seven billion years'. It would be understandable for a reader unfamiliar with the population debate to feel that this flamboyant sentence did not really represent Simon's views. However, the same theme is mentioned in Barnes' (1998) obituary on Simon and in other volumes edited by Simon (1981, 1995). Ehrlich and Ehrlich (1996) refute this concept by noting that simple mathematics shows that, if the planet's population of 5.6 billion continues to rise at the current rate, it would only take 774 years before 10 humans existed on every foot of ice-free land on the planet. However, a number of people strongly support Simon's views, and some even voice strong anti-environmental statements (Anon, a,b; Barnes, 1998; Sowell, 1998). As Tullock and Brady (1992) note, a clear risk is inherent in crying wolf when there is no wolf, since doing so repeatedly will result in disbelief when a wolf does appear. Even one false alarm may have unfortunate results.

The risks associated with implementation, or non-implementation, of the goals and conditions required for global sustainability are diverse and complex. No generalized agreement concerning types, probability, or magnitude of the risks can be found among scientists, economists, and policymakers. However, risks will clearly include those that are biological, economic, societal, and political in nature.

There are two quite different ways to view sustainable use of the planet, each with associated risks. View 1 is to modify the planet so as to stabilize, as much as possible, conditions favorable to *Homo sapiens*. View 2 is to modify societal and individual behaviour so as to protect the integrity of natural ecosystems.

Implementing view 1 would probably result in an accelerated rate of extinction of other species, which now alarms most biologists and many others as well. This acceleration almost certainly will disrupt the delivery of ecosystem services, although the various response thresholds are not easily documented. Nevertheless, a major loss of ecosystem services would have severe consequences for human society and is a risk worth avoiding. Clearly, determining thresholds of stress that would impair delivery of ecosystem services is an important first step in clarifying the risk of continuing trends of energy use, increasing per capita affluence, and population growth.

Implementing view 2 would require major changes in human behaviour, with the inevitable risks of uncertainties about how this will affect the economic and cultural systems. Most important, it cannot be done effectively without a far more robust environmental monitoring system than now exists. Invariably, monitoring systems of all kinds produce false positives (a change has occurred when it has not) and false negatives (nothing has changed when is has) during development stages. This shortcoming could result in premature loss of faith in the system.

Biological risks associated with true implementation of sustainability goals and conditions should be reduced as compared to those associated with the alternative of non-implementation. Ideally, ecosystem services would be maintained, or even improved, if humankind reduces its impact on ecosystems. However, it is plausible that adverse biological effects may occur if decisions are made on the basis of irrational arguments or poor science. Non-implementation of sustainability goals and conditions will, in all probability, cause a decrease in the quality and quantity of biotic resources on Earth.

Economic risks associated with implementation are likely to have significant monetary and personal impact. It is conceivable that the gross national product (GNP) and relative productivity of some developed countries may actually decrease; individuals will be encouraged, and perhaps rewarded, for purchasing and consuming less; the public and private sectors will be required to minimize pollution and waste, as well as implement extensive recycling and energy consumption minimization programmes; land development practices will be controlled more by governments; and current standards of living in developed countries may be altered. Economic risks most likely will delay or void implementation of many of the goals and conditions proposed because (1) individuals and societies are not likely to assume risk if the standard of living is jeopardized, (2) individuals and societies tend to be concerned only with risks that have direct applicability to human health (Patrick, 1992), and (3) policymakers are unlikely to assume the consequences of their decisions when scientists cannot come to a consensus on whether a risk (global warming for example) is or is not caused by anthropogenic factors (Robinson and Robinson, 1997) .

Societal risks associated with implementation will also likely be significant. Populations will be required to stabilize; individuals will be required to make distasteful modifications in their personal and family lives; standard of living could be perceived as decreasing in some developed countries; transportation practices, particularly in the United States, will be affected; per capita energy consumption will be forcibly reduced; food consumption could be forced to shift to lower trophic levels; and individuals from different cultures will have to accept a single paradigm on sustainable use of the planet. Given the history of human civilization, it is difficult to imagine a world whose inhabitants can agree on anything. Yet, the alternative to implementation presents a world where many of these same results will occur, perhaps after some delay, in a forced manner (Cairns, 1997a). Attaining sustainability will be a significant challenge to both developed and developing nations.

Political risks will be extensions of those described for the economic and societal scenarios. The political climate in most developed countries is driven by consensus building and continued economic growth. Developing countries are often politically unstable because of poor economies, excessive population growth rates, or outright warfare. Given the performance of national governments at the recent Rio and Kyoto environmental conferences, it seems unlikely in today's political climate that a major political leader, who espouses implementing goals for global sustainability that may adversely affect his/hers country's short-term economic viability, would even be given the opportunity to run for office, let alone be elected. Since 'managers do things right while leaders do the right things', it will take a change in the thinking of the people to change the thinking of the world's political parties. Many Indian tribes, including the Iroquois in New York, ascribe to a ruling system where the consequences of a decision are estimated not on the present generation but on the seventh generation into the future. All humans on the biosphere known as Earth, including their leaders, could learn something from this decision-making system.

The final risk presented has been coined by Tullock and Brady (1992) as 'the risk of crying wolf'. Relating the child's fable, Tullock and Brady point out that the villagers looking for the imaginary wolf incurred both the costs of looking for the wolf as well as the lack of productivity that occurred while they were not performing their normal jobs. The optimal situation, the authors believe, is that when the boy cries wolf, there is a wolf present and the wolf is driven away. The relevance to implementing goals for sustainability is obvious – humankind gains when addressing significant environmental issues but loses when addressing an issue that is a result of nearsightedness or outright falsity. Economists, as a whole, believe that technology and the capitalist incentive have and will address any problems faced by man. The classic example usually cited is the Prophecy of Malthus. Thomas Malthus, a British economist, formulated a theory in 1798 that the human population was indeed capable of increasing faster than the food supply. Malthus believed that widespread famine and pestilence would occur during the 19th century as the human population continued its uncontrolled increase. However, as detailed by Tullock and Brady (1992), the prediction never came true. Malthus failed to take into account the technological increase in per capita food production that accompanied the industrial revolution of the 1800s. Tullock and Brady also criticize the more modern predictions of 'latter-day Malthusians,' including Paul Ehrlich, author of *The Population Bomb*. According to Tullock and Brady (1992) '... it is fashionable for ordinary intellectuals to worry about population as a menace and for specialists in population demography or economics to downplay it'. Tullock and Brady also cite another classic economic premise, the idea that natural resource depletion is not as detrimental as most scientists portray it. They also extend the application of economic theory to the fears of global climate change, citing uncertainty in models, improved technology to address unforeseen problems, and the need for cleaner energy sources (including nuclear power). Cairns (1997a), however, warns against society's relying on unknown technological solutions to future problems since such solutions may come too late to correct severe damage. Finally, Tullock and Brady (1992) believe that environmental concern is a luxury afforded by good economic times that occur in wealthier, developed countries. Concern peaks immediately after an economic boom, for example 1973 and 1989 in the United States, and declines when any economic decline appears likely.

This cycle has onerous significance for implementing goals and conditions should the public associate economic declines with sustainability.

While many risks and scenarios are conceivable when implementing the required goals and conditions necessary for ensuring global sustainability, one needs to pause and reflect on the course of no action, that is, non-implementation. While short-term economic, societal, and political risks would likely be minimal, risk to ecosystem services may rapidly increase if the assimilative capacity of Earth is exceeded by anthropogenic stressors or if the carrying capacity of Earth is exceeded by human population. Given that the upper monetary estimate of ecosystem services conducted by Costanza *et al*. (1997), $54 trillion, is not implausible, a relatively minor 10% reduction in such services may have significant and permanent implications for humankind.

ENDPOINTS FOR ASSESSING RISK

An important aspect to the risk assessment process is the development of endpoints to predict or assess risk, as well as measure success of any corrective measures. Endpoints have the following characteristics [modified from Hunsaker *et al*. (1990)]: societal relevance, biological relevance, unambiguous operational definition, accessibility to prediction and measurement, and susceptibility to stressor(s).

To date, risk assessment on any large spatiotemporal scale has not been sufficiently documented. While endpoints have been developed and proposed for regional risk assessment (e.g., Hunsaker *et al*., 1990; Suter, 1993), adapting these to the spatiotemporal scales needed for global assessment will require additional study. Regional endpoints such as vegetation cover type, algal productivity, species extinction, changes in species abundance, and loss of wetlands can also be cautiously extrapolated to even wider spatiotemporal scales that transgress many ecoregions. Such steps will be necessary to validate endpoint performance before its use at an even more widespread scale is justified. Cairns (1992) believes that, while structural endpoints such as macroinvertebrate diversity have been demonstrated to be quite valuable in localized assessment, functional endpoints will probably be shown to be more applicable to the scale required for regional and global assessment.

Global monitoring of biological systems will be expensive but should furnish valuable information. Although used for mapping and some ecosystem analysis, further development of remote satellite imaging will enhance the monitoring of selected ecological functions over large spatial areas. Cairns (1992) describes five goals that should be supported by global monitoring: (1) maintain balanced biological communities, (2) protect the structural and functional integrity of ecosystems, (3) facilitate no-net-loss of habitat by category, (4) sustain customary ecosystem service availability, and (5) maintain global diversity by ecoregion. Carefully selected endpoints will only enhance the usefulness of any global monitoring plan.

While controversial and broad, the endpoints proposed for consideration (Table 2) should provoke discussion and provide insight into trends with regard to assessing risk either from implementing goals for sustainability or humankind's choosing not to implement goals. Historical data for many of these endpoints already exist. Some endpoints will need to be modified or dropped because of a lack of biological or societal relevance, but it is better to gather too much data initially than too little. Multivariate analysis of large data sets can determine which factors are important for continued analysis. It will be extremely difficult to characterize risk initially, but these endpoints should show important trends in whether or not humankind is achieving sustainability, whether the economic predictions become fulfilled, and whether or not environmental damage continues.

Table 2 Proposed risk assessment endpoints for estimating the risks associated with implementing goals and conditions for global sustainability

Biological/Environmental
- area of land cleared for development in developed and developing countries
- seasonal greenhouse gases mean concentration, seasonal by selected region
- global mean temperature
- ocean mean temperature
- ozone depletion
- standing timber per country
- gross primary productivity via remote sensing
- area of selected ecoregions
- species extinctions, by ecoregion
- selected species diversity, by ecoregion
- bird censuses, by ecoregion
- global fisheries production
- human life expectancy at birth and at age 10, by country
- annual production of xenobiotics that are concentrated or dispersed in ways harmful to the biosphere
- amount of recyclable materials that are actually recycled, by nation
- changes in food web structure and function, e.g., predator-prey relationships and biomass at each trophic level
- mass balance of major biogeochemical cycles in selected, critical ecoregions

Socioeconomic
- population
- arable land per capita
- total fertility rate (tfr), by country
- per capita production for the three major grains
- total labour force
- labour force unemployed for >6 months
- per cent of work force employed in agriculture
- gross national product, by nation
- per capita production, by nation
- per capita consumption, by nation
- per capita mean income

UNCERTAINTY WHEN ASSESSING RISK ON A GLOBAL SCALE

Uncertainty must be estimated during risk assessment. On a regional scale, the same sources of uncertainties are sometimes involved as are found for local risk assessment (Hunsaker *et al*., 1990). When estimating risk at larger spatiotemporal scales, uncertainty will undoubtedly be greater and endpoint signal-to-noise ratios will decrease. These changes are to be expected, especially given the natural variability at such a large scale. Reducing uncertainty will incur immense cost, if it can be reduced at all. Regardless, techniques such as Monte Carlo models allow uncertainty estimation that will be beneficial to policymakers and politicians. It will be important to include uncertainty when determining potential impacts as variability may affect whether or not the true causal factor is determined (e.g., Smith *et al*., 1993).

CONDUCTING RISK ASSESSMENT ON A GLOBAL SCALE

The estimate of risk on a spatiotemporal scale that is untested with current paradigms will undoubtedly cause many to speculate that insufficient data currently exist for the level of precision needed. Efforts to initiate the needed estimates will be stymied by those who favour a course of no action for political or economic reasons. However, it appears that sufficient data do exist from federal and state governments, conservation organizations (e.g., The Nature Conservancy, The Audubon Society, and The Sierra Club), academic researchers, and other stakeholders to initiate the risk estimation process and to begin refining existing paradigms for risk estimation on a global scale.

CONCLUSIONS

Many scientists believe that significant and permanent change is required by humankind to continue its existence on Earth for more than three or four additional generations. Such changes may be voluntary or may be forced by necessity as ramifications from the present way of living become apparent. If voluntary changes, as proposed by Cairns (1997a) and others, are to be seriously considered, the risks associated with implementing such changes must be estimated. Such risk estimation can then be useful to politicians, policymakers, and other stakeholders when weighing the biological, socioeconomic, and political costs of addressing a problem that may be the most significant one ever faced by human civilization. As Mount (1992) states: 'Few people even connect a long hot shower in the morning with the greenhouse effect and climate change'. It is finally time for the connection to be made.

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Balancing Ecological Impairment and Repair for Sustainability

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Abstract

Although this manuscript was prepared for a specific region, the North American Great Lakes, the major elements are important to the quest for sustainable use of the planet anywhere in the world. Since sustainability will often involve an eco-region that consists of more than one political entity, a bio-regional entity will be essential. The unifying theme is the intent to leave a habitable planet for future generations. In order to accomplish this, a consilience (literally leaping together) of the social and natural sciences is essential. When one considers the often bitter fragmentation of human society in many parts of the world and the isolation of disciplines in educational institutions, consilience seems visionary and utopian. But, visions of a better future can be very powerful and produce major paradigm shifts. The future of human society depends on the development of robust sustainability initiatives for Earth's bioregions. This 'futures studies' manuscript explores the broad outlines of such an undertaking.

Leaving a habitable environment for future generations

The World Commission on Environment and Development of the United Nations (1987) defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." A common theme in publications on sustainability is the need for human society to change its behavior because many present practices are not conducive to sustainable use of the planet.

Most parents hope for a bright future for their children! These parents inoculate their wards against diseases, sacrifice for their education, and regularly reorganize their personal lives to meet their children's needs. However, the payoff from all this care and attention will be dramatically reduced if the larger environment in which these children spend their adult lives is markedly worse than the present condition. What appear to be insignificant, small decisions individually can collectively determine the outcome of future societies. Traffic jams and other such situations illustrate how a series of individual actions, incapable of causing the problem alone, can collectively cause massive tie-ups. A number of global realities are obvious:

1. resources are limited, but many biological resources are self-maintaining if their integrity is not impaired, 2. Earth's finite area is used to meet a wide variety of actual and perceived needs, and humans must increasingly adapt to recognizing community and future needs as well as individual

needs, 3. although all organisms enter life under circumstances over which they have no control, humans have a capacity to make choices; by doing so, they alter their circumstances for better or for worse, 4. both individuals and systems are constrained by biophysical limits and laws; sustained use is facilitated by enlightened use without abuse,
5. ignorance does not provide immunity from biophysical natural laws, 6. sustainable use is optimizing the utilization of natural resources over large temporal and spatial spans.

Recognizing human society's dependence on both technological and ecological life support systems

Cairns (1996) recognizes human society's dependence on a life support system that has both technological and ecological components. For most of human society's existence, its only life support system was ecological. However, with the dramatic increases in population and its concentration in urban and suburban areas, food and materials had to be transported to users, instead of being used near their production site; waste had to be treated and removed; and the like. The human condition worsens when the technological system is disrupted by such catastrophes as earthquakes, hurricanes and floods. The ecological life support system has been taken for granted because it has been reliable and nature's services have been free. Among these ecological services are the maintenance of the atmospheric gas balance favorable to humans and many other life forms, transformation and recycling of waste materials, provision of models for medicinal drugs, etc. (Westman, 1977; Cairns & Niederlehner, 1994; Cairns, 1995; Daily, 1997; Costanza et al., 1997). Regrettably, the technological component of human society's life support system is often managed in such a way that it injures the ecological component of the life support system. This situation need not be the case and would not be if human society recognizes its dependence on both components, rather than favoring the technological over the ecological.

Balancing ecological impairment and repair

If the rate of ecological impairment exceeds the rate of ecological repair, as it now does by a very significant margin, leaving a habitable planet for future generations will not be possible, nor will sustainable use of the planet as it is now envisioned. Fortunately, many industries are now taking a serious interest in sustainability through industrial ecology (Tibbs 1992) and strategies for manufacturing through an ecosystem approach (Frosch & Gallopoulos, 1989). Tibbs (1992) espouses balancing industrial input and output to natural ecosystem capacity – probably based on the concept of assimilative capacity of natural systems, or their ability to assimilate societal wastes without having their integrity impaired. Cairns (1977d) notes, however, that the concept of assimilative capacity as he originally intended it (protecting ecosystem integrity) has regrettably been distorted in recent years. If the technological and ecological components of the life support system are to be balanced, a monitoring system to assure that neither is impairing the other is essential (Cairns, 1997a). If such a monitoring system is used, it will be possible to protect the delivery of ecosystem services (Cairns, 1997b); however, enjoying the benefits of both components of the life support system will require changes in human behavior that will lead to sustainable use of the planet.

Benefits of a sustainability initiative

Bringing the generations together

I have given talks to retired groups, college students from all disciplines, high school students, regional business people, and academic organizations. A colleague told me of his meeting with a fifth grade class in Athens, Georgia, and how impressed he was with their dedication to preserving the environment. One of my talks to a high school group was longer than was planned because buses were late to pick up the students. I devoted the time to questions and was overjoyed at the students' interest and positive response. If a 76-year-old is willing to spend his retirement years working to protect their future, the students want to be part of the sustainability effort as well.

Establishing citizen pride in ecological restoration

I was fortunate to serve on the National Research Council (NRC) Committee (1992) that prepared the report "Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy". The committee visited as many restoration sites around the United States as funding permitted. At each location, the citizens were bursting with justifiable pride in their accomplishments. It was heartwarming to be asked to remain longer than was originally scheduled so that these citizens and scientists could show more of the restoration. Restoring ecosystems is nothing more than rehabilitating ecological neighborhoods, and such efforts regularly bring people together. Moreover, the efforts give them an incentive to be guardians of ecosystem health. I often feel despair, sometimes verging on controlled panic, about the damage human society is doing to natural ecosystems globally, but I have been greatly reassured about the future after talking with citizens involved in ecological restoration who are concerned for sustainable use of the planet.

Reestablishing a sense of community through ecological restoration and enhancing sustainability

Fortunately, ecological restoration, which I believe to be pivotal to achieving sustainable use of the planet, almost always results in an ecological condition markedly superior to the damaged condition. Furthermore, an improvement can often be realized in a relatively short period of time, which is important for people who want concrete evidence of the efficacy of their work. Last, but far from least, the rehabilitation of the tidal Thames (e.g. Gameson & Wheeler, 1977) and the rehabilitation of the Guanacaste dry forest in Costa Rica (e.g. Janzen, 1988) have resulted in economic benefits. The Thames had serious odor problems, a paucity of fish, was not attractive to tourists, and had a number of other difficulties. With restoration, the fish species increased to over 100, the water no longer had an offensive smell, and the river became a much more useful tourist attraction with all the spin-off economic benefits. Janzen's terrestrial ecological restoration in Costa Rica also produced economic benefits through ecotourism, which made sustainable use of the area much more feasible. As I found personally (when some of my graduate students worked extensively with a Governor's School class in a nearby high school on a project to restore a closed landfill by establishing wild flowers and other species), young people have positive reactions to such activities and shock at the damage caused by a solid-waste-generating society. Working together to restore damaged ecosystems and striving towards sustainability in one's area should develop a community spirit in an era where individual 'rights' have been carried too far without accompanying community and civic responsibility. Humans are social creatures, and working together on a mutually agreed goal, especially one that benefits future generations, should develop a better balance between individual rights and responsibility.

Developing a bioregional sustainability initiative

A bioregion is an assemblage of interactive habitats associated at the landscape level. Sustainability refers to the intent to leave a habitable planet for future generations or, more explicitly, using present ecological resources so that future generations will have essentially the same options that the present generation has. Developing a restoration plan for any damaged area within a bioregion will be most effective at the systems level. Approaching ecological restoration within a landscape context works well when preventing ecological deterioration to the degree that it precludes sustainable use of the planet and the ecological resources. Opportunity-cost analysis (see NRC [1992] book) can be used to determine where the largest ecological/sustainability gains can be made for the least money. Additionally, areas can be selected that will provide results fairly quickly and reliably. This strategy will bolster everyone's confidence in the plan. If mistakes have been made, it would be well to apologize for the mistakes and then proceed with the sustainability initiative. Achieving sustainability requires a collaboration of all components of society, not divisions of 'them' and 'us' with accusations, finger-pointing, and attempting to fix blame. Most of the restoration efforts used as examples in the NRC (1992) book had some rough spots, but the strong intent to improve the environment overcame the divisiveness of fractional disputes. A bioregional plan should provide buffer zones around ecologically fragile areas, provide ecological corridors connecting otherwise isolated components and use conservation designations for property owners wishing to join the bioregional plan while acquiring tax and other benefits but retaining ownership and use of their property.

The ecological restoration/sustainability initiative should have clear-cut explicit goals and objectives
An inventory of damage to ecosystems and any illustrative examples of restoration should be available. Also helpful would be a survey of how many political units exist within the larger bioregion and are willing to take on an ecological restoration project so that all educational facilities would have a project nearby for students to work on or to visit and observe. Local academic institutions could provide scientific and engineering resources for these efforts and coordinate them into a larger bioregional plan. This procedure would also improve ecological restoration/sustainability literacy by encouraging citizen discussion and education about the projects and, ideally, widespread citizen involvement.

Self-maintaining systems and ecological capital
The ability to be self-maintaining is one of the desirable attributes of a restored ecosystem. Since ecosystems are dynamic and, therefore, changing in a variety of ways, attaining this attribute means ensuring that the normal processes of succession, energy flow, nutrient cycling, and the like continue without human management intervention. One of the attributes of healthy ecosystems is resilience – when the structure and/or function is displaced, the system can recover and restore its integrity without human intervention. Obviously, sustainable use of the planet will be greatly facilitated if management of ecosystems to deliver ecosystem services is minimal because these services are automatically delivered as they have been for most of human history. Self-maintenance is more easily viewed at the species level. For example, if the brood stock of a particular species is not depleted, spawning and recruitment replace the brood stock regularly without human intervention. This cycle, of course, includes harvesting of the species at a rate that permits recruitment of brood stock naturally without a subsidy through hatcheries. Natural processes had replenished brood stock for thousands and thousands of years until humans created a disequilibrium in the system, which either eradicated the species or placed it in serious trouble. Brood stock could be viewed as ecological capital, which generates interest in the form of harvestable resources as long as the capital itself remains intact through restrained use. Obviously, over long periods of time, species may become extinct through nat-

ural cause; however, human activities have seriously impaired self-maintenance of fisheries and the larger ecosystems inhabited by fish.

Ecological restoration can be viewed as building ecological capital, ideally to the point where a once self-maintaining system that is no longer functioning that way has been rehabilitated to its pre-disturbance condition. Ecosystems are also self-maintaining, otherwise the species that inhabit them would have a difficult, arguably impossible, time surviving. Cairns (1993) has described a number of ecological restoration options – only one is self-maintenance without human assistance. Too little may be known about ecosystem structure and function to guarantee that management techniques to assist in self-maintenance will always work. In addition, return to a pre-disturbance condition may not always be a viable option (e.g. Cairns, 1989). Restoration has been defined (NRC, 1992) as an emulation of a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs. In short, the antecedent species may not necessarily be replaced, but re-establishment of antecedent physical-chemical conditions is essential. As a consequence, all ecological restorations are exercises in approximation and in the reconstruction of naturalistic, rather than natural, assemblages of plants and animals with their physical environments (NRC, 1992; p. 18). As Cairns (1989) notes, return to precise pre-disturbance condition may not be possible because: 1. the precise pre-disturbance condition is not known, 2. pre-disturbance species may not be available for recolonization or may be prevented from recolonizing because of the presence of exotic species, and 3. if the site is badly disturbed, pioneer species may be essential because the pre-disturbance species may not be able to survive under the now disturbed conditions, even if the cause of the disturbance has either been mitigated or removed.

Exotic species that have either been deliberately or accidentally introduced into ecosystems will have to be factored into the sustainability effort. Eradication of these exotics may be exceedingly difficult and, arguably, impossible with the information presently available. The choice becomes attempting to control them or allowing the ecosystem to reach a new equilibrium with the expectation that a significant portion of the impaired ecosystem services will again become available. Since answers to all the questions that might be raised about self-maintaining ecosystems may be unanswerable in the short term, sustainability must be achieved by doing rather than waiting for research to solve all the problems.

Monitoring to determine that previously established target conditions have been met

Cairns (1997c) lists a number of ecological goals important to sustainable use of the planet with one or more conditions and sub-conditions associated with each of the goals. All are intended to enhance ecological integrity and to develop human society's relationship with natural systems in such a way that the possibility for sustainable use of the planet is enhanced. Clearly, each geographic and bioregion should develop goals and conditions to fit unique attributes of the area. Once goals and conditions have been established, monitoring would be essential to see whether the plan is on target or deviating significantly from it. Methods and procedures should be standardized to the degree possible within the bioregion. This standardization will facilitate quality control in data gathering, exchange of information and assessment of progress throughout a large and ecologically diverse region. Necessarily, since each subregion will have unique ecological conditions, standardization of methods and procedures could be carried to an extreme. A balance must be achieved between recognizing the uniqueness of each area and recognizing the value of a data base gathered by relatively uniform, widely utilized methods and procedures. Ideally, one organization should be responsible for the storage of the data generated by the various regional units and for disseminating information about the entire bioregion to all the subregions (or take a strong role in assuring that this responsibility is being met).

The state of the bioregion report

An annual state of the bioregion report could be distributed in brief summary form to the news media and various political entities. Large amounts of data could be available electronically and shared with other organizations interested in ecological restoration and sustainability initiatives. This distribution of information would also provide the opportunity to reexamine goals and the degree to which the conditions for meeting these goals are being met.

Viewing the life support system as a gradient

Most people view industrial areas and ecological areas as totally separate entities and never the twain shall meet. Tibbs (1992) views the relationship as a gradient – industry at one end and nature at the other. Along this spectrum, starting with single material ecosystems (Tibbs views ecosystems as both industrial and natural), the transition is to inter-industrial ecosystems, then hybrid industrial ecosystems, then bioengineered ecosystems, then modified natural ecosystems, then reclaimed natural ecosystems, and then original natural ecosystems. The latter, original natural ecosystems, are generally considered pristine ecosystems or ecosystems with high integrity. However, Tibbs (1992) also views these as dynamic systems with the continuum representing the present circumstances, but leading to an eco-industrial infrastructure. In this gradient, Tibbs moves from compliance to partial recycling initiatives, to development of management tools, to highly developed closed-loop recycling, to significant changes in products and packaging, to environmentalism fully integrated into the corporate culture, to the development of synergistic industrial ecosystems. Instead of a polarization of environmentalists *versus* industrialists thought to exist today, Tibbs envisions a co-evolution of the two groups that would lead to a single interactive system. Instead of technological and ecological components of human society's life support system being distinct entities, as they are often considered presently (with the technological regularly threatening the ecological), Tibbs envisions them as a single entity in which neither is harmful to the other, but they actually are synergistically interactive (the combined result is more than their single additive results). If mutual benefits cause the merger envisioned by Tibbs of two groups now essentially polarized, then it seems quite possible that mutual interest in preserving and enhancing components of the life support system should further any cooperation between groups with differing views.

Sustainable use of the planet will undoubtedly require the sort of gradient proposed by Tibbs, where some pristine ecosystems exist and some sites are dedicated almost entirely to industry. However, most sites will probably be a mixture of the two, at least on a bioregional level. That is, housing, industry and other human artifacts, such as airports, will be in moderately close association with natural systems, and natural systems in any type of isolation will be rare. These mixtures are even more difficult to manage when a region is particularly attractive. Therefore, balancing ecosystem services and technological services so that the delivery of each is at a sustainable level and the delivery system retains its integrity is a challenging but necessary activity. It is also a complex activity, requiring multi-dimensional thinking and reasoning. This admonition is not to denigrate the importance of the component parts, but rather to indicate that there is a substantial, almost inevitable, likelihood of the component parts routinely being in conflict with others, especially if viewed in isolation from the larger system. A group that could devote much effort to carrying out this multi-dimensional activity skillfully should be the world leader in sustainability in this regard.

Demographic considerations
Human impact on a region will be governed by a combination of the number of people living in the region and their average per capita use of raw material and generation of waste. The population numbers are the result of natural increase (births and deaths) and net immigration (immigration - emigration). As part of bioregional planning, it would be helpful if census bureaus could prepare a range of population projections based on various combinations of human fertility, mortality, immigration and emigration, together with the propensity of people to concentrate themselves in a region. The best estimate of the most likely demographic future should be a key variable in bioregional planning. Prudent planning might well be based on a worst case scenario rather than the most optimistic scenario.

Educators and students
With internet communications increasingly available to schools, educators could motivate their students by sharing local activities with other students in the bioregion. Sharing local data and success stories of ecological interventions would encourage a sense of connection. Without extensive curriculum revision, educators could increase their students' ability to 'think globally.'

Mass media can be used to disseminate vital information as to distressed ecosystems. Jacobson & Mazur (1995) in 'Marketing Madness' discuss the effectiveness of infomercials as a way of reaching the public in a cheap way. Infomercials sometimes masquerade as news segments and are often used by elevision channels to fill in time on the airwaves. These are not as costly as 30-second television commercials ($250 000) and may be between $15 000 and $40 000 to produce. They can be used by television stations throughout the year with no cost to the station while sending messages to viewers. This use of mass media could prove to be cost effective and have an impact on the public.

Concluding statement
Kuhn (1970) defines a paradigm as a belief so strongly held that, when contrary evidence appears, the evidence is rejected. When the evidence becomes overwhelming, a paradigm shift occurs. At one time, practically all developed countries had a firm belief in a growth paradigm, which was thought to solve all of society's ills. However, the growth paradigm as once viewed may endanger the ecological life support system in a variety of ways. The paradigm shift toward achieving a balance for both components of human society's life support system (technological and ecological) now seems to be emerging. Unquestionably, achieving a balance between ecological impairment and repair, ensuring protection of both the technological and ecological components of the life support system, involving citizenry in a major bioregional effort, and all the other elements discussed briefly constitute in the aggregate a major paradigm shift for human society. This undertaking is bold and requires major shifts in many trends. However, there is also widespread recognition that some of these trends (e.g. unlimited deforestation, global climate change, present rates of water contamination, holes in the ozone layer, biological impoverishment, and the like) unaltered could be damaging to the stability of human society at best and cause severe disequilibrium at worst. If the planet is to hospitable for future generations, it is essential that strong system-level

efforts be initiated early in the next century. The scale of the problems will not diminish, but the number of options in addressing these problems will. Taking no action will not reduce risks for human society, although taking action is clearly not risk free either. Nevertheless, taken as a whole, this seems to be a marvelous opportunity to launch the ecological restoration/sustainability initiative because public awareness of the need is developing rapidly.

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Commentary

Assimilative Capacity – The Key to Sustainable Use of the Planet

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Assimilative capacity has been defined as the ability of a natural system to absorb various materials, including anthropogenic wastes, at certain concentrations without itself being degraded (Cairns, 1977). The term was originally used by engineers to describe the use of streams to process simple organic wastes such as sewage. This process is very well understood. Oxygen declines that follow various levels of organic enrichment can be modelled, and the point downstream at which oxygen levels will recover to their original levels can be predicted. When concentrations of humans were small and wastes simple, there were few concerns about the appropriateness of the use of streams for treating anthropogenic organic wastes. These same streams processed organic wastes from the surrounding watershed, including formidable quantities of tree leaves and the occasional wildlife carcass. No new process was involved. However, large human populations made it obvious that the assimilative capacity of streams for organic wastes could be exceeded and that this overuse could have unpleasant consequences. Stream uses other than waste treatment, such as production of fish, safe drinking water, recreation, and aesthetic enjoyment, were precluded by the overuse of the stream as a waste treatment system.

The concept of assimilative capacity has been expanded to include the ability to absorb wastes other than simple organics without being degraded. In addition, natural systems can break down, render biologically unavailable, or disperse some other types of contaminants.

Even complex organic chemicals such as pesticides and hydrocarbons are broken down in the environment through both biotic and abiotic processes (e.g., Howard, 1991). Microbial mineralization, oxidation, hydrolysis, and photolysis all decrease the environmental concentrations of complex organic chemicals. However, the rates of degradation and losses to other media are typically much slower for complex organics than for simple organic materials, so any assimilative capacity would be lower.

In aquatic ecosystems, metals can be sequestered in a form that is no longer biologically available. In anaerobic sediments in wetlands, lakes, and depositional areas of rivers, metals can be bound as insoluble sulfides. In these sediment systems, if the metal concentration remains less than the concentration of acid volatile sulfide (AVS), no toxicity is observed (e.g., Ankley et al., 1993), and deleterious effects in contaminated systems are most pronounced where AVS concentrations are lowest (Pascoe et al., 1994).

Another example is nutrients that can be trapped in the soil and vegetation or moved to other systems where their effects are more desirable. Nitrification and denitrification remove ammonia, nitrate, and nitrite from aquatic systems and release nitrogen gas to the atmosphere. Aquatic plants that have trapped nutrients can be harvested and incorporated into agricultural soils. This type of assimilative capacity is the basis for modern management practices in which wetlands are used to protect riparian systems from agricultural run off (Schlosser & Karr, 1981), restore hypertrophic lakes (Lowe et al., 1994), or treat secondary sewage effluents (e.g., Hammer, 1989).

Assimilative capacity is often linked to toxicant concentration. However, altered hydrology usually leads to major changes in vegetation (e.g., Hackensack River Meadowlands in National Research Council, 1992) as well as other changes. Vegetational changes generally result in changes of assimilative capacity, particularly for organic materials. During any transitional period, it will almost certainly be reduced.

Socolow (1994) notes that to overwhelm natural systems implies a focus on a ratio, changing over time, that compares some human enterprise with some pre-existing characteristic of the natural environment. Except in cases of gross ecological damage, changes in assimilative capacity go unrecorded because there is little or no robust evidence of pre-existing conditions and, therefore, little evidence of modest but significant changes in assimilative capacity for hydrologic change (drainage of 34,000 acres of floodplain wetlands) resulted in the loss of 5 billion small fish and 6 billion shrimp (Loftin et al., 1990) as well as extirpation of six indigenous species of fish (Toth, 1990).

Wetlands are arguably the most carefully studied ecosystems in recent years because they can assimilate and transform organic wastes from inflowing waters (e.g., Tuschall, 1981; Best et al., 1982; Best, 1987) as well as toxic compounds, including heavy metals.

Possibly the most persuasive example of assimilative capacity involves the damage to and subsequent recovery of the Thames River in England (Gameson & Wheeler, 1977). The assimilative capacity of the Thames had been exceeded from 1620 until the pollution load was reduced in 1955. The recovery was remarkable and many lost amenities and services returned. Fish species returned to the Tidal Thames, the stench from the river diminished to the point that recreational (tourist) sightseeing boats returned, etc. The Thames is also a major source of both drinking and industrial water. A colleague once estimated that a drop of Thames water might well pass through eight human kidneys before reaching the ocean.

It is regrettable that assimilative capacity becomes most evident when exceeded. One of the purposes of this article is to focus more attention on the need to develop more robust predictive models. This should be facilitated by the widespread use of simulated ecosystems (e.g., microcosms and mesocosms) in recent decades.

Like many scientific constructs adopted by policymakers, the process of defining assimilative capacity operationally has lead to considerable distortion of the original scientific concept (Stebbings, 1992). Assimilative capacity has been commonly misinterpreted as the “right to pollute” or “the permissive principle” (e.g., Earll, 1992). In the debate on waste disposal to marine systems in the United Kingdom, the term *assimilative capacity* has become associated with a management approach that places the burden of proof for environmental damage on monitoring after release rather than on demonstrating safety before discharge. This is unfortunate! As Stebbings (1992) points out, the assimilative capacity concept itself has no intrinsic stance on burden of proof nor does it assume that some assimilative capacity exists for any and all wastes. As the caveat “without being degraded” in my definition (Cairns, 1977) makes clear, the purpose of determining assimilative capacity is to find the degree of use of a natural system that is consistent with preserving the integrity and health of that natural system. This, in turn, allows other uses to continue. If no waste can be absorbed without degradation, then any addition exceeds assimilative capacity and compromises other uses of the system.

The concept of assimilative capacity also can be expanded beyond the use of natural systems for waste treatment to the may other needs of human society fulfilled by natural systems. Those ecosystem functions perceived as useful to human society are called ecosystem services. They include capture of solar energy and production of food and fiber, purification and storage of water, maintenance of the gas balances in the atmosphere, regeneration of nutrients in usable forms, recreation, aesthetic enjoyment, and provision of a genetic library for development of new foods, medicines, or fibers (Westman, 1977). Variations in temporal or spatial extent and intensity of usage of a natural system for one ecosystem service will affect other ecosystem services. In this sense, assimilative capacity ultimately refers to balancing potentially conflicting uses of a single resource. The classic example of assimilative capacity, overuse as a waste treatment system, precludes the use of the same stream for a fishery, drinking water source, or recreational resource. In the same way, use of a national forest for recreation and aesthetic enrichment may affect its use as a genetic library, preserving a variety of species by preserving appropriate habitat. Determining the assimilative capacity of a natural system for a given use allows us to determine whether some uses can be continued or intensified or new uses can be added without compromising other uses or future use of the system.

Compare this view of assimilative capacity to current notions of sustainablity. The term *sustainable development* has been defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). I prefer the term *sustainable use* because it does not imply that more efficient use of resources is somehow less desirable than expanded use of resources. The underlying assumption of sustainable use is that resources may be extracted from natural systems and then reincorporated into natural systems after use.

Much of my work has had an underlying assumption that natural systems can coexist with technological society if sufficient care is taken to avoid exceeding the assimilative capacity of natural systems. Even in early periods, humans altered natural systems by selective harvesting of various species of animals and plants. However, with increasing human populations, a major question is: what spatial extent, temporal extent, and intensity of use can natural systems survive without compromising other current uses and future uses? If natural systems have no assimilative capacity for any human use and these uses invariably damage the systems humans depend upon, then sustainable use of the planet is impossible.

Because of the linkages between the concepts of assimilative capacity an sustainable use, it may be worth while to reconsider some major criticisms surrounding the hypothesis of assimilative capacity as they relate to sustainable use.

Criticism #1: All additions to natural systems will change them, and all changes in natural systems are harmful.

Changes in natural systems are the rule, not the exception. Day and night, seasons with their leaf fall or lake turnover, floods, droughts, hurricanes, volcanoes, and ice ages all occur without human help. Even catastrophic changes are common – occurring on a small scale with every foot fall or rock movement. Fortunately, the frequency of catastrophic change decreases with spatial scale. To assume that all change is deleterious is to assume that, at any point in time, optimal conditions exist for natural systems and even changes unrelated to human interventions are undesirable. In fact, much literature indicates that some ecosystems are perturbation dependent (e.g., Townsend, 1989; Ward & Stanford, 1983). Paradoxically, these systems cannot persist without change. In addition, natural systems recover even from catastrophic change. In a review of literature describing the recovery of aquatic systems from disturbance, Niemi et al. (1990) found that a typical recovery time for macroinvertebrate communities was 1 to 3 years. Some species may be lost, but ecological integrity can be maintained or restored except after truly horrendous conditions. So, ecological evidence indicates that ecosystems are dynamic and constantly changing in response to alterations in their environment and that many ecosystems have substantial resilience. Human society needs a more selective criterion than change to decide whether management efforts need to be invoked. That is where the idea of harm comes into play.

Harm is not an objective construct. Harmfulness must be judged, and it must be judged in reference to a specific component of the ecosystem. What is good for the goose is sometimes catastrophic for the gander. Explicit goals about the level of each ecosystem service that human society is willing to devote its efforts to protect might be used to provide clear criteria for deciding which changes should invoke management action. Clearly, a rate of change that causes massive biotic impoverishment or loss of biodiversity is harmful to many ecosystem components, including humans, because it compromises many ecosystem services. Biotic impoverishment is, in fact, a clear warning that assimilative capacity has been grossly exceeded.

Criticism #2: Assimilative capacity is an artifact – the result of the inability to measure small changes in natural systems.

Some observers believe that all materials introduced into natural systems by human society harm them, but some changes are too small to be measured by current methods. Unquestionably, the ability to detect change in natural systems is limited by the complex multivariate and cyclic phenomena that are the norm in these systems. Additionally, anthropogenic wastes have aggregate or cumulative effects, which are not readily apparent over the short spans of time or limited geographical area that are typical of most human inquiries.

There is a more basic problem. In fact, scientific methods cannot verify harmlessness (e.g., Stebbings, 1992). Even with a truly harmless substance, the least damning result possible is to fail to find change. When no change is found, any confidence in this result must depend on the effort expended in looking for change – the spatial, temporal, and hierarchical completeness of the investigation and the statistical power of the experiments. We can and do detect gross damage to the environment. We can also detect subtle damage to very simple and noninteractive components of ecosystems. However, subtle damage to complex systems that may be important over long time scales or large and cumulative geographical areas is much more difficult to demonstrate.

So, despite the best scientific efforts, important change is not necessarily detectable, and detectable change is not necessarily important. Society can only make sound professional management judgments on the basis of the information available. However, the ultimate question is really not “is there a change?” The question is “do we choose this change to fix before all others?” Even without much precision in determining assimilative capacity, gross differences can easily be seen between risks posed by different uses of natural systems. Development of a sustainable use strategy might begin with reducing those human activities known to have deleterious effects upon natural systems and then progressing to the presently undetectable changes after known deleterious changes have been remediated.

Criticism #3: Assimilative capacity is free.

For the most part, ecosystem services have been provided at no cost to human society. The economic system has not allowed pricing for either short- or long-term services provided by ecosystems. This is an obvious distortion of their actual value. The supply of assimilative capacity is clearly finite, yet desirable to many users. Similarly, the supply of other ecosystem services is finite and the market global. Avise (1994) calculated that replacing basic ecosystem services (i.e., provision of food, breathable air, drinkable water, waste processing, etc.) through technological means in Biosphere 2 cost $9 million per person per year. Even given the economies of scale, a technological fix for loss of ecosystem services does not seem viable for the near future.

Explicitly coupling the use of assimilative capacity to the economy makes sense. One concept of a market for assimilative capacity would create tradeable units for each body of receiving water (e.g., Stebbings, 1992). The total number of units available would be less than the amount of discharge that would cause unacceptable harm, then these units could be freely traded. Industries and conservation groups could vie to accumulate units. One problem with this approach is that the number of units already in use may well exceed existing assimilative capacity. Another problem is that the units are inequitably distributed. Inequities over space mean developed nations produce more waste and use more assimilative capacity than developing nations. And, if assimilative capacity is exceeded and natural systems are harmed, assimilative capacity will diminish along with other ecosystem services. In that case, the units are also inequitably distributed over time with the present generation using too many units, which would result in fewer units for future generations.

Conclusion

Sustainable use of the planet will only be possible if the integrity of natural systems is maintained by not exceeding their assimilative capacity. Regrettably, it is not known whether enough ecosystems are presently available to supply all the ecosystem services necessary for sustainable use of the planet. It seems a matter of simple self interest not to destroy the natural systems upon which society depends for many uses by overusing them as waste disposal systems and exceeding their assimilative capacity.

Because the planet has been inhabited for millions of years by many species, the assimilative capacity concept seems plausible. The ecological collapse of ancient civilizations (e.g., Diamond, 1994) indicates that a limit exists to the abuse that ecosystems can endure. Skill will be required to balance the two components – ecological and technological – of human society's life support system. Ecosystem health should play a pivotal role in developing this important information base because, by protecting ecosystem health, all uses of a natural system are sustained and sacrificing one use for another is avoided.

If the present situation is viewed as a co-evolution of natural systems and human society (e.g., Cairns, 1994, 1996) in which a life support system is preserved with both technological and ecological components, then the feedback of information from natural systems must be sufficient to ensure that their integrity is not destroyed as a consequence of focusing on human society's life support system. The concept of assimilative capacity is based on the assumption that natural systems can be used but should not be abused. Viewed from this perspective, the production of technological services must be balanced with the preservation of delivery of ecosystem services, which will require restraint in the production of the former. As a result of this view, assimilative capacity is arguably the key to sustainable use of the planet. In addition, a healthy ecosystem will provide many services to human society other than assimilative capacity. Therefore, while the capability of assimilating wastes and other products no longer useful to human society is definitely an important service for sustainable use of the planet, sustainability also requires maintenance of atmospheric gas balance and maintenance of the genetic pool necessary to meet changing climatic and other conditions in a variety of other activities. Therefore, assimilative capacity should be considered as one of the many benefits of ecosystem health and integrity. It is worth re-emphasizing that excessive focus on one service might well cause impairment of other services. The best way to avoid this is to ensure ecosystem health and integrity, which will then automatically ensure that the services provided to human society by ecosystems will continue and, thus, foster sustainable use of the planet.

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Article 12

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Exemptionalism vs Environmentalism: The Crucial Debate on the Value of Ecosystem Health

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Abstract

The concept of exemptionalism holds that human society is exempt from the biophysical laws that control other species because of human ingenuity, technology, creativity, and economic systems. Some economists believe that resource depletion is irrelevant because alternative resources will be developed if there is enough demand backed by money. A related statement is that any problem created by technology can be resolved by technology. Within these frames of reference, ecosystem health is of minor, arguably no, importance to the exemptionalist.

The concept of environmentalism views *Homo sapiens* as just another biological species that is tightly controlled by biophysical laws, but which is able to modify the biophysical laws more than other species. This view acknowledges human society's dependence on ecological life support systems and the services they provide and assumes that the well-being of human society is closely linked with the health of natural systems. Only within the later framework will ecosystem health be a major concern of human society.

Keywords: Sustainable development; Carrying capacity; Sustainability; Biophysical laws

> I know of no instance in which a species of plant or animal gives willing support to another without extracting some advantage in return.
>
> Wilson as quoted in Larson (1998).

1. Conditions that gave support to belief in exemptionalism

One school of thought (exemptionalism) believes that human ingenuity and technology provide continuing opportunity for economic growth and solutions for limits to growth; that economic activities create more than they destroy; and that the history of the world refutes claims of limits to growth, carrying capacity, and other assumptions of dependence on organic, natural systems. Exemptionalists can point to situations, such as the Great Depression and World War II, where seemingly insurmountable obstacles were overcome. During the Great Depression in the United States, I remember sitting by our Atwater Kent radio and hearing then U. S. President Franklin Delano Roosevelt state in his inaugural address that "the only thing we have to fear is fear itself."

During World War II, the situation in the Pacific theater looked grim for the United States and its allies. However, the United States was on the winning side of World War II, and prosperity returned to the country. In the long term, even the losers enjoyed prosperous economies and material abundance much greater than the pre-World War II level.

2. The ecologically destructive aspects of growth

This progressive improvement in the human condition was clearly the result of human ingenuity, resourcefulness, and technological advances, but also resulted in unprecedented destruction of ecological capital (e.g. old growth forests, top soil, species diversity, and the like). At present, however, human society must redirect economic growth so as to minimize environmental degradation and to preserve and enhance ecological health and capital, to the degree necessary to permit sustainable use of the planet.

The dominant world view focuses on increases in material goods, human life expectancy, and economic growth. The minority view (environmentalism) is that leaving a habitable planet for future generations requires major attention to the health and condition of the ecological component of Earth's life support system. As a caveat, there are many variations of both environmentalist and exemptionalist positions, but it is abundantly clear that there is little, if any, middle ground for the two positions.

3. The consequences of choosing the wrong paradigm

If the exemptionalists are wrong, human society is in for some major destabilizing events. If the environmentalists are wrong, needless adjustments will have been made. For example, exemptionalists believe that exponential growth can continue on a finite planet. This scenario may actually be possible. But, environmentalists think it may not. This debate will mark a major threshold in the history of human and other species whatever the outcome.

Schrader-Frechette (1991) describes a risk spectrum with cultural relativists (who believe that risks are cultural constructs) at one end and naive-positivists (who believe that different risks may be evaluated by the same rule and that risk assessment is completely objective, neutral, and value-free) at the other end. Cultural relativists underestimate or dismiss the scientific component, and the naive-positivists underestimate or dismiss any ethical components. Arguably, a third group – exemptionalists (e.g. Simon's debate in Myers and Simon (1994)) – believes that human creativity and technology exempt human society from the biophysical laws of nature (e.g. limits to population size) that affect other species. A related but less sweeping view (a fourth group?) is that a technological solution exists for every problem created by technology. Both latter views are especially dangerous since they diminish the importance of risk assessment and analysis and depend to a large degree on economic/technological solutions to problems after the consequences have appeared in clear-cut, unmistakable form. However, a primary purpose of risk assessment is preventing harm whenever possible. Surely, there is no zero risk for either economic or technological approaches because both reduce public apprehension about potential risks rather than provide an additional incentive to gather evidence designed to reduce uncertainty, thus providing a sounder basis for risk reduction. Finally, benefits and costs, including human health and the environment, are unlikely to be distributed equitably and fairly, especially when there is an incentive for those who will benefit disproportionately to minimize risks to the general public. Probability distributions do not assure equity and fairness among the entire population, especially when there are vast differences in per capita income. For example, wealthy nations produce a disproportionate amount of greenhouse gases; however, if global warming occurs, both rich and poor will be affected. This scenario is especially true for low lying areas (such as the Maldive Islands) that will suffer from moderate sea level rise.

Human society benefits from a variety of ecosystem services (such as maintenance of the atmospheric gas balance, transformation of waste materials) (e.g. Westman, 1978; Cairns, 1997a; Daily, 1997), which are of tremendous economic value (e.g. Costanza et al., 1997) even though human society is not now directly paying for them. Until the agricultural and subsequent industrial revolutions, humankind's global life support system was entirely ecological. Human society is still taking much from other species, even though (arguably) they outnumber humans as much as 50 million to 1. Nevertheless, little of value is returned to natural systems by human society (Wilson, 1998). The quest for sustainable use of the planet has as a sine qua non that human society will return something of value to natural systems so that ecological integrity of the natural systems is maintained and a habitable planet may be passed on to humankind's descendants. This assumption is basic to The Natural Step Program (e.g. Robèrt et al., 1997) and is the foundation of other publications (Tibbs, 1992; Hawken, 1993). My own views on how to achieve sustainable use of the planet from an ecological standpoint are summarized in another publication (Cairns, 1997b).

Environmentalists acknowledge that human society is *a part* of nature, not *apart* from it. They acknowledge dependence on a life support system that is both ecological and technological, although more extreme environmentalists might not acknowledge the latter. Nevertheless, with the present human population size and level of affluence, as well as population concentration in cities, there is little doubt of dependence on a technological component to the life support system. This dependence is most evident in disruptions in the delivery of technological services caused by strikes, earthquakes, hurricanes, floods, and the like. For members of many ecological societies, who go beyond protecting ecosystems from observable harm and damage to espousing ecosystem health or robust condition, there is a considerable awareness of the services and other amenities provided by ecosystems to human society and a concomitant awareness that the technological component of the life support system often damages or impairs ecosystem health through fragmentation, toxicants, loss of area, introduction of exotic species, and the like. Cairns (1994, 1996) espouses achieving a balance between the ecological and technological components of the life support system. This balance is also the aspiration of those advocating sustainable development, sustainable use of the planet, and other terms and concepts with similar goals. If human behavior changes so as to balance the technological and ecological components of the life support system, which will permit sustainable use of the planet, then human society and natural systems will be co-evolving (e.g. Cairns, 1997c). Achieving sustainability will require a major paradigm shift for human society. Although most people would immediately subscribe to the notion of leaving a habitable planet for their descendants, the status quo will prevail until changes in present practices necessary to do so are brought to their attention (as well as the consequences of not doing so). An even more insidious paradigm (arguably as influential in practice as the environmental paradigm) is exemptionalism!

I first encountered the use of the term exemptionalism in the writings of Wilson (1993; subsequently reprinted in Wilson, 1996). However, this idea is not new in the 1990s. Simon (1981) certainly espoused this point of view when he indicated that humans are no longer resource-dependent to the degree that other species are. The depth of support for this belief of exemptionalism is well documented in the obituaries of Simon (Anon., 1998; Sowell, 1998). Regrettably, the two contrasting views of exemptionalism and environmentalism are not often presented adequately, although a notable exception is a debate by Myers and Simon (1994). Myers (1997) has updated his views on one aspect of this debate.

4. Problems with exemptionalism

1. Despite past successes, such as the green revolution, there is no assurance that accomplishments will continue at a rate of development that will free human society from the biophysical laws of nature.
2. Absence of evidence about risks does not mean the risks are not present.
3. Multigenerational equity and fairness (the core component of sustainable use of the planet's resources) require that future generations have as much ability to use a resource, such as water, as present generations.
4. Continuation of the delivery of ecosystem services requires that the natural systems that provide them have resources (e.g. land and water) allocated to them. Technological substitutes that satisfy human needs may not be adequate for natural systems.
5. Many of the technologies designed to replace ecosystem services do not appear to be cost effective (e.g. Avise, 1994; Costanza et al., 1997). Some potential options do not appear technically feasible.
6. World population growth and increased per capita consumption may outstrip the rate of development of technological alternatives. For example, the United Nations (1996a) concluded that freshwater use has been growing at more than twice the rate of population increase during this century, and already a number of regions are chronically water short. The report also concludes that about one-third of the world's population lives in countries that are experiencing moderate to high water stress, resulting in part from increasing demands that are fueled by population growth and human activity. The report estimates that, by the year 2025, as much as two-thirds of the world's population will be under stress conditions. Thus, a bad situation may rapidly worsen and increase the risk that technological developments will be too slow and that natural systems will be deprived of both the quality and quantity of water needed to preserve their integrity. I focus on water because it seems unlikely that a cost-effective substitute will be developed and because the hydrological cycle is so important to both human society and natural systems. Moreover, the quantity of water on Earth is fixed, so preservation of quality becomes very important.
7. Even if human society were entirely independent of natural systems, it is morally and ethically responsible for preservation of natural systems.

Human society has had a major effect upon natural systems even during the long "hunter/gatherer" stage. The impact increased significantly with the development of agriculture roughly 10,500 years ago (e.g. Diamond, 1997). Unquestionably, species that are sensitive to anthropogenic effects have declined or have become extinct (e.g. Wilson, 1988) and resistant species have increased (i.e., pests). Just how long this ecological adjustment can continue without resulting in major disequilibrium is uncertain.

5. Uncertainty, risk and the burden of proof

Unquestionably, settlement and development of sparsely inhabited lands, such as North and South America and Australia, have relieved population pressures on world resources during the past 200 years, as have technological developments in agriculture, energy, transportation of food, and the like. The United Nations (1996b) has reported that there were three regions with an average life expectancy of below 50 years: Eastern Africa, Middle Africa, and Western Africa. The lowest life expectancies in the world are in Rwanda (22.6 years), Sierra Leone (34.4 years), and Uganda (41 years). Further, only inhabitants of the developed countries are living an affluent life in sizable numbers (and not every individual even in them). The less developed countries and developing countries have billions of people with an income of US$ 2 per day or less. Earth unquestionably is supporting a far larger population with longer life expectancies, less disease, higher levels of affluence (particularly in the developed countries), and a number of other benefits that improved the human condition. On the other hand, natural resources (such as old growth forests, top soil, groundwater, and a number of other resources) are being depleted at a rate that is not sustainable. The only way that one can justify continued increases in levels of affluence as measured by resource depletion is to assume that resource substitutions can be made; however, again, there is no substantial evidence for infinite substitutability of new resources for depleted ones. As Miles' (1995) translation from the German *Damit die Deutschen nicht Aussterben* ("Saving the Germans from Extinction") notes, "the previous one-way street – even less work for an ever higher standard of living – will come to an end, not only on ecological, but also on demographic grounds." As the mutual fund prospecti are so fond of saying: past performance does not guarantee future results! Are people to believe that the planet's ecosphere is more predictable than the stock market? If not, how can it be assumed that technology will be able to solve every problem it creates or that human ingenuity will solve every problem it creates? Some ancient myths and fables (such as the Greek myth of Icarus, who wished to be free of the law of gravity and fashioned wings that initially looked promising but ultimately failed) illustrate the dangers of overconfidence. Confidence is certainly admirable, but hubris can easily result in disaster if human society really believes that it is immune to the limitations that affect other species. The past 200 years do not validate the assumption that human society can continue the practices of these two centuries indefinitely. In geological or ecological time, this span is really a tiny fraction of time. As Wilson (1984) notes: "When very little is known about an important subject, the questions people raise are almost invariably ethical. Then as knowledge grows, they become more concerned with information and [become] amoral, in other words, more narrowly intellectual. Finally, as understanding becomes sufficiently complete, the questions turn ethical again." In this regard, I find it interesting that the number of theologians commenting on the human condition and relationship with the environment seems to be increasing. For example, Austin (1998) feels that the collapse of the international economic system can revive imaginative social, economic, and political discourse about Earth's condition. Wall (1997) believes that, rather than concentrate on economic development, human society needs to think about economic stability, that is, economic sustainability. Some writers (Anon., 1997) are even espousing pursuing moral solutions to environmental problems. Despite these courageous and badly needed statements and opinions, it seems fair to say that human society is more inclined to embrace the economic growth paradigm than the ethical and moral paradigm with regard to the environmental condition. Economic growth is viewed as the solution to all human problems – overpopulation, poverty, ethnic conflict, and the breakup of the nuclear family. Environmentalists are viewed as the ones who are blocking the development of enough resources to last indefinitely and to spread affluence to the impoverished peoples of the world.

The key issue is: which group should bear the burden of proof? Since I have spent much of the last 50 years of my professional life on problems of ecotoxicology, it seems that assertions of no harm resulting from exposure to a particular new chemical, for a specific length of time, under well-defined conditions should be based on more than lack of robust evidence. I expect to see persuasive evidence before risking personal exposure and believe the burden of proof should fall on those putting me at risk.

The exemptionalists claim that the biophysical laws operative for billions of years are now invalid because of technological developments of the last two centuries. Surely, if humans were truly exempt from natural laws, then most would not be living in the poverty that affects the majority of the world's peoples. In any case, the burden of proof of this assertion should be on those making the assertion. Environmentalists may have slowed the planetary spread of human artifacts and effects upon natural systems slightly in some developing countries, but, even in these, development at the expense of natural systems has been slowed but not stopped. One could argue that destruction has not been slowed much. Exemptionalism is an unproven, unvalidated hypothesis that surely needs more robust supporting evidence before the future of human society depends on it! The old adage, "if something seems too good to be true, it probably is" seems appropriate in this regard.

Weston (1995) lists a series of conditions leading to the call for sustainable development:

1. increasing population densities;
2. concentration of populations in urban areas;
3. increasing rate of per capita resource use;
4. overharvesting of renewable resources;
5. exhaustion of nonrenewable resources;
6. mismanagement of natural capital;
7. degradation of environmental quality;
8. extinction of species;
9. greater risks to individual human health, safety and security;
10. increasing disparity in living standards;
11. escalating terrorism, local warfare, and threats to national security.

Surely it would be insane to expect technological solutions to all of these problems when changes in human behavior and practices using technologies presently available can markedly reduce the environmental impact of human society upon natural systems and upon itself. Some researchers have already provided practical, implementary solutions to many present problems without invoking exemptionalism (Tibbs, 1992; Hawken, 1993).

How are those of us interested in ecosystem health going to cope with the exemptionalist view? The public is faced with conflicting views that global warming is a hoax and that global warming is a high probability. Partly, this conflict is a battle between empiricists and modelers. However, when the issues cover large temporal and spatial scales and the body of evidence is often at the wrong level of biological organization (i.e. single species versus landscapes), the conflict becomes more complex. In the United States and, regrettably, in many other countries of the world, there is a focus on individual rights, instant gratification of perceived "needs," and a deep impatience with any failure to get immediate results on any problem. In some fairly large subcultures, science is regarded as just another point of view – no better or worse than any other point of view regardless of the weight of evidence. The evidence is, of course, considered to be biased and gathered primarily to further a particular set of beliefs. The process of science, which weeds out and discards erroneous ideas or hypotheses that cannot be validated or confirmed, is essentially ignored. Worse yet, the increasing tendency to insist that all views be heard ignores that the mainstream in science may hold firmly to the high probability of global warming occurring, but the preponderance of scientists supporting this idea is not given serious consideration in the news media. Furthermore, the increasing insistence on incontrovertible evidence (in the parlance of the US legal system, "the smoking gun") permits massive evidence to be ignored, as it was in the controversy over cigarette smoking in the United States, even after then Surgeon General C. Everett Koop made a lucid and persuasive case regarding the danger of cigarette smoking. Scientists are accustomed to probabilistic statements based on scientific evidence, but, increasingly, the general public does not trust the conclusions because of a massive counterattack by financial groups who feel threatened by the conclusions of mainstream science. As I have pointed out elsewhere (Cairns, 1997d), yet another consequence of the increasing temporal and spatial scale of environmental problems is an increase in the uncertainty of the predictions of environmental outcome and consequences. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made on any environmental problem. However, they are linked – acting with an intolerance of uncertainty often demands a high tolerance for risk. If the consequences are severe, one should be willing to act even in the face of high uncertainty; impairment of ecosystem health definitely falls in this category. Absence of information does not mean absence of risk. Many years ago, before germ theory was developed, surgeons routinely went from one operation to another without washing their hands. The consequences of this practice were suffered by their patients, even if the underlying theory of cause was far from robust. Funding for and support for research has declined in many developed countries and was minuscule in the less developed and developing countries to begin with. This withdrawal of funding comes at a time when, arguably, humankind's worst environmental crises may well manifest themselves in the first half of the next century. I firmly believe that we must continue to gather evidence regarding ecosystem health and continue to educate the general public and its elected representatives that absence of certainty (the smoking gun) does not mean absence of risk while the evidence gathering takes place. However, time may now be too short to rely entirely on scientific evidence, especially given the conditions just described. Therefore, it seems prudent to try to rely strongly on the ethical approach while, at the same time, getting as much robust scientific evidence as possible. From an ethical standpoint, some of the following illustrative questions may be useful.

1. Does the exemptionalist paradigm excessively discount or ignore socially imposed long-term risks?
2. Is there some way to validate the exemptionalist paradigm other than using historical evidence, primarily from the last 200 years? Why should not exemptionalist predictions be given the same systematic and orderly scrutiny that is given to predictions of ozone depletion, global warming, and the like?
3. Even if the exemptionalist view is correct and we no longer need other species, is it an ethically sound position to destroy them because they are no longer needed? After all, they did constitute our life support system for most of our existence.
4. Are we so confident that our technological parachute will work that we are willing to depend on it even when there are alternative and proven ways of living in harmony with natural systems?
5. If we someday find that there are other intelligent species in the universe and that we are not necessary to their survival but are occupying space that they would find useful, have we any right to complain if humans are driven to extinction?
6. Do we really believe that we can control all species on earth, even those now able to elude our control (i.e. pests)?

7. Is it possible that we can produce pesticides so selective that they will only affect the target species and not humans or the species that humans depend on?
8. Would it be prudent to develop a fail safe position until more robust evidence is gathered for the exemptionalist position?
9. How should predominantly exemptionalist cultures treat other cultures and ethnic groups that consider all life to be sacred?

6. Conclusions

I am optimistic about what human society can do toward sustainable use of the planet, but not encouraged that we will do so in time to avoid major human suffering far greater than that already endured by many of the planet's inhabitants. I am also concerned that the exemptionalist attitude may lead to a total disregard for other species, for which there is no incontrovertible evidence that they are of use to human society. This could easily lead to a disregard for those members of human society no longer perceived as useful. In a very real sense, our own humanity is inextricably linked to our treatment of the other species with which we share the planet. Callous treatment of them is but one step removed from such treatment of members of our own species. The members of this society should be deeply concerned because ecosystem health is of minor importance to exemptionalists.

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Article 13

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Is the Quest for Sustainable Use of the Planet Unworldly?

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Key words: sustainable development, unworldly, utopian, pragmatic, self-interest

SUMMARY

Is the quest for sustainable use of the planet utopian and unworldly, or an act of enlightened self-interest? Few would label the attempts to increase human longevity unworldly, yet what significance will it have in an unsustainable world? Achieving sustainability will require entire societies to emulate attributes that humans profess to admire in others. Among the dictionary definitions of unworldly are: not seeking material advantage and spiritually minded. Since our global life-support system is vulnerable to irresponsible individual and societal practices, the consequences of unethical behaviour and lack of compassion might well be catastrophic for human society. This paper consists of a preliminary exploration of some of these issues.

> What lies behind us and what lies before us are tiny matters compared to what lies within us.
>
> Ralph Waldo Emerson

This manuscript was inspired by a reader's thoughtful comments about one of my editorials (Cairns, 1999). I believe that sustainable use of the planet requires minimizing risks to its ecological life-support system. This belief is embodied in the precautionary principle, which asserts that it is prudent to attempt to diminish risks with particularly severe consequences, even if the probability of occurrence is moderate or the uncertainty high. The correspondent felt that 'the whole nature of the essay seems very otherworldly, austere, trusting, and to my mind, not very applicable to real situations or my discussions with those who might disagree with your ideas'. This comment is a very charitable summary of the doubts that are with me each time I write about sustainability. I need to confront these doubts, even if the result is not entirely satisfactory.

For those who believe that human ingenuity, creativity, and technology free human society from the laws that limit other species, these ideas about sustainability must appear ludicrous! To those who believe in a technological solution for every problem created by technology, my concerns are a predictable response by one who is technologically challenged. Economists who believe in the infinite substitutability of resources must feel that I have not paid attention to the dramatic events since Malthus published his essay on population just over 200 years ago. Finally, there are those who believe that, if individuals suffer the consequences of inappropriate choices, things will still work out for their species in the long run. Other alternative views exist, but the ones just mentioned are most on my mind.

In my opinion, no robust evidence supports any of the first three alternative views (i. e. freedom from limits; technological solutions to any problem; substitution of resources). Nor is there robust evidence to support the belief in sustainable use of the planet by *Homo sapiens*. Mass extinctions have occurred in the past, and the human species may be one of the losers if a mass extinction occurs in the future. Extinction could result from the impact of the planet with a large extraterrestrial object or because humans have fouled their own 'nest'. The first may be beyond human control, but not the second.

I am drawn to the quest for sustainable use of the planet because: (1) it acknowledges human society's dependence on other species; (2) it acknowledges that technology can modify but not ignore natural laws; (3) it focuses on leaving a habitable planet for future generations – a goal humans profess to admire, so why not practice it; (4) it encourages individual 'rights' to be exercised in ways that do not diminish the 'rights' of future generations or those of other species.

The flaw, perhaps a fatal one, is the basic assumption that sustainability requires substantial numbers of honest, ethical people with compassion for future generations, other species, and less advantaged living members of the human species. Even if such people exist, and I believe they do, manipulation of public opinion is a big business today. Successful manipulators are frequently rewarded with financial subsidies, even when their activities undermine public health and cause considerable environmental damage (e.g. see Myers, 1998). Society often rewards dishonest perpetrators of erroneous information with considerable financial gain. This side of human nature does not bode well for success in sustainability. One could easily be forgiven for adopting the stance 'When on the Titanic, one might as well go first class!' One of my colleagues, Scott Geller, studies 'road rage' and still believes in an actively caring model (Geller, 1994). His optimism makes me wonder if we are impoverished or enriched when our aspirations are so lofty that they appear unattainable.

In the United States, and elsewhere in the world, there is a considerable anti-science backlash. The Ehrlichs have called this 'brownlash' when it applies to 'green' environmental matters (Ehrlich and Ehrlich, 1996). One plausible reason for the backlash is that scientists frequently fail to distinguish between value judgments and probabilistic statements, as do economists and most other professionals. Still, scientists and other professionals should engage in social commentary, especially when their experience exposes them to evidence that bears on the value judgment being made. Some go too far ('Lake Erie is dead'), think that their discipline has all the answers, or are simply arrogant. Academe has always had the 'guns for hire' who will selectively gather evidence to support any position if the consulting fee is sufficiently large. No wonder the public is confused at best and hostile at worst. Most practitioners have trouble sorting through the issues in their profession. However, we should not refrain from making value judgments with humility and understanding, and always with references to other points of view that we do not espouse so the diligent person can examine both sides.

Accommodation to other points of view is mandatory for the resolution of problems that transcend the capabilities of a single discipline. Arguably, this strategy includes all major aspects of sustainability. It is a pity there are not enough planets to carry out controlled tests on the various speculations with which I began this discussion. Consequently, society must experiment on one planet, using both precautionary stances and assumptions that creativity and technology will solve all problems. In most cases, judging who will benefit from either course of action will be extremely difficult and, arguably, impossible in some cases. Excessive zeal will diminish useful experimentation; lax accountability will favour the exploiters.

If, indeed, limits to growth exist on a finite planet, they should become abundantly clear in the next century. Exploration at present of the issues and alternatives should facilitate decisions on appropriate actions if/when necessary. In this context, consider the following scenarios.

Scenario 1 – Humans are not exempt from natural laws that limit other species

This scenario is based on the assumption that the carrying capacity of the planet for humans cannot be increased indefinitely despite continued technological advances. World food reserves are presently low and some populous countries have been importing food for years (e.g. Brown, 1995). Recent turmoil in many parts of the world has occurred as a result of irresponsible conduct in the financial markets. Is it likely that irresponsible use of natural resources will have any less of a destabilizing effect? The essence of sustainable use of the planet is prudent use of resources, particularly the preservation of ecological capital. Just as prudent financial policy increases security, prudent resource use without abuse should increase sustainability. Failure to stay within the carrying capacity of the planet could cause massive human suffering and devastate natural systems.

Scenario 2 – Creativity, ingenuity, and technology exempt *Homo sapiens* from the iron laws of nature that limit all other species

This scenario assumes that resources are no longer limiting for the human species and that infinite substitutability for otherwise scarce resources has been achieved. It also assumes that materialistic needs have been fully met, but spiritual needs and ethical dilemmas remain. A few illustrative examples follow.

1. Since humans are no longer dependent on an ecological life-support system, what should their relationship with other species be?
2. How should human cultures that profess reverence for all forms of life be accommodated?
3. Should humans expect compassion from a technologically superior species that arrives on Earth from elsewhere in the universe and has no need for the human species?

This scenario needs to consider the idea that being free from resource limitations neither frees society from spiritual needs nor ethical responsibility. There are no technological solutions to these, arguably, unworldly issues. Cairns (in press) has a more substantive exploration of these issues.

Scenario 3 – Developed countries can reach an uneasy consensus on sustainability initiatives, but impoverished developing countries refuse to participate because they fear continuing inequities in the distribution of the world's resources

A better appreciation of this issue emerges by examining the *New York Times 1999 World Almanac* beginning on page 760. The following countries have 40 or more percent of their population under age 15: Afghanistan (42.9), Angola (44.9), Belize (42.2), Benin (47.9), Bhutan (40.1), Botswana (42.3), Burkina Faso (48.0), Burundi (47.4), Cambodia (45.4), Cameroon (45.9), Cape Verde (45.7), Central African Republic (43.9), Chad (44.2), Comoros (42.6), Congo (48.2), Democratic Republic of the Congo (42.6), Côte d' Ivoìre (46.7), Djibouti (42.8), Equatorial Guinea (43.1), Eritrea (42.8), Ethiopia (46.0), Republic of the Gambia (45.8), Ghana (42.9), Grenada (43.1), Guatemala (42.9), Republic of Guinea (43.9), Guinea-Bissau (42.4), Haiti (42.6), Honduras (41.8), Iran (43.3), Iraq (44.1), Jordan (43.3), Kenya (43.6), Laos (45.2), Lesotho (40.2), Liberia (44.7), Libya (48.3), Madagascar (44.7), Malawi (45.5), Maldives (47.2), Mali (47.4), Marshall Islands (50.0), Mauritania (46.5), Mozambique (44.9), Namibia (44.2), Nepal (44.2), Nicaragua (44.0), Niger (48.1), Nigeria (44.8), Oman (40.5), Pakistan (41.8), Rwanda (44.7), São Tomé and Principe (47.5), Saudi Arabia (43.0), Senegal (48.1), Sierra Leone (45.2), Soloman Islands (45.1), Somali (44.2), Sudan (45.4), Swaziland (46.4), Syria (46.1), Tajikistan (41.4), Tanzania (44.6), Togo (48.3), Uganda (51.1), Yemen (48.1), Zambia (49.2), and Zimbabwe (43.8).

Of course, population size x the level of affluence x the resource efficiency of technology = environmental impact; consequently, population size and age distribution are not the only factors to be considered. This list is not intended to minimize the problems of rapidly growing populations with less than 40 percent under age 15. The list illustrates the diversity of cultures and unique types of ecosystems involved, each requiring a different approach to sustainable use of the planet.

If *Homo sapiens* is resource limited despite creativity and technology, there is still no justification for despair, despite seemingly overwhelming obstacles. Even though creativity and technology do not free human society from universal laws, creativity and technology can be used to live sustainably within universal laws! The attributes of not seeking material advantage and being spiritually minded have brought justified deep respect to Mother Theresa, the Dali Lama, Mahatma Ghandi, Martin Luther King, and many others. Should society be reluctant to aspire to achieve, to a lesser degree, the attributes that are admired in others? To achieve spiritual mindedness, society must encourage a free and open exchange of ideas and beliefs with humility and understanding of other views. An open exchange does not require acceptance of all views, but it is an essential step toward consensus.

When sorting out my thoughts on different issues, I frequently turn to the Durant's (1968) book *The Lessons of History*. One of the major lessons is that, when inequities of resource distribution become too great, they are reduced by revolution or harsh political action. Historically, this action has occurred primarily within some political unit. However, it could now occur globally, given the ever-increasing globalization of economies. Since Darwin and Wallace, the scientific community has been aware of the incredible resource partitioning that natural systems achieve when free of human interference. The studies of Galapagos finches show that this partitioning can occur rather rapidly in evolutionary time. The lessons of paleontology, which cover much greater time spans than human history, teach that episodic, major ecological crises result in notable ecological disequilibrium, which is accompanied by mass extinctions of species and reallocation of resources. The quest for sustainability seeks to reduce the probability of anthropogenic ecological disequilibrium, which could easily have adverse effects upon humans, particularly the ones at or below subsistence levels. I find the quest for increasing human longevity rather curious because it does not seem to be linked closely to the nature of the world that the increased life span would permit humans to experience. The planet as an enormous human feedlot is not appealing! The compassionate view necessary to achieve sustainable use of the planet could also be described as enlightened self-interest. Individuals have never had control of their life-support systems, both ecological and technological. What is new is the capacity to destroy both!

CONCLUSION

If being worldly is defined as instant gratification of perceived materialistic 'needs', regardless of the condition of less fortunate members of the species, then one could justifiably be pessimistic about the implementation of sustainability initiatives. I fear what human society will do, but remain optimistic about what could be done to achieve sustainable use of the planet. It also remains possible that sustainable development is being used to reassure people that present practices can continue indefinitely. It is indeed curious that many segments of society, which have vigorously opposed almost all restrictions on their activities designed to protect the environment, have enthusiastically embraced the concept of sustainable development. There is a very real possibility that those who publicly endorse sustainability initiatives are being duped to provide an environmental facade behind which business as usual continues.

There is also the possibility that even the sustainability practices espoused by dupes may acquire a life of their own and be embraced by a reluctant society as a result of catastrophic consequences of present practices of human society. As Homer notes in *The Iliad*, ‘When damage has been done, even a fool can understand it’.

Of course, there is always the unthinkable possibility that the little creatures that really run the world will take over completely again if the larger creatures with larger brains fail (e.g. Wilson, 1993). Intelligence may be an evolutionary mistake that resulted in much ecological disequilibrium.

It may well be that my involvement with the quest for sustainable use of the planet is just an escape from reality. It worked well for Cervantes’ Don Quixote de la Mancha. However, my quest may actually benefit our own and other species to some small degree and provide some discussion of the alternative future for human society and its relationship to the 50+ million other species that inhabit the same planet!

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Article 14

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Maintaining the Habitable Condition of the Planet: Balancing Technological and Ecosystem Services

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Infinite growth cannot continue on a finite planet. One reason is that human society is dependent on a life-support system that is both technological and ecological. Ecosystem services (including regeneration of topsoil, maintenance of atmospheric gas balance, cleansing of water, and maintenance of a genetic library to meet climate changes, whether induced by humans or by nature) are provided by nature. In meeting the perceived needs of human society, the ability of the ecological life-support system to deliver services may be compromised. To prevent this, human society will have to undergo major changes in behavior. Change will be facilitated if a common sustainability paradigm is accepted to meet certain conditions and goals. The main goal is to provide human descendants with a habitable planet, and this entails protecting natural systems that provide necessary life-support functions. If this goal is accepted, then a number of goals can be stated and the conditions necessary to meet these goals can be outlined.

SETTING THE STAGE

As the eminent ecologist Eugene P. Odum (1992) noted, a certain amount of confrontation is necessary to maintain order and to protect territories and cultures, but more important are the peace and cooperation needed to maintain human quality of life. Odum used as an example the relatively recent (at the time of Odum's remarks) dramatic shift in the relationship between the two superpowers, the United States and the then Soviet Union, and the increased production of weapons purportedly for defense. However, the cost of this confrontation reached approximately 15% to 20% of the wealth of each nation and resulted in a perceived neglect of consumer, social, and environmental needs. The pressure to address these internal needs became increasingly urgent, and the opportunities to shift from the Cold War to cooperation, arguably even were welcomed by both countries. Although the transition has proved difficult, there seems to be little support for returning to a Cold War confrontation. Similarly, the end of the confrontation between the industrialist and environmentalist is long overdue. Cairns (1996) notes that human society's life-support system is both technological and ecological. The technological services are well understood and need not be outlined in this article, but the ecosystem services (those ecological functions perceived as useful to human society) need to be more fully described for the benefit of many who view themselves as environmentalists. This does not mean that species and ecosystems should not be treasured for their own inherent value, but rather that society also must acknowledge its dependence on them. Illustrative examples of ecosystem services follow.

- Capture of solar energy and conversion into biomass, which then is used for food, building materials, and fuel
- Decomposition of wastes such as sewage
- Regeneration of nutrients in forms essential to plant growth (e.g., nitrogen fixation)
- Storage, purification, and distribution of water (e.g., flood control, drinking-water purification, transportation)
- Generation and maintenance of soils
- Control of pests by insectivorous birds, bats, insects, and other species
- Provision of a genetic library for development of new foods and drugs through both Mendelian genetics and bioengineering
- Maintenance of breathable air
- Control of both microclimate and macroclimate
- Provision of buffering capacity to adapt to changes and recover from natural stresses such as flood, fire, and pestilence
- Pollination of plants, including agricultural crops, by insects, bats, and other species
- Aesthetic enrichment from vistas, recreation, and inspiration

Additional discussion of these services may be found in Cairns (1997a), Cairns and Niederlehner (1994), Westman (1977), and Ehrlich and Mooney (1983). With the present human population density, distribution (i.e., strongly urbanized), and levels of affluence, society clearly is dependent on technological services, although this has not been true for most of human history. Regrettably, development of technological services already has had serious impacts on natural systems and almost certainly will affect the reliable delivery of ecosystem services. Using the term *ecosystem services* has drawbacks. The most worrisome is the possibility that, as a consequence, ecosystems will be considered commodities. In a sense, this situation is already manifested when the term *natural resources* is used. On the other hand, those who do not presently place a high value on ecosystems may alter their attitude if they become more aware of their dependence on ecosystem services for societal survival.

Attempts to achieve sustainability are likely to draw the environmental and industrial communities together, because a cooperative effort and a sharing of a common paradigm will be needed for sustainability to succeed. Many people still feel that human ingenuity and technology can replace the services provided by ecosystems. However, Avise (1994) noted that in Biosphere 2 (Biosphere 1 is Earth) the cost of providing ecosystem services through human engineering was a staggering $9 million per person per year. Even then, Biosphere 2 was not as self-maintaining as Biosphere 1. To maintain life support in Biosphere 2, electricity was utilized at the rate of 700 kW per hour and natural gas at a rate of 23 million kJ per hour (Dempster, 1993).

SUSTAINABLE DEVELOPMENT: HOPE FOR THE FUTURE OR SOPHISTICATED DENIAL?

Although a number of authors have focused on the problem of sustainability, crucial political attention only relatively recently has been given to this subject with the publication of the World Commission on Environment and Development's report (1987). This commission was chaired by then Prime Minister of Norway, Gro Harlem Brundtland. In the commission's report, *sustainable development* is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This report also asserts that the present trends of economic development and consequent damage to the environment are unsustainable and that the survival of human society requires substantive behavioral changes immediately. In many portions of the planet, the word *development* is associated with replacing natural systems with human artifacts such as cities, shopping malls, highways, and industry. Perhaps in response to this all too common definition of development, the United Nations Education, Scientific, and Cultural Organization issued a report (1991) edited by Goodland et al. (1991) that distinguished between economic *growth*, that is, becoming larger or quantitative growth, and economic *development*, getting better qualitative growth, without increasing the total consumption of energy and raw materials beyond a level that is reasonably sustainable. Nevertheless, it is difficult to change the definition of development from a long-held interpretation of replacement of natural systems with artifacts (housing tracts and shopping malls) deemed useful to human society. The intent, of course, is to provide a habitable planet to future generations. Odum (1997) notes that sustainable growth or sustainable development can be interpreted as maintaining balances and resources into the future, or, alternatively, as continuing to sustain growth forever (bigger is obviously better). Odum (1997) prefers the word *maturity* to describe these goals for society, because individuals experience the difficult transition from physical growth to maturity and thereby understand what is really involved in going from quantitative to qualitative development (i.e., from getting bigger to getting better). Odum's definition seems to fit the goals of the Earth Summit convened in 1992 in Rio de Janeiro, Brazil. The Earth summit did note that some means of combining economic and ecological needs is essential. However, as Odum notes, humans usually wait until a problem gets really bad before taking action. Good environmental planning is acknowledged, but nothing is done until the consequences of bad planning have been suffered, sometimes repeatedly. It is also possible that society is in a state of denial (Orr and Ehrenfeld, 1995) about the consequences of the various ways in which the environment is damaged, species are driven to extinction, and the human population on the planet may be exceeding the carrying capacity, even though technological advances have temporarily diminished many of the consequences.

Basically, the worst polluters are also the worst-managed industries. Nevertheless, they can survive because there are still parts of the planet where any industrial development will be received with open arms, possibly even subsidized. The frontier paradigm still flourishes in some parts of the United States, which is interpreted as the right to do whatever one wishes, not only with private property, but with government land. Ironically, some of the strongest opposition to government subsidies with adverse environmental effects comes not from environmentalists but from already established industries that feel they are being given an unfair competitive advantage. A quite vocal, although arguably less well-organized, group is the taxpayers, who feel that taxes are already too high and should not be raised to pay for improvements that will attract newcomers who will need more schools, police services, and the like or who feel that already overcrowded schools should be renovated before more industry is attracted.

Obviously, however, cooperation between all components of society will be necessary to achieve sustainability. Fines for poor management resulting in environmental harm are still appropriate, even though a sense of public obligation is by far preferable. On the other hand, in the United States at least, it is far cheaper to sue in court, not only because implementation often can be delayed, but also because some technicality often can be used to avoid any payment of fines.

THE SUSTAINABILITY DILEMMA FOR INDIVIDUALS

The concept of sustainable development is intellectually and ethically satisfying, but is not presently helpful in making individual decisions. Individual decisions, for most people, almost certainly will be based on compassion for other individuals, now living and not yet born, of their own species and for other species with which they share the planet. However, over 30 million of these other species may exist, and individual humans have difficulty coping with such large numbers. Most people have equal difficulty in thinking about ecosystems or natural systems comprised of large numbers of species. Even ecologists tend to focus on populations as a more manageable unit. The general public usually concentrates its individual compassion on charismatic megafauna or species portrayed as having particular characteristics: cuddly (koalas), stately (cranes), free (wild horses, eagles), humorous (monkeys, penguins), powerful (lions), or wise (owls). Regrettably, these attitudes are acquired more often from films, books, and the like than from personal observation. Walt Disney Studios' film *Bambi* strangely has influenced many generations worldwide and arguably has become the most enduring statement against hunting in the American culture. A national, even global, debate is being waged about hunting and other means of controlling populations of deer and other animals that have greatly exceeded the carrying capacity of local and regional habitat. At one extreme are those who feel that, since humans have eliminated the large natural predators, humans are obligated to keep game species in balance with their environment. At the other extreme are those who value the lives of individual wild creatures and seek to prevent their destruction. Keeping in balance with nature is the essence of sustainability. This balance would permit the largest numbers of humans to occupy the planet over a long period of time. Properly managed sustainability should concomitantly make the planet more habitable for other species. The position taken in this discussion is that targeted compassion for charismatic species rather than for ecosystem integrity is inappropriate for sustainable use of the planet – it will not leave a habitable world for future generations.

ESTABLISHING GOALS AND CONDITIONS FOR SUSTAINABILITY

The goals and conditions briefly outlined here are discussed in greater detail elsewhere (Cairns, 1997b). Certain conditions must be met that should result in sustainability, or a habitable planet. However, a common paradigm must be agreed upon first. This paradigm may be expressed most easily as a series of goals. Each goal has at least one condition that must be met in order to achieve that goal, some have as many as four, and a few conditions have subconditions. This list is not complete, by any means, because it hardly seems likely that a habitable planet could be maintained with so few goals, conditions, and subconditions, even for the ecological components of sustainability. Rather, the list should serve as discussion initiator, that owes its genesis to the Natural STEP program initiated in Europe and the USA National STEP program that subsequently was established. A greatly condensed summary of goals and concomitant conditions, without discussion of any, from the original paper (Cairns, 1997b) follows.

Goal 1

To assure that the machinery of nature has sufficient energy to deliver the necessary ecosystem services.

Condition

Human society shall not co-opt so much of Earth's energy that ecosystems can neither furnish services nor endure for substantial periods of time.

Goal 2

To avoid poisoning or impairing the machinery of nature by altering both the structure and function of natural systems by means of toxicants.

Condition

Substances extracted from Earth's crust or synthesized from raw materials must not be concentrated or dispersed in ways harmful to the biosphere (e.g., metals, oil, or pesticides).

Goal 3

To ensure that ecosystem services, such as the maintenance of atmospheric gas balance, favorable to human and other life forms continue at their present or, preferably, better levels.

Condition 1

The physical and biological basis for the services provided by nature shall not be systematically diminished (e.g., overharvesting whales or fishery breeding stocks).

Condition 2

Artifacts created by human society may not systematically increase on the planet.

Condition 3

A balance must exist between ecological destruction and repair – an obvious, almost platitudinous, statement; yet, this concept must be included in public policy.

Condition 4

Management strategies for sustainability must allow natural processes such as succession, evolution, predator-prey relationships, and the like to continue.

Goal 4

To devise a better balance in meeting short-term and long-term "needs" of human society.

Condition

Short-term human "needs" may not be met if doing so endangers the planet's ecological life-support system.

Subcondition 1. If a world food shortage develops, grains will be shifted from domesticated animals to humans, rather than conversion of more natural systems to agriculture.

Subcondition 2. Society must not depend on yet-undeveloped technologies to save it from the problems it has created.

Goal 5

To ensure that most of Earth's population has the opportunity for a high quality life.

Condition

Human population over the long term must be stabilized at a point where adequate per capita resources are demonstrably available.

Subcondition 1. When defining sustainable use of the planet, society should use quality of life as the primary criterion.

Subcondition 2. Human "rights" may not be met if the ecological life support system is endangered by doing so.

Subcondition 3. The majority of people and countries on the planet must accept a single paradigm on sustainable use of the planet.

Goal 6

To avoid a human-induced episodic environmental catastrophe that would cause much human suffering.

Condition

When employing environmental management strategies about which the precise consequences are still somewhat uncertain, large protective safety margins (i.e., either slowing development or carrying it out extremely cautiously) are essential until the outcome has been better defined and the consequences have been determined to be acceptable and not of significance to long-term sustainability.

Goal 7

To diminish the conflict between generations caused by U.S. Social Security and Medicare, and elsewhere by the perception that future generations will lead impoverished lives because of present greed.

Condition

Older people must become deeply involved in sustainable use of the planet to demonstrate by deeds, not words, the older generation's concern for generations to follow.

Goal 8

To reincorporate all waste from human society into natural systems without damaging their integrity.

Condition 1

Materials that cannot be safely reintroduced into natural systems should not be produced.

Condition 2

Assimilative capacity of natural systems shall not be exceeded.

Condition 3

Robust predictive models must be developed regarding assimilative capacity, and these models must be validated and continually monitored to ensure that previously established quality-control conditions based on these two prior activities are being met at all times.

Goal 9

To develop equity and fairness in resource distribution within human society and with other species with which it shares the planet.

Condition 1

A sufficient majority of humans must acknowledge the reality of equity and fairness so that there is an incentive to preserve the ecological life-support system for sustainability.

Condition 2

Ethnic and racial strife must cease so that destructive energy can be rechanneled into constructive activities.

Goal 10

To develop a holistic sustainability initiative

Condition

Each specific or targeted sustainability initiative (e.g., agriculture, transportation, energy, cities, fisheries) must not act as if it is the only "flower facing the sun!" It will be difficult to orchestrate these special interests but, otherwise, holistic sustainability will fail.

CONCLUDING STATEMENT

Leaving a habitable planet for future generations will require the development of a widely shared paradigm to replace the "once-through" economic growth paradigm now in place. A paradigm shift from growth to sustainability might result either from suffering painful consequences of continuing to follow outmoded paradigms or by discussing what sort of ecosystems will be available for future generations.

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Article 15

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An Epic Struggle: Sustainability and the Emergence of a New Social Contract

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Abstract

Human society is addicted to growth on a finite planet. As is often the case for psychological dependence, contrary evidence is ignored and wishes are confused with reality. When Malthus noted that exponential growth of the human population was a major problem, he was ridiculed and scorned – a practice that has continued for two centuries. Those who believe in infinite substitutability of resources show no concern for the concept of sustainable use of the planet. This assertion has been termed *exemptionalism*, which holds that human ingenuity and technology provide continuing opportunity for economic growth and solutions for limits to growth; that economic activities create more than they destroy; and that the history of the world refutes claims of limits to growth, carrying capacity, and other assumptions of dependence on organic, natural systems. The opposing view, *environmentalism*, asserts that *Homo sapiens* is basically just another biological species that is tightly controlled by biophysical laws, despite its unique ability to modify natural systems more than any other species. Others believe that sustainability can be achieved by relatively modest changes in the present system. None of these groups has paid sufficient attention to the consequences of exponential growth of either human population or affluence. If human society continues on the present path – as many advocate – and this direction turns out to be wrong, cataclysmic events are highly probable. This scenario justifies the application of the term *epic,* since the transition will be traumatic rather than comfortable. The widespread expectation of economic growth rates of no less than 7 percent annually for some countries and no less than 10 percent for some industries simply cannot continue in a finite world. Some contrasting illustrative choices are provided here as a preliminary effort toward the development of a new social contract on the relationship of human society and natural systems.

The more optimistic the prediction the greater is the probability that it is based on faulty arithmetic or on no arithmetic at all.

– Bartlett (1994)

Bartlett (1997-98) is arguably the most outspoken critic of the loose, imprecise use of the term *sustainability*:

> *And so we have a spectrum of uses of the term "sustainable." At one end of the spectrum, the term is used with precision by people who are introducing new concepts as a consequence of thinking profoundly about the long-term future of the human race. In the middle of the spectrum, the term is simply added as a modifier to the names and titles of very beneficial studies in efficiency, etc. that have been in progress for years. Near the other end of*

> *the spectrum, the term is used as a placebo. In some cases the term may be used mindlessly (or possibly with the intent to deceive) in order to try to shed a favorable light on continuing activities that may or may not be capable of continuing for long periods of time. At the very far end of the spectrum, we see the term used in a way that is oxymoronic (p. 7).*

Development is customarily associated with growth. Sustainable development implies to many that minor adjustments in societal behavior are all that is needed to permit indefinite increases in the use of the planet. The tendency to discuss sustainability by components (e.g., sustainable agriculture, sustainable cities, sustainable transportation) leaves the impression that the status quo of each particular category will not be threatened, and it suggests that these are independent of each other. Even my favorite terminology, *sustainable use of the planet*, implies mainly human use, not necessarily use by other species.

Because achievement of sustainable use of the planet will require a major commitment of a significant majority of humans and political entities, there has been a reluctance to acknowledge the epic nature of the ideological struggle now underway. Although minimally poetic, the struggle is certainly of great size/extent both temporally and spatially. The components of an epic are present in the struggle between human society and other species for limited space and resources of a finite planet. The irony is that we appear to be dependent (exemptionalists would disagree) upon an ecological life support system made up primarily by other species that need a significant portion of these resources to continue functioning. The classical components of an epic struggle in this context follow: (1) cataclysm – loss and fragmentation of ecosystems and species impoverishment/social disruption, (2) rebirth – ecological restoration, and (3) heroines and heroes – e.g., Rachel Carson, Aldo Leopold, Edward O. Wilson. (During a visit to Virginia Tech in 1996, Norman Myers stated that the generation developing a harmonious relationship with natural systems will be viewed as heroic figures, as well they should.) Ecological restoration is a major component of this relationship (Cairns, 1994) because it is human society's partial atonement for the damage it has done to natural systems. This attempt to restore mitigates, to a degree, the harsh penalties exacted when one attempts to circumvent the laws of nature. Ironically, much of our research and technology are designed to avoid natural law.

The Epic Struggle

This epic struggle is not about the survival of nature, because many species will persist regardless of human society's practices. Much biological damage will be done, as in past major extinctions, but life will endure. Instead, the epic struggle concerns the survival of human society if the ecological life support system is badly damaged and the ecological island Earth becomes a far less hospitable environment for *Homo sapiens*. Biological diversification and concomitant ecological recovery, unaided by humans, have followed past major extinctions, but have required millions of years. Ehrlich and Ehrlich (1981) note Peter Raven's estimate that for every plant that vanishes, 10 to 30 other organisms go down with it. Thus, the ecological life support system could collapse rather quickly.

There is a second epic struggle concerning sustainable use of the planet that is not the focus of this discussion, but which deserves mention. Planning for the well-being of remote descendants forces each person to confront mortality. Many people fear making a will for this reason. Discussing the idea of leaving a habitable planet for remote descendants involves considering a future that does not include everyone, and this concept is frightening, arguably unthinkable, for many. It is important that the epic struggle to confront mortality not override the analysis of the other epic struggle that is the focus of this discussion.

Huxley (1957) describes humans as “evolution become conscious of itself.” Surely this revelation includes an acknowledgment both of human society’s dependence on other species and the cruelty of driving many other species to extinction to satisfy short-term perceived human economic needs! But traditionally, this admission is not the case.

What value system should human society use to deal with the following situation? As human population approaches 6 billion, there are tiny numbers of whooping cranes in North America, giant pandas in China, or golden lion tamarins in Brazil. And, these endangered species are the exceptions because most species are gone forever before human society even knows how they lived. Many species have not even been named. Should they be mourned less when they vanish because human society did not take the time to know them? Does ignorance of the consequences of their loss protect human society from risks? Does a callousness toward the fate of other life-forms presage a similar indifference toward members of the human species that are unknown and cannot be called by name? I would answer "yes" to this last question and note that population growth increases our indifference to the welfare of other humans. These illustrative questions are raised as a reaction to present exemptionalist beliefs (the belief that humans are exempt from the laws of nature because of the omnipotence of science and technology), which threaten the ability of humankind to leave a habitable planet for future generations. The "epic struggle" may result in a major paradigm shift. We are experiencing one of the greatest ecological dramas of all time, but we are missing the play because we are all bit players on the stage! As the human population continues to grow, each of us becomes a smaller part of the expanding whole.

The Cause of the Epic Struggle

The continuing economic growth paradigm touted by most elected officials, chambers of commerce, and the like is arguably the choice social contract of this era. The growth paradigm seems to be accepted by most citizens – probably because it is the only way of life that our political "leaders" espouse. Two growth areas cry out for attention: (1) growth of populations and (2) growth of per capita consumption of resources. The Public Television specials “Affluenza” and “Escape from Affluenza” document the way that many lives are dominated by the quest for material goods, but show clearly that many people are deeply concerned about the effects of consumerism on their own lives and the environment. (It seems ironic that videos of both programs could be purchased with credit cards, which exacerbate affluenza!)

One book on alternative lifestyles is the pioneering work of Helen and Scott Nearing (1979). I had the pleasure of hearing them lecture at the Philadelphia Ethical Culture Society in the 1950s and 1960s on their seminal book, *Living the Good Life.* An illustrative recent book has been written by Luhrs (1997), who also publishes *The Simple Living Journal* (Box 149, Seattle, WA 98103). In addition, what has been lost from the past is beautifully described in Brower’s (1990) autobiography. Neither he nor I deplore the technological advances that extend productive life (e.g., bypass heart surgery or blood pressure and diabetes control), but we do deplore ravaging nature for more and more material goods.

Table 1

Factors affecting population (Bartlett, 1994). Nature chooses from the right-hand column; people choose from the left-hand column.

Factors Increasing Population[1]	Factors Decreasing Population
procreation	*abstinence*[2]
motherhood	contraception
large families	abortion
immigration	small families
medicine	halting immigration
public health	disease
sanitation	war
peace	murder/violence
law and order	famine
scientific agriculture	accidents
accident prevention (55 mph speed limit)	pollution (cigarette smoking)
clean air	
ignorance of the problem	

[1]Many of the activities in the left-hand column are subsidized with taxpayer money (my comment, not Bartlett's). For details, see Myers and Kent (1998).
[2]Added by Cairns, with Bartlett's approval.

The New Social Contract

A new, desperately needed social contract governing human society's relationship with natural systems should be explicitly stated and should also ensure that future generations have at least the same opportunities to enjoy natural systems as the present generation: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on the Environment and Development, 1987). The contract could even go further and embark on an era of ecological restoration that would provide even better opportunities to enjoy natural systems than those of the present – approaching those Brower (1990) enjoyed in his early years. Cairns (1995) speculates that the integrity of ecosytems might be approximated by examining the practices of the human society inhabiting them. In short, much of their fate depends on human behavior.

Human society cannot achieve any of these goals if the number of humans on the planet keeps increasing and if economic growth (as now experienced) continues, unless humans are exempt from the biophysical laws of nature that apply to all other species, which, of course, they are not! There is persuasive reason for this belief. Natural systems have breakpoints or thresholds just as do elevators, bridges, electric power grids, etc. Until the threshold is crossed, all appears well. The problem is further complicated because thresholds are not fixed but modified by an array of other factors. Thresholds are recognized for humans in high stress professions (thus, such sayings as "the straw that broke the camel's back"). Technology has modified these biophysical laws by finding ways around them or substituting resources, etc., which some people interpret as abolishing or repealing the biophysical laws. This idea is an unfortunate interpretation and has scanty supporting evidence.

A new social contract (as always, I gratefully acknowledge the inspiration furnished by the Natural Step Program) governing human society's pledge to esteem other species with which it shares the planet and its common ecological life support system follows.

1. We will immediately balance ecological destruction and repair. This action is the only way to leave a habitable planet for our descendants.
2. The health of humans depends on the health of ecosystems. We affirm that other species have a right to a sufficient share of the planet's resources, including space, to ensure their survival. As a minimum, we pledge that ecosystem health will not be further impaired.
3. The owner of land is responsible for off-site damages that may result from activities carried out on the land.
4. Environmental debates should be on a level playing field. Politicians maintain that society can have growth and still save the environment if environmentalists will just compromise – read "give up." However, developers and environmentalists never debate as equals. The developers want to destroy a lot of the environment while the environmentalists want no destruction. If they debated as equals, the developer would say "I want to build this shopping center," and the environmentalist would say "Fine, take out that subdivision and restore nature on that site, then you can build your shopping center." Such a debate would be between equals – it never happens this way (Bartlett, 1994).
5. We pledge that the health and condition of the planet for both human society and natural systems will take precedence over affluenza (the addictive, never-satisfied quest for possessions).
6. We pledge to examine vigorously any claims of benefits for continued population growth of any kind.
7. We pledge to view exponential growth (as now understood) as a mechanism for increasing the imbalance of resource distribution both among human generations and among species.
8. We pledge to restore ecological capital (e.g., old growth forests, topsoil, quality water resources) at a rate substantively in excess of depletion rates.

Surely something this beneficial to future generations should be possible in a democracy.

Indices of Happiness, Misery, Sustainability, and Compassion

As I was completing the first draft of this manuscript, I received a call from a scientist in one of the government agencies asking about a Gross National Happiness Index (GNHI) that had come to my attention when Tashi Wangchuck, a citizen of Bhutan, was taking my field course on restoration ecology at Rocky Mountain Biological Laboratory in Colorado (Cairns, 1993). Tashi told me then that the concept could not easily be conveyed from one language to another and one culture to another. We were discussing Gross National Product (GNP), which would be increased if a hydroelectric power dam were constructed in Bhutan, but that such an activity might well not result in a concomitant rise in the GNHI of Bhutan. I recalled a proverb that happiness is like a butterfly; pursue it and it is exceedingly elusive; but sit quietly and it may light on your shoulder.

I think the point that Tashi was making is that happiness is not as quantifiable as the Dow Jones industrial average. Additionally, happiness in the American culture may be dominated by whether one possesses the latest computer hardware and software (if conversations in a university town are a good criterion) or, for the younger generation, possession of the fanciest automobile. But in Bhutan, although they have roads, most people walk and they are not yet, if pictures are any indication, a bicycle culture as is the People's Republic of China and as we are an automobile culture.

Happiness in Bhutan may be brought on by the arrival of cranes to the aquatic ecosystems near the monastery, whereas happiness in the American culture may be standing behind a rope and screaming at the television camera on one of the early morning TV shows.

The question is how human society can re-think its "mythologies" about the natural world in light of growth patterns never envisioned in the earlier, and still commonly accepted, world views. In a very real sense, it is a call for a paradigm shift, especially in the Western scheme of things, toward a position more compatible with Eastern religions/philosophies by putting aside for the moment the economic growth paradigm that now seems global.

Specifically, in the Eastern view (Hindu, Buddhist, etc.), the biosphere is part and parcel of the entire creation, which is inhabited by all sorts of life-forms. No one species can dissociate itself from the entire system, since life is a continuum in space and time, encompassing the "lowest" to "highest" life over a large span of time. Life-forms change state and status over time, but the universe continues to embrace them all. On this continuum, there are no hard division lines between humans and other animals, or even between animals and plants. Life migrates from one stage to another, depending on the degree to which it has conformed to its inherent role in the whole – a good ant can progress "upward" in the scale; a bad human can sink to a "lower" form of life. All actions have inevitable consequences at some point in time, although it may not be apparent to humans just when these consequences will become evident. Ignoring pedestrian crossovers may or may not get one caught by the police; however, violating laws will affect future driving habits. Not getting caught leads to the belief that the violation has no consequences. Getting caught may lead to better driving habits or a letter to the editor condemning the police. In short, the Eastern paradigm sees a more interrelated universe, closer to the ecological model, than the western version, closer to the economic growth model.

For Westerners (Jewish-Christian-Muslim), the biosphere is a backdrop for human activity (e.g., "subdue the earth") intended for human use because humans are a unique species. Only humans have the ability to make something new from existing materials. Some Westerners believe that human creativity and technology free us from the laws of nature that limit other species. Charles A. Kennedy (personal communication) notes that the word *paradise* borrows its meaning from the Persian formal gardens, related to the Mughal gardens of India, as well as the formal gardens of Europe. It is a fabricated garden, rigidly ordered, not a wild habitat.

Acknowledging our dependence on natural systems and penalties for violating natural law (the judgment motif) is ignored these days as a "gloom and doom" mentality. The idea of accountability and responsibility for actions is not very popular in an era of individual rights and freedom. But, the idea of infinite growth on a finite planet is untenable. Sooner or later, there will be an accounting. Elected officials, corporate executives, and many individuals hope that all the consequences will occur after they are out of office or dead. Here is where the notion of community needs to extend intergenerationally.

Arguably, this continuing debate began 200 years ago with Malthus' insightful publication. The basic problem is human population and affluence. In my opinion, the most difficult opposition comes from the "diverters." Bartlett (1998) notes that debaters of Malthus' theory could be divided into two camps: (1) believers and (2) critics, which include (a) nonbelievers and (b) diverters. The diverters he, in turn, divides into three groups:

> *The "other causes" group would have people believe that the problems of population growth are best addressed not by looking at the numbers, but by focusing our attention on other things.*

Table 2

Illustrative choices that will hamper or facilitate sustainable use of the planet.

1. Born to shop	1. Simple living
2. Exponential growth of resource use	2. Frugal use of resources
3. Flagrant individualism	3. Community spirit
4. Misery as the primary means of human population control (e.g., Boulding, 1971)	4. An enlightened social contract as the primary means of population control
5. Live for the moment	5. Compassion for future generations
6. Technology and ingenuity free humans from natural laws	6. Acknowledgment of human dependence on ecological life support systems
7. Species extinction, if it actually occurs, does not bother me	7. Humankind has an ethical and moral responsibility to cease anthropogenic extinction of other species
8. Economic development can and should raise all humans to the U.S. per capita level of affluence	8. The planet cannot support Earth's present population at the U.S. per capita level of affluence
9. Nobody can tell me what to do on my property	9. Property owners should be financially responsible for ecological damage resulting from their management practices
10. With low oil and coal prices, why spend money on alternative energy sources?	10. Solar and other alternative energy sources should be developed at an accelerated rate
11. No sharing of resources until human needs are fully satisfied	11. We should share resources equitably with other species – now
12. It is my right to drive wherever I please and own as many cars as I can afford	12. Environmentally, mass transit is essential for sustainable use of the planet

The sustainers try to convince people that we need not worry about population because "sustainable development" will solve the problems.
The "them:not us" group seeks to divert attention away from the population problem in the United States and focus people's attention on the growth of populations elsewhere.

The last point uses "elsewhere" to assign the consequences of the world's environmental crises to the nations with very high birth rates, conveniently ignoring the amount of the world's energy used by the United States and many other developed countries. These diversionary or marginalizing tactics have been used for environmental problems in general. Orr and Ehrenfeld (1995) believe that human society is in a state of denial about ecological problems, while Ehrlich and Ehrlich (1996) believe that there has been a substantive betrayal of science and reason. Both of these perceptions are probably operative and not mutually exclusive. Unfortunately, there is no clinic that human society can visit to solve these problems; a new social contract must be a self-healing process!

Conclusion

Few people faced reality as unblinkingly as the late Kenneth E. Boulding (1971)! I had the privilege of sitting beside him at a conference, which was eventually summarized in his "Ballad of Ecological Awareness" (Boulding, 1969). A small portion follows (with permission from Doubleday & Company, New York).

Development will conquer the diseases of the poor,
By spraying all the houses and by putting in the sewer.
And we'll know we have success in our developmental pitch,
When everybody dies from the diseases of the rich.

These four lines humorously describe today's situation, although it is nearly three decades since they were first written. Also, Boulding (1971) offers three theorems on human population limitations as follows.

> *First Theorem: The Dismal Theorem*
> *If the only ultimate check on the growth of population is misery, then the population will grow until it is miserable enough to stop its growth.*
>
> *Second Theorem: The Utterly Dismal Theorem*
> *This theorem states that any technical improvement can only relieve misery for a while, for so long as misery is the only check on population, the [technical] improvement will enable population to grow, and will soon enable more people to live in misery than before. The final result of [technical] improvements, therefore, is to increase the equilibrium population which is to increase the sum total of human misery.*
>
> *Third Theorem: The Moderately Cheerful Form of the Dismal Theorem*
> *Fortunately it is not too difficult to restate the Dismal Theorem in a moderately cheerful form, which states that if something else, other than misery and starvation, can be found which will keep a prosperous population in check, the population does not have to grow until it is miserable and starves, and it can be stably prosperous.*

As Boulding noted at that time, the moderately cheerful form of the dismal theorem remains a question mark. (We now refer to the cheerful form of the dismal theorem as sustainable development, sustainability, sustainable use of the planet, etc.) We know that misery can surely be as effective today as it was when Boulding originally proposed the three theorems, but we hope, in our quest for sustainability, that a new social contract using intelligence guided by reason and scientific evidence will do so with less suffering. Whether we have the will to change or whether those who call attention to the planet's carrying capacity, resource exhaustion, destruction of ecological capital, and the like will be regarded as "enemies of the people" (as Ibsen's play "An Enemy of the People" [Fjelde, 1965] so vividly described) remains to be seen.

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Article 16

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Increased Longevity, Quality of Life, and Carrying Capacity on a Finite Planet

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ABSTRACT

One event, such as increased human longevity, is impossible to accomplish without having other, perhaps unintended, effects. In addition to the effects on human society, other arguably equally important, effects will occur in the biosphere – the planet's ecological life support system. Sustainable use of the planet requires an objective evaluation of the consequences of changes in any critical parameter such as human life span. Preliminary action can then be taken to address unfavorable consequences and to enhance the likelihood of favorable ones. The central issue is whether humans can continue to increase in both numbers and per capita affluence without causing irreparable harm to the biosphere. This issue is a matter of enlightened self-interest to human society. A concomitant ethical issue is whether humans have an obligation to share the planet's resources in a fair and equitable manner with the many millions of other species on the planet. Human longevity is only one of the factors in this multidimensional problem. However, addressing this issue will almost certainly result in a reexamination of human society's relationship with natural systems and what changes are needed to result in a sustainable co-evolution of the two systems.

When one tugs at a single thing in nature, he finds it attached to the rest of the world. – John Muir

INTRODUCTION

A substantial body of literature is devoted to sustainable use of the planet, sustainable development, and related terms. There are a number of professional journals whose specific focus is sustainability (*The International Journal of Sustainable Development and World Ecology, Sustainable Communities Review,* and *The Natural Step*) and a number of recent, well-referenced books,[1-7] which are likewise central to this area.

The concepts of toxicological and ecological thresholds are central to understanding sustainable. Although some thresholds may be experimental artifacts, they are the best of the currently available analytical tools for making a variety of judgments and policy decisions. Although regulatory and legislative systems often act as if only a single threshold exists, there is actually an abundance of thresholds and breakpoints – some a matter of life or death, others only invoking mild stress or discomfort.

Arguably, the most important threshold for human society is the carrying capacity of a finite planet. The ecological carrying capacity is "the number of organisms of a particular species that can be supported over time without damaging or degrading the habitat."[8] However, the present worship of infinite growth on a finite planet is regarded as progress and any reference to limits of growth as "gloom and doom."[9]

Substantial literature speculates about the number of people Earth can support (carrying capacity). Malthus[10] explored this topic over 200 years ago and his ideas are still hotly debated, often by people who appear not to have read his original publication, although readily available. Cohen[11] suggests that Earth's carrying capacity for humans is a complex matter, complexly determined by affluence, life style, etc. One persuasive viewpoint has been that the planet is already overpopulated.[12-15] Conversely, Eberstadt[16] believes there is a population implosion. Arguably, the most incisive debate on these starkly contrasting views of carrying capacity is presented in a volume by Myers and Simon.[17]

Another major component of the debate on both carrying capacity and the quality of life is the vast disparity in per capita consumption of resources – referred to as the size of the "ecological footprint."[18] In this vein, Wackernagel and Rees[19] make the reasonable argument that carrying capacity can be increased by reducing the size of the per capita ecological footprint.

Increased human longevity without a concomitant reduction in birthrate will increase population size. More people on a finite planet results in fewer per capita resources. At best, this would lower the quality of life; at worst, it would ultimately reduce population size through disease, starvation, and conflict over resource distribution. During the previous century, world population has increased from approximately 1.6 to just over 6 billion, a nearly four-fold increase. However, even with zero population growth (i.e., 2.1 children per female), demographic projection suggests that it would take two to three generations (50-75 years) to achieve stability, and then only at a population considerably higher than the current figure. Increased longevity would clearly exacerbate this increase. Although each society may face different, sometimes even dramatically different, problems, there are both underlying commonalities and (as Muir noted) interdependencies. One of the commonalities, as Bartlett[20] notes, is that exponential population growth will markedly reduce our available decision time. Indeed, what might be achieved in the short term (a "stable" population level) is likely to be neither sustainable nor optimal in the long term. Resource limitations and space for further expansion almost certainly will have major restricting effects in the first half of this century.[21,22]

THE QUEST FOR SUSTAINABLE USE OF THE PLANET

The World Commission on Environment and Development[23] defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations of meet their own needs." Development implies growth, and infinite growth on a finite planet is an oxymoron. Perhaps sustainable use with robust societal ethos (directed toward planning a future world with highly cooperative behaviors that are responsive to natural systems) is a goal worth pursing.[24] Can human society reduce per capita environmental impact sufficiently to counterbalance the explosive effects of population growth and a probable increase in per capita consumption? Hawken et al.[1] consider this problem, providing numerous case histories of industries, cities, etc. that effectively combine sound ecological management with an appropriate attention economic profit. Although technological innovation may not be sufficiently elastic to make our carrying capacity infinite, [25] a humane and environmentally sustainable world may het be conceptually possible and realistically attainable.[3,6,26,27] There are business[2] and policy[4] paradigms that support this view.

THE ELEVATOR METAPHOR

As humans live longer and longer, population "bottlenecks" become inevitable. Metaphorically, an elevator which stops at each floor quickly becomes overcrowded if riders do not get off as others continue to get on. The ride (quality of life) becomes less attractive as the number of occupants increases. This metaphor, while illustrative, fails predictively when applied to global population growth: the carrying capacity of an elevator is more easily calculated than is the carrying capacity of a planet. The problem, as Costanza[28] says, is that "one knows one has a sustainable system only after the fact." In reality, "optimal" levels of global resource use are a function of trial and error; the complexity and dynamic nature of the ecosystems render confident predictions unlikely. The resultant planetary "experiments" may have irreversible and potentially mind-boggling consequences [29,30] Despite the inherent complexity, recent developments may not result in robust predictive models.[31] One result may be an improved stewardship of vast and essential marine domains.[5]

ALTERING BEHAVIORS

Sustainability will require more than either robust models or blind obedience to simple laws. Rather, it will require (a) environmental literacy, (b) a willingness to alter personal needs to the needs of natural systems (for example, not using all the water from a river during a drought), (c) an acknowledgment of our dependence on the entire ecological system, and (d) a concern for future generations that tempers personal concerns. We do not need mere adherence, but enlightened behavior. The Athenian statesman Pericles stated it concisely over 2000 years ago: "All honor to him who does more than the law requires." Though not attained, the possibility remains.

Altering both individual and societal behaviors is a formidable task, but the consequences of failure promise to be appalling! Among such consequences would be a dramatic loss in the attractiveness of increasing human longevity. People associate increased longevity with a greater quality life, not with deprivation and suffering. Pittendrigh[32] notes: "The study of adaptation is not an optional preoccupation with fascinating fragments of natural history, it is the core of biological study." Historically, the failure to adapt has resulted in extinction, the fate of many previous species on this planet. Natural systems will adapt, of course, but not always in ways that facilitate sustainable use of the planet by *humans* (e.g., antibiotic resistance, causing a recrudescence of human diseases). Although natural systems are often depicted as fragile (as many systems and species are), some component species – pests from the human perspective – are quite robust, adapting and resisting human control. An increased human longevity would be more attractive given a quality life on a quality planet, but these will not be achieved by complacent acceptance of our current behaviors and practices.

THE POSSIBILITY OF DECREASED CARRYING CAPACITY

Postel[33] notes that most irrigation-based civilizations have failed and speculates as to whether the fate of our current civilizations will be any different. Unquestionably, irrigation has been a major force of human advancement for six thousand years and is still a cornerstone of agriculture today. However, mounting water scarcities and salinization of agricultural soils[33] diminish the probability of meeting the food demands of our still-increasing human population. There are already bitter legal battles over water in comparatively water-rich North America and equally bitter actual battles elsewhere in the world. India, one of the most populous nations of the world, is currently suffering drought. Mozambique and, to a lesser extent, nearby countries have suffered devastating floods, which also impair agricultural productivity.

Another pressure, which could decrease our carrying capacity, is the impending rise in sea level due to global warming. Most recent evidence suggests that we are justified in considering coping strategies to reduce the rise or rate of rise in sea level. Since coastal areas are commonly more densely populated than elsewhere, even a modest rise in sea level could produce a substantial number of otherwise inundated “environmental refugees.” A relatively modest prediction for such refugees might be 20 million outside of the United States.[34] If the United States produces 22% of the world’s greenhouse gases,[35] should it (morally and ethically) assume responsibility and care for 22% (nearly 5 million) of these refugees? Such questions highlight not only the impending environmental stresses, but the equally difficult social and legal stresses that we may soon face.

To a degree, much of such stress is a result of being unpredictable. Bright[36] discusses three types of environmental “surprise.” The first is a discontinuity: an abrupt shift in a trend or a previously stable state. The abruptness is not necessarily apparent on a human scale; what counts is the time frame of the processes involved. The second is a synergism: a change in which several phenomena combine to produce an effect that is greater than would have been expected from adding up their effects separately. The third is an unnoticed trend, which may do a surprising amount of damage prior to its discovery, even if it produces no discontinuities or synergisms.

Unquestionably, there are technological trajectories, such as increased energy efficiency, comparatively nonpolluting sources of energy such as wind and solar power, improved irrigation techniques, agricultural biotechnology, and the like, that may both improve the human condition and lessen the frequency and diminish the amplitude of environmental problems.[37] But the precautionary principle[7] states that “when an activity raises threats to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.” There is still considerable uncertainty about the form that various trajectories will take and the rate at which they will be implemented, as well as the costs of implementation. Perhaps the highest degree of uncertainty is due to the unpredictability of human behaviors in different cultures as they react to such complex, multivariate situations. Increasing the human life span is an important variable, but far from the only operative component.

As Hawken et al.[1] suggest, technological systems require natural resources in ecological systems: ecological “capital.” Consequently, to ensure sustainable use of the planet, the two systems (economic and ecological capital) must be co-managed as a single system. Since both are constantly changing, in order to achieve a sustainable outcome, they must co-evolve, interacting synergistically rather than antagonistically. The antagonistic relationship fostered by extremists on both sides, which delights the news media, is not conducive to sustainable use of the planet.

Ecology has shown what happens if other species exceed the carrying capacity of their environment. The habitat is damaged and the original carrying capacity reduced, often dramatically. Studies of humans on isolated islands[38,39] provide useful information of the effects of an ecologically-induced caused collapse of civilization. Such collapses are definitely not situations which increase the attractiveness of an increased life-span. An examination of Menzel’s[40] global family portraits dramatically illustrates the vast differences in material affluence of families in different geographic locations. As the Durant’s[41] note, when the disparity in affluence becomes too great, there is either a revolution or a political redistribution. This, too, might well significantly diminish the attractiveness of increased longevity to those in developed countries who are expecting the material affluence during retirement to continue at the same level it had been prior to retirement.

Although there is a well-documented contrast between expressed belief and actual behavior, the integrated causal model of Barkow et al.[42] and social exchange theories[43,44] suggest that humans behave altruistically toward closely related individuals (kin or peer groups) and when reciprocity is expected. Can this be applied to more extended and complex levels of social organization (e.g., the entire planet)? At the global level, long-term or societal risks and benefits are difficult for most individuals (even political decision makers) to perceive, let alone act upon. To a degree, however, a lack of appreciation of the risks may be responsible for lack of behavior change. Though scarce commodities, sustainable use of the planet requires environmental literacy and reason. Any potential increase in human longevity must be evaluated within this multidimensional, complex context.

CONCLUSION

Increased human longevity in the context of sustainable use of the planet raises serious ethical and moral issues. In the absence of a sustainable use of the planet paradigm, will increased human longevity be as attractive to those who measure quality of life primarily in terms of material affluence? Science and technology may enable humans to modify the laws of nature, but not to break them with impunity. The sustainable use of our planet and the desirability for increased human longevity are inexorably connected. May the relationship get the attention it deserves.

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Article 17

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Sustainability and the Future of Humankind: Two Competing Theories of Infinite Substitutability

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Abstract. Toward what kind of future is humankind now tending? Is human society engaged in a global gamble based on the assumption that technology, aided by human ingenuity and creativity, can remake the world and manage its resources for immediate material benefit to humanity without regard to natural law and the fate of other species? Infinite substitutability of species has been tested over evolutionary time, but infinite substitutability of resources is a relatively recent hypothesis based on a faith in human creativity and technological prowess. The choice made will affect both the future of human society and of many other species.

One of the major questions of the present time is quite basic: Toward what kind of future is humankind now tending? Is human society engaged in a cosmic gamble that technology, driven by "the indomitable spirit of humans," can remake the world and manage its resources for the immediate and material benefit of humanity without regard for the unmanageable cosmic forces that govern the way the world works? Basically, the conflict centers on two dramatically different cultural designs – ecological versus economic/technological. Ironically, both designs are based on an assumption of infinite substitutability. The ecological design is based on the assumption of an infinite substitutability of species that is orchestrated by natural law (evolution). The economic/technological design is based on the assumption of an infinite substitutability of resources that is orchestrated by human society. If both were valid, either could lead to sustainability; but, the outcome would be vastly different. The infinite substitutability of species in the interdependent web of life has been tested over evolutionary time. The infinite substitutability of resources is a recent concept based on a faith in human creativity and technological prowess. Even if valid, it does not address the ethical responsibility of humankind to the millions of other species that lack comparable levels of technology.

One of the most important issues facing human society is how to achieve sustainable use of the planet for many generations into the future. Regrettably, the most commonly used expression of this objective is from the World Commission on Environment and Development (1987), which uses the term *sustainable development* to mean "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Note that *sustainable* is an adjective modifying the noun *development,* which most people associate with growth. Entrepreneurs who replace natural systems with human artifacts are called *developers.* Development defined as growth is absurd on a finite planet if it is expected to continue indefinitely. The quest for sustainability is endorsed by almost every major category in human society (e.g., industry, political entities, conservation groups) because each defines the concept of sustainability differently.

To some, sustainable development is the path to corporate immortality and *sustained profits.* For others, sustainability means job security and professional longevity – thus, the word *sustainable* is used as an adjective for such entities as agriculture, transportation, cities, energy, water use, forestry, and the like. Some believe sustainability is the best means of preserving the integrity of the biosphere. Others view sustainability as a means of attaining intergenerational equity, although they remain curiously silent about the gross inequities that exist in the world today. Brown et al. (1987) note the emphasis on such themes as indefinite survival of humans on Earth, continuation of biological stock and agricultural systems, stable human populations, limited economic growth, and continual improvement in ecological condition.

Clearly, sustainability should be multidimensional and require major changes in both institutional practices and individual behavior. Sustainability has been endorsed, in principle at least, by an astounding array of special interest groups, even though these groups have not reached a consensus on any environmental initiative in the past. In some cases, such as the Natural Step Program (see Holmberg, Robèrt, and Eriksson, 1996; Robèrt et al., undated), the consensus was reached after extensive discussion by an environmentally literate but diverse group. Hawken (1993) and Hawken, Lovins, and Lovins (1999) give examples of both an effective, informed sustainability consensus and the folly of continuing present practices.

The Race Between Education and Catastrophe

H. G. Wells once remarked that human society is in a constant race between education and catastrophe. But, never in human history has society had the power to affect so drastically the lives of many future generations. Human artifacts are bigger, more ubiquitous, and are appearing at a greater and ever increasing rate. Most important, these artifacts are displacing, but not replacing, natural systems. They do not, however, escape disruption by various organisms (e.g., Cairns and Bidwell, 1996a,b). Ecological restoration is beginning to receive some attention, but ecological destruction still vastly exceeds ecological repair. Moreover, ecological destruction is rapid; ecological recovery is slow.

Hawken, Lovins, and Lovins (1999) foresee another industrial revolution. This one would replenish nature rather than impair ecological integrity. Even though persuasive evidence indicates this revolution is feasible, a strong resistance continues against changing the status quo. Myers and Kent (1998) document numerous perverse subsidies and the environmental and economic damage they do.

Ecological/Environmental Design

The ecological/environmental design has been tested for billions of years, albeit without humans until very recently in geological time. However, a dominant or ubiquitous culture has not evolved that places a high priority on a harmonious relationship with natural systems. Such cultures do exist (e.g., Thomas, 1958), but they exist in habitats not considered desirable by the dominant (i.e., technologically advanced) cultures. These cultures are busy remodeling the world rather than designing a culture that is harmonious with natural systems. A harmonious relationship with nature would require a reevaluation of the guiding beliefs (ethos) that govern both individual and societal behavior, which would be extremely painful. For example, at the societal level, change would require an examination of human society's addiction to economic growth that is, as presently practiced, very damaging to the environment. Former United States President Jimmy Carter spent the early years of his boyhood in a home that had a privy (outdoor toilet) (Carter and Carter, 1987).

Despite a penchant for simple living, he still had a dramatic increase in affluence including, as President, his own jet plane. The Carters measure success in terms of service, not affluence, but they are exceptions to the rule. In the United States, "rags to riches" stories never tire the news media or the public. However, if too many people actually realize this dream, the environment will suffer even more. Only one species – humans – manages to attain such affluence, and it is at the expense of millions of other species.

As always, this dominance has a price. Eliminating species that are not tolerant of the practices of human society selects for species that are tolerant (e.g., Cairns, 1994, 1996, 1997). As a consequence, society is now dealing with antibiotic-resistant organisms, pesticide-resistant invertebrates, and tolerant-invasive exotics, to mention just a few. At present, 30 million species live on the planet. Most of them are smaller than humans, and many are able to endure conditions intolerable to humans. Is it reasonable to assume that one species, *Homo sapiens,* can control all of them without major risks to itself or without spending an unacceptable amount of time, resources, and energy? In addition, many of these species, and perhaps all, provide ecosystem services (e.g., maintaining the atmospheric gas balance) of tremendous economic value (e.g., Costanza et al., 1997).

Perhaps the threshold that may be the worst for human society globally is a climate change of anthropogenic origin. Recent evidence suggests that major climate changes can occur in 10 years (e.g., Taylor, 1999), and it is not always immediately apparent when an environmental threshold has been crossed. Crucial symptoms are often delayed. Still, it is possible to cross an environmental threshold and take effective corrective measures to prevent irreversible damage if there is a will to do so. The remote Easter Island in the Pacific Ocean exceeded its carrying capacity for humans (e.g., Diamond, 1994), primarily due to ecological destruction. This erring society paid a tremendous price, including cannibalism.

One of the major problems in the public's understanding of carrying capacity is the failure to distinguish between the space individuals occupy and the space that provides the resources they utilize. Williams (1999) notes that the entire population of the United States could move to Texas and each family of four would enjoy 2.9 acres of land. But, 2.9 acres of land is far less than the "ecological footprint" of even a single average individual in the United States (e.g., Wackernagel and Rees, 1996), which is roughly 10 times the 2.9 acres. So, a family of four would require 40 times more space just to provide resources for its current lifestyle.

And, there is even worse news. Dunning (1997) found that, of several undergraduate classes (622 responses), only 23% realized the population of the United States was between 250 and 300 million. Many of the students had no idea of how large a billion is – an important number since Earth's population is measured in billions. As United States Senator Everett M. Dirksen once said, "a billion here and a billion there soon adds up to real money." The same statement applies quite well to population numbers.

Smail (1997) addresses a topic that few demographers, ecologists, scientists, or politicians dare to mention – whether Earth's carrying capacity for humans has already been exceeded. It does not pay to be a contrarian in an era in which economic growth, accompanied by increased numbers of human artifacts, is mentioned with pride by both small and large political units. So, the great global experiment (e.g., Schneider, 1997) with the planet's ecological life support system continues, for which the outcome is fairly certain if the carrying capacity concept has any validity. The classic Kaibab Plateau (north of the Grand Canyon in the United States) study illustrates the penalties of exceeding the carrying capacity (a recent summary is in Straub, 1999). The plateau was originally estimated to be capable of supporting 40,000 deer with growth limited by natural predators (wolves, cougars, and coyotes). Bounties encouraged hunters to kill the predators, and the deer population increased to 50,000. The life support system was damaged, and the carrying capacity plunged to 10,000, mainly due to starvation. Estimating the optimal carrying capacity for deer is relatively straightforward. Society will tolerate manipulation of deer populations even though such manipulation is unacceptable for the human species. Estimation of "optimal human" carrying capacity is far more difficult, given the present range of socioeconomic systems (e.g., Parsons, 1998).

Many analysts are convinced that cessation of destruction and degradation of natural systems requires limitation and even rollback of human population size. If present trends continue, livable limits will someday be encountered, but perhaps not without irreversible damage to the biosphere and impoverishment of the quality of life – at worst, diminishing prospects for survival of the human species. It is essential to examine this unpalatable possibility because doing so may increase the duration of human life on the planet.

Many believe that human society must function within ecological constraints. In this regard, there are some useful case histories, such as Easter Island (Diamond, 1994) and Naru Island (McDaniel and Gowdy, in press) where ecological damage has reduced both carrying capacity and quality of life. Since carrying capacity thresholds for humans are so complex, it would be prudent to stay well below them. Nature's alternative is to substitute species until one is found that is capable of staying within resource limits.

Economic/Technological Design

Simon (1981) and many others believe that human ingenuity, creativity, and technology exempt *Homo sapiens* from the iron laws of nature that restrict other species (i.e., carrying capacity). Arguably, the single best contrast of the ecological vs economic/technological design is given in Myers and Simon (1994). In this economic/technological design, sustainable development is a matter of developing alternative resources for those that are depleted. Denial of serious environmental damage often accompanies this view (Budiansky, 1995; Easterbrook, 1995; Ray and Guzzo, 1993a,b; Maduro and Schauerhammer, 1992; Chase, 1995). Although most people are unaware of the debate on the two conflicting theories, the economic/technological model is dominant in practice by a substantial margin. It would be an error to assume it is not valid.

Postrel (1998) divides Americans into two camps – dynamists (change-oriented) and stasists (against change) [stasists – word coined by Postrel; from *stasis*]. Environmentalists are viewed as part of the latter camp. Nature can also be viewed as both goalless and variable. Worster (1997), for example, believes that ecology should never be taken as an all-wise, always trustworthy guide and that human society will have to formulate an answer to the meaning of environmental damage out of its own values. These values must include acknowledgment of dependence upon the planet's ecological life support system. The value system must also include recognition that humans cannot dominate nature – it is fragile in the short term but tough in the long term. Evolution may be goalless and mindless, but it does rearrange genes to produce organisms with a competitive edge.

Fruit juice companies were shocked in 1996 when *Escherichia coli* 0157:H7, a greater threat to humans than common strains, appeared in unpasteurized apple juice. *Escherichia coli* could tolerate the acidity of fruit juice, but humans could not tolerate it. *Escherichia coli* can reproduce in less than an hour; humans require years. Humans may drive the large, charismatic species, such as the snow leopard, to extinction, but the millions and millions of small species – never.

Clearly, human society is, as always, making a variety of choices (i.e., at the lowest level either displacing natural systems or designing human artifacts that preserve the integrity of natural systems). However, with such a low level of environmental and human population literacy, will these choices lead to sustainable use of the planet? The popularity of eco-tourism indicates a human desire to at least associate with nature, particularly with charismatic species. Properly managed, it appears to be both profitable and sustainable. But, poorly managed eco-tourism already is damaging many ecoregions that are popular with tourists, so even this tourist economy has drawbacks. In addition, a relatively small number of people spend much time and money on eco-tourism. The latter is an important, but not crucial, factor in environmental protection since protection for eco-tourism is unlikely to affect enough natural areas to provide essential ecosystem services.

Possibly the most important value of ecosystems is the services they provide. The economic value of these services is enormous (e.g., Costanza et al., 1997), but the delivery system is poorly understood. It is unlikely that a technological substitute for such ecosystem services as maintaining an atmospheric gas balance will be developed at an acceptable per capita cost very soon. One might even assert that per capita cost is the only value that could impress the majority of people, even though it has had a minor impact thus far, possibly because understanding the concept requires a high level of ecological literacy.

Nature: Fragile or Tough?

One of the obstacles to a close relationship between human society and natural systems is the belief that any use of them is damaging. Environmentalists regularly focus on the fragility of natural systems. Biotic impoverishment of many species on islands after the arrival of humans is well documented. But, 50 years of experience in the field now labeled ecotoxicology has taught me how incredibly resistant some species are to physical and chemical stress. Furthermore, experience with pesticides and medicinal drugs has provided abundant evidence of the ability of many species to increase resistance to them. Suppose humans eliminated approximately 90% of Earth's biota, a level thought to have happened at least once in the past (although not caused by humans). What would the relationship be between humans and the 10%, nearly 3 million, species that remained? These species would be the ultimate survivors, arguably well beyond effective human control or management. To some humans, these species would be an exploitable resource; to others, a competitor for resources. The probability of a harmonious relationship is not high, and the probability of an improved quality of life for humans is even lower. Humans are unlikely to stop evolution but are likely to redirect it toward resistance to human control. These creatures are now labeled "pests," and their numbers will increase as the species that control their population decline. The economic/technological design has not given this aspect of evolution adequate attention.

The Future of the Economic/Technological Design

Human society is enamored with growth, defined as more human artifacts (e.g., highways, shopping malls), more material goods, and expanding economies. There is a virtually unshakable belief that a technological solution exists for every problem. Another belief is that nature is quaint and entertaining, but is not essential and should not impede development and progress. Growth – meaning more, not better – is the primary descriptor used for mutual funds, towns, cities, and all sorts of organizations (even churches). There are both subsidies for economic growth (e.g., Myers and Kent, 1998) and vast numbers of lobbyists in the federal government who defend these often perverse subsidies and promote new ones. The economic/technological design seems formidable and unstoppable. Jitters in the world's financial markets suggest that many investors have concerns about the stability of the economic growth model. But, even dramatic failure of the present model may signify only time to replace it with another model based on the same assumptions. Changing to a "design with nature" model may well require unmistakable evidence that society cannot abuse Mother Nature without suffering consequences. This drama is now playing on the environmental stage. Just in case the present design, Plan A, proves unsustainable, it would be prudent to have at least one alternative, Plan B, for sustainable use of the planet. Perhaps one that is more congruent with natural system structure and function is worth trying.

War and the Inequitable Distribution of Resources

The *sine qua non* and *ne plus ultra* of sustainability are the intergenerational distribution of resources. Although peace does not ensure equitable distribution of resources, war is a major obstacle to achieving this goal. Even within a single political system, numerous petty fiefdoms are often based on the intent to gain a disproportionate share of pooled resources, whether they be tax dollars or privileged access to particular markets or government lands. Elected officials get reelected by appearing to or actually getting more than their home district's fair share. This system is not designed for sustainable use of the planet. Cessation or reduction of war would at least make more resources available for other purposes. However, equitability (especially intergenerational) requires far more responsibility than avoiding war, but it is far from clear how this utopian vision will be achieved.

As a caveat, it is not safe to assume that war, as waged in the nineteenth and twentieth centuries, will characterize future conflicts. An Orwellian world of endless and localized civil, social, and ethnic conflict may prevail with disastrous consequences for societal and ecological sustainability. It is quite evident that this condition exists today, and it is difficult to predict when, if ever, a world-ordering regime will be brought into existence. Since it may not be possible to banish war, it might be more productive to seek near universal consensus on a minimum but critical sphere of world governance that would focus on sustainable use of the planet.

Perhaps the most that present generations can hope for is the end of destruction due to war and the cessation of destruction of natural systems, without attempting to repair them, to produce anthropogenic artifacts. Some environmental destruction is inevitable, but the present temporal and spatial scales of such destruction do not appear to be sustainable. Whatever the outcome, I am confident that some species will persevere and the ecological drama will continue.

Conclusions

Of the two competing theories of infinite substitutability, only the ecological one emphasizes an ethical responsibility for the fate of other species. The unpalatable feature for most humans is that their own species might be replaced. The quest for sustainable use of the planet is a tacit admission that human society's present practices are unsustainable. Infinite substitutability of resources is based on the assumption that, if there have been successful substitutes for some resources, there are substitutes for all resources. Even if true, they might not be accessible to the billions of people who cannot afford resources presently available. The effects of these new technologies on millions of other species will probably be no more benign than present technologies.

If human creativity and ingenuity are so exemplary, why are they not being used to develop a better relationship between human society and natural systems? Surely this objective involves fewer risks and environmental surprises than attempting infinite substitutability of resources as they become depleted. Natural capitalism advocates protection and restoration of natural systems (natural capital). The good news is that numerous case histories provide evidence that protection and restoration can be done. The “bad” news is that human society will have to alter many present practices to achieve sustainable use of the planet.

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Article 18

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World Peace and Global Sustainability[1]

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SUMMARY

War and the preparation for war divert increasingly scarce resources from civilian use, especially long-term efforts such as the quest for sustainable use of the planet. War also damages natural systems both directly and indirectly. As a consequence, ecosystem services essential to sustainability are diminished. Achieving world peace does not assure that sustainable use of the planet will also be achieved, but it is a necessary precursor. Other factors diminishing the prospects for sustainability include major and rapid demographic changes, addiction to exponential economic growth, excessive individualism, and production of artifacts and wastes not readily reincorporated into natural systems. On the other hand, if intelligence is not an evolutionary mistake, then it, combined with reason and creativity, can be used to overcome the obstacles just mentioned. If intelligence is an evolutionary mistake, the creatures that ran the world before humans appeared will doubtless take over again.

INTRODUCTION

Peace cannot be kept by force. It can only be achieved by understanding.
Albert Einstein

Only in our virtues are we original, because virtue is difficult. . . . Vices are general, virtues are particular.
Iris Murdoch

Humans expect their species to endure until the Sun dies and, perhaps, beyond if colonization of other planets becomes possible and they are not already occupied by a technologically advanced species that is able to exclude the human species. However, only about 1% of all species that have ever lived are now alive. Why should the human species not be among the majority that has become extinct? Intelligence, guided by reason and compassion, is arguably the best answer. If reason and compassion fail, society can always establish taboos with severe penalties (this option is discussed later).

War is not beneficial for either the biosphere or human society. In addition to killing and maiming, war diminishes Earth's carrying capacity for humans. However, sustainable use of the planet requires that carrying capacity not diminish. Peace and sustainability are inextricably linked!

Suppose the global society actually achieves world peace – then what? Peace does not assure sustainable use of the planet, but it is an important precondition! Peace is primarily a particular relationship among societal components, whereas sustainability is a particular relationship of the

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human species with the entire biosphere. Sustainability requires acknowledgment of the dependence of humans upon Earth's ecological life-support system and holding its component species in esteem. It requires compassion for future generations and for living individuals who are inadequately fed and housed. Since the carrying capacity is finite, one requirement is a skillful balancing of values that are often in conflict. If nations and individuals do not practice intelligent control of Earth's resources, natural law may impose severe penalties. Life will go on, although probably not in ways favourable to the human species.

WAR AND THE BIOSPHERE

Youngquist (1997) notes that, during the Iran/Iraq War, the real cost of each barrel of oil for the United States was about $135US, not the $17US/barrel of the marketplace. Addiction to oil often has a high price, and the US was not even formally at war. Most people do not know the cost of a barrel of oil – their awareness of cost is associated with the amount they pay per gallon at the gas pump.

During the Gulf War that started with Iraq's invasion of Kuwait, Saddam Hussein threatened to set fire to all of Kuwait's oil wells. During the speedy Iraqi retreat, the sky was black from burning oil. At one time, 4.6 million barrels of oil were burning daily (Hobbs and Radke, 1992). In addition, an estimated 11 million barrels of oil that entered the Persian Gulf had devastating ecological effects (Golub, 1991). The lakes of oil from sabotaged wells were as deep as 8 feet before they sank into the sand – even visual effects will last many years (El-Baz, 1992). Ecological effects, of course, will last much longer.

Ecological terrorism does not arouse the same levels of indignation that arise from US embassy bombings. However, in the long run, ecological damage will adversely affect many more humans, as well as huge numbers of other species.

VISIONS OF SUSTAINABILITY

Can 10 billion people (population numbers will likely expand to this figure sometime in the first half of the next century) have all the material possessions they want? The material expectations (some would even say *needs*) of that many people cannot be satisfied without seriously damaging the biosphere and driving many more of the planet's species to extinction. Just how much can humans reshape the planet's ecological landscape to suit the wants of its own species? And finally, what will signal when Earth's carrying capacity has been grossly exceeded?

Menzel's (1994) haunting book, which pictures average family possessions in a variety of countries, should be studied carefully by every inhabitant of a developed country. Hard numbers are fine, and the book has these also; but, the pictures drive home the message that the level of affluence in the world varies from shockingly poor to needlessly extravagant.

The US Public Television special 'Affluenza' (1999) depicted excessive materialism in the US. However, a global perspective requires knowledge of the material possessions of other cultures in the global community. Brooks (1998), with 'tongue in cheek', provides examples of conspicuous consumption. Even his examples have a much smaller environmental impact than the gas guzzling sports utility vehicles that are now the rage in the US. One notable feature of Menzel's (1994) book was the number of poor families with television sets, and many without televisions had radios or films available. They either know, or will soon know, the global disparity in material possessions. All these people cannot be raised to the US level of affluence without causing even more ecological destruction. It would be outrageously unfair to blame the poor for the additional ecological degradation. They merely wish for some of the material goods (stuff) that others possess in considerable abundance. As humans approach or exceed the planet's carrying capacity, individual ecological impacts must be limited if a sustainable world is to be a reality. A new, less materialistic paradigm is essential, but will be strongly resisted by producers, advertisers, and those who support them. However, in the global ball game, Mother Nature always bats last! Fortunately, a recent book by Hawken *et al.* (1999) provides persuasive case histories of an ecological design that is both sustainable and profitable.

THE TYRANNY OF EXPONENTIAL GROWTH

A society whose people boast of not being able to balance their chequebooks is inadequately prepared to cope with exponential growth. Legislators are either unaware of it or, more likely, are afraid to ask the public for any reductions when everything seems fine. Bartlett (1994) uses microbes in a superb illustration of exponential growth.

Visualize a microbe that divides every minute in a flask that it can fill in 1 hour. If the illustration begins at 11:00 a.m., then (a) at 11:56, the flask is only 6.25% full, (b) at 11:59, the flask is half full, and (c) at 12:00 noon, the flask is full. Would 'intelligent' life recognize the overcrowding problem at 11:56?

Now suppose that, at 11:59 a.m., an exceptional microbe discovers three empty flasks – the equivalent for humans of three new planets! An amazing discovery that, using conventional thinking, would solve the population pressure problem for a long time. However, using they previous rate of growth of doubling every minute, then (a) at 12:01 p.m., flasks 1 and 2 are filled and (b) at 12:02, flasks 1, 2, 3, and 4 are filled. Now visualize any developed country's legislature handling that problem in a timely fashion!

STUFF AND ANTI-STUFF: WAR AND ANTI-WAR

My family's house is situated on 8.5 acres on the side of a hill in a forest. At each door to the house, the welcome mat is reversed to remind us as we leave the house that we are Nature's guests and should behave accordingly when we enter the biosphere. The house occupies about 1000 square feet and is reached by a narrow gravel driveway from the main road. The rest of the property has always been left alone except for occasionally cutting down a tree likely to fall on the house. Trees that die are left for woodpeckers, and trees that fall are left to diversify the habitat. We try to design our activities to be compatible with nature, which means keeping human artifacts to a minimum.

Why do some societies have more stuff (material possessions) than do others? Diamond (1997) has a fascinating explanation of this phenomenon. Cultures that successfully domesticated plants and animals were in a better position to produce more material goods. However, the opportunity was not equal for all cultures nor was the spread of domesticated organisms uniform. Chance associations were more important than cultural or racial differences in humans. But, the basic question is: how much stuff can Earth endure as the human population increases on a finite planet?

Humans once had a spiritual relationship with nature: a very few still do. Now the relationship is with stuff – an uncharitable person might call it an addiction since acquisition is more important than long-term use. Humans no longer perceive nature as a means of expressing spirituality, but as a source of stuff. Displacement of nature by human artifacts – shopping malls, six-lane highways, landfills, and housing and industrial complexes – is termed progress, and progress has no tolerance of spirituality. The endless, repetitive, tiny, soul-killing cubicles in some comic strips epitomize the ultimate unnatural world that would be free of any trace of spirituality!

The increasing popularity of simple living is the anti-stuff response. The *sine qua non* of simple living is the reaffirmation of the hunger for better relationships with other humans and other species. Merely expressing a concern for the environment or a respect for the interdependent web of life is not the basis for a rewarding spiritual relationship!

But, the quest for oil to produce stuff and then make it operate inevitably results in war – the oil war in the Arabian Gulf region in the early 1990s and military commitment still going on is a fairly clear example. Anti-stuff is not synonymous with anti-war, but the relationship is a close one! The premise of the Tofflers' (1993) book is that the way society makes wealth is the way society makes war. They note that rich nations cannot survive if the poor wage ecological war on them by manipulating their environment in ways that damage everyone. The Tofflers insist that treaties aimed at preventing ecological warfare depend on verification of compliance. Arguably, diminishing conspicuous consumption would lessen the disparity between rich and poor and, thus, qualify as anti-war. It would also diminish the war on the planet's ecological life-support system and enhance the prospects for sustainable use of the planet.

THE PERCEPTION OF THE BIOSPHERE AS AN ESSENTIAL ECOLOGICAL LIFE-SUPPORT SYSTEM

A major change in the perception of the biosphere as an essential ecological life-support system is essential to attaining both peace and sustainable use of the planet. When natural systems were far more extensive and in robust health and the global human population was smaller (e.g. approaching 3 billion in 1930), there was a much greater per capita production of ecosystem services than there is now. Illustrative ecosystem services are given in Table 1 (Cairns, 1997a). Although Earth's precise carrying capacity for humans is still not known, crossing this dangerous threshold is nearer than it was in 1930. Some would state, in terms of quality of life (e.g. Los Angeles smog), that crossing this threshold has already occurred.

The importance of this changed perception is that it is a reminder that damaging the biosphere in geographically distant areas is not risk free! Ecosystem services are produced in eco-regions, not political units. Contaminants are not stopped by political boundaries. Severe ecological damage caused by war, export of wastes to other political units, or exploitation of ecological capital (e.g. old growth forests) in geographically distant areas will have short-term deleterious effects that are manifested locally, but long-term effects could be manifested globally. As always, the individual acts of ecological degradation may seem insignificant but, in the aggregate, they have powerful effects. Similarly, individual economic decisions (e.g. to buy or not to buy a house or an automobile) are individually insignificant, but collectively they spell life or death for many industries. For most individuals, the more distant an event is in space or time, the less attention it is given. The global economy has already made this view obsolete, but the perception of dependence on a biospheric life-support system still is far from being accepted, and time is running out before penalties of exceeding Earth's carrying capacity can be avoided. A particularly troublesome problem is the universal availability of cheap, highly portable weapons (e.g. Committee on International Security Studies, 1999). Even in the unlikely event that the major military powers reach some sort of accommodations, small disgruntled groups with cheap, easily concealed weapons (supplied by one or more of the major powers) can significantly disrupt sizable areas of the planet. Biological warfare will doubtless extend this vulnerable area to the entire planet. Even without ethnic and religious conflict, the ever increasing disparity of personal income virtually guarantees sizable pockets of enraged individuals everywhere on the planet.

Table 1 A list of some ecosystems services

Capture of solar energy and conversion into biomass that is used for food, building materials, and fuel
Breakdown of organic wastes, such as sewage, and storage of wastes that cannot be broken down, such as heavy metals
Maintenance of a gas balance in the atmosphere that supports human life; absorption and storage of carbon dioxide and release of oxygen for breathable air
Regeneration of nutrients in forms essential to plant growth (e.g. nitrogen fixation) and movement of those nutrients
Purification of water through decomposition of wastes, regeneration of nutrients, and removal of sediments
Storage of freshwater, retention and slow release of water after rains that provides flood peak reduction, and groung/water recharge
Distribution of freshwater through rivers
Generation, maintenance, and binding of agricultural soils
Control of pests by insectivorous birds, bats, insects, and others
Pollination of agricultural crops by birds, insects, bats, and others
Development and archiving a genetic library for development of new foods, drugs, building materials, and waste treatment processes through both Mendelian genetics and bioengineering
Development and archiving a variety of 'replacement' species, preventing expected disturbances such as fire, flood, hurricanes, and droughts from disrupting the provision of other ecosystem services
Storm protection through physical dispersal of wind and waves by plants
Control of both microclimate and macroclimate
Recreation and aesthetic satisfaction

There is considerable justification for the development of a global ecological perspective. Mooney (1998) notes that the environment has been shown to be changing in a directional manner due to human activities. Further, applied ecology (which was scorned and sneered at by many classical ecologists and many other biologists when I entered the field in 1948 and up to the early 1990s) is now beginning to be accepted, albeit under the cloak of a variety of euphemisms. I applaud the British Ecological Society for starting the journal *Applied Ecology* in May 1964. Why be ashamed of research applied for the purpose of ensuring a habitable planet for both humans and other life forms?

SPECIES AND ETHNIC CLEANSING

Much horror and indignation have been caused by acts of ethnic cleansing prevalent in, but not restricted to, the 20th century. The justification is based on a 'them' and 'us' dichotomy. Getting rid of 'them' will somehow make things better for 'us'. As I sat in a building (it could have been a church, university, or municipal building) listening to a speaker deplore ethnic cleansing, it occurred to me that the site of the building now occupied had once been inhabited earlier by other species. They were displaced or killed to make things better for 'us'. True, they were not of our own species, but basically we viewed ourselves as 'superior beings' and our 'needs' had higher priority. Most important, the other species were powerless to stop us. Does this scenario resemble an ethnic cleansing scenario? Might not our ('us') treatment of other species ('them') be the origin of ethnic cleansing?

When another species gets too much of a resource (e.g. grain) that we view as ours, that species is described as a pest and strong measures are undertaken to eliminate it. Were other species able to articulate as well as humans, we would be labelled pests because we take a disproportionate percentage of solar energy and exert other attributes of dominance (e.g. Vitousek *et al.*, 1997). Human spatial dominance is visually displayed very effectively by nighttime radiation emissions over North America and Europe (Elvidge *et al.*, 1997).

The major question for the 21st century is: how much human dominance can the biospheric life-support system stand? Wilson (1990) defines ecological dominance as 'relative abundance, especially as it affects the appropriation of biomass and energy and impacts the life and evolution of the remainder of biota'. The appropriations and impacts are already enormous despite 841 million malnourished people, 1.2 billion lacking access to clean water, and 900 million illiterates (Brown *et al.*,1999). Although 'only' 80 million people are added to the world population annually, most of the increase will be in the 66 countries expected to double or even triple their populations over the next 50 years (Brown *et al.*, 1999).

DEPENDENCE UPON TECHNOLOGY

Consider the problems of regenerating the present level of human technology after a single, massive, globally catastrophic event or the cumulative effects of a closely spaced series of lesser catastrophes. The sophisticated technology of today was developed over centuries and aided by relatively easily extracted metals, fuel, and biomass. Although much present technology is energy efficient, one wonders if it could be reestablished in an environment where energy and raw materials are comparatively scarce and competition for them more severe. The knowledge base may be even more fragile than the technology, as the preoccupation with the year 2000 transition demonstrates. With so much instability in the world today, there is little justification for exuberant optimism. On the other hand, society did manage to avoid a nuclear holocaust in the 1950s. As a consequence, I can spend the remainder of my professional career on issues of sustainable use of the planet. No political system on the planet seems able to exert a positive control over human excesses that are destroying the biosphere, which constitutes human society's ecological life-support system. Human yearning for utopias indicates that there are theoretical models for appropriate behaviour, but a global ethos (set of guiding values) seems more elusive than ever as the end of the 20th century nears.

Two recent books have moved me from controlled panic to very cautious optimism. Wilson (1998a,b) remarks on the unifying and highly productive understanding of the world that has evolved in the natural sciences due to a fortunate combination of three circumstances: (1) the surprising orderliness of the universe, (2) the possible intrinsic consilience (literally 'the jumping together') of all knowledge concerning it, and (3) the ingenuity of the human mind in comprehending both. The second book (Hawken *et al.*, 1999) provides persuasive case histories of businesses and industries operating very profitably and sustainable while protecting and enhancing natural capital, which includes all the familiar resources used by human society – such as grasslands, wetlands, savannas, estuaries, oceans, coral reefs, riparian corridors, tundra, and rainforests. Those not acquainted with Hawken's (1993) earlier book will also find interesting similar case histories there.

The only other optimism I have is that the harmonious world described in 'other worldly' discussions may stimulate enough people to make positive change possible (Cairns, 1999a). It is indeed ironic that, although there is much interest in increasing the human life span, there is much less interest in the kind of planet the additional years will be spent on (Cairns, 1999b). Yet humans are the primary threat to the planet's ecological life-support system.

THE OPTIMAL CATASTROPHE

Garrett Hardin (letter of April 1, 1999a,b) uses the term *ostrichism* to describe the way people shield themselves from unpleasant thoughts by burying their heads in the sand. Orr and Ehrenfeld (1995) label it *ecological denial*, when applied to the fate of natural systems. Both avoidance tactics are certainly alive and well in the United States and most of the rest of the world today. Hardin (1999c) argues that the nearly complete freedom of competition fostered by society leads to a perverse extension of Gresham's law that states that bad money drives out good money. Although Hardin (1999c) focuses on cheap labour and lowering the cost of goods produced, there is persuasive evidence elsewhere that environmentally irresponsible industries can lower the cost of goods produced. There is also a comical spin put on the environmental positions – an editorial (1999) in the *Albuquerque Journal* notes:

> When lawyers argue against reintroducing Mexican grey wolves because they take food away from the spotted owls, from which ranchers 'derive substantial aesthetic enjoyment', a federal judge might consider sanctions for filing frivolous pleadings. Ranchers' organizations derive as much 'aesthetic enjoyment' from endangered species as they do from grazing fee hikes.

THE ELUSIVE OPTIMAL CATASTROPHE

An optimal catastrophe is defined as one capable of producing a social paradigm shift, but from which recovery is possible within a timeframe of interest to human society, for example, a global warming incident accompanied by persuasive evidence that it was caused by greenhouse gases. Although crop losses were severe, mass starvation was avoided by shifting to a vegetarian diet. Ecologists have recognized for many decades the enormous attrition of useful energy as it passes upward through the food pyramid. For discussion purposes, suppose 90% of the resources are used by a steer and 10% is passed on to a human who is fond of beef. For the poor of Asia, meat is a luxury. If the goal is to pack the planet with people, then vegetarianism is the way to go. Wallace (1998) has a superb example of the rapidity with which the upper levels of a food pyramid decline in numbers – if the entire world's production of rice, wheat, corn, and other grains were devoted entirely to the support of polar bears, the entire world's population of these bears would number in the tens of thousands. Polar bears are big (1000 pounds) and are at the apex of a seven-layer food pyramid. Corrective measures to reduce greenhouse gases were global, effective, and reversed the warming trend. An optimal catastrophe would require ethnic, religious, and political cooperation in addressing the problem. Despite its horrible nature and consequences, the AIDS epidemic in Africa may be an optimal catastrophe now that the African and global political leadership is beginning to acknowledge its existence. Ecologically, it would require that the biosphere have sufficient resilience to recover within a timeframe of interest to human society.

The improbable ‘optimal catastrophe’ has been used to drive home the point that taking precautionary action to protect the ecological life-support system and not exceeding Earth’s carrying capacity for humans is not as ‘unworldly’ as it first appears. Only three major common sense steps are required.

1. The biospheric life-support system must be protected as if human lives depended on it – they do!
2. Continual exponential growth in population and human artifacts on a finite planet is not possible.
3. Human population size and per capita level of affluence must be kept within bounds that natural systems can tolerate – i.e. at a sustainable level.

Once people realize that an *in*tolerable catastrophe is much more probable than a ‘tolerable’ catastrophe, there may be more incentive to implement the three steps just listed. All three can be achieved, but are unlikely without a major paradigm shift toward sustainable use of the planet.

LIMITS TO INDIVIDUAL FREEDOM

Just as nations will be forced to exercise restraint (i.e. seek peace) in order to achieve sustainable use of the planet, so too will people have to restrain excessive expressions of individualism that have adverse environmental effects. For example, clear cutting one’s forested property causes increased runoff, has adverse effects upon water quality, and is aesthetically displeasing, all of which lowers the economic value of adjacent property. Furthermore, adverse water quality effects may extend for considerable distances downstream. Increased runoff erodes banks downstream and increases the likelihood of property damage through flooding. Additionally, silting behind dams decreases their life expectancy. If the property owners were required by law to be recompensed by the offending property owners for their economic losses, such practices would decrease dramatically, but this rarely happens because the offenders’ individual ‘rights’ are protected by law (at least in the United States) and sometimes even subsidized by governments (e.g. Myers and Kent, 1998). The truth feared most (at least in the United States) is that the freedom of individuals to manage their personal property in ways that damage the biosphere is less and less tolerable as the carrying capacity of the planet is approached or exceeded. Total individual ‘freedom’ as just described on a finite planet that is at or near full carrying capacity is simply not possible. For the wealth, escape is still possible, although the options are decreasing yearly. For the poor, emigration (legal or illegal) to the United States or Canada is an option available to a small percentage and will probably decline dramatically with the first major recession in these countries.

NATURE’S FORCES FAVOURING SUSTAINABILITY

The present environmental crisis is the result of underestimating the forces of human nature. In 1869, the Grand Canyon in the United States was a vast unexplored area. Now there are complaints of excessive noise caused by tourist helicopters and planes, and the pristine canyon has been threatened by people and pollution. Society is underestimating the forces of nature that operate when a particular species exceeds the carrying capacity of its habitat. The primary forces are (1) starvation, (2) disease, and (3) predation (for humans, war – or one nation attempting to prey on another). Starvation is already operative – arguably for over one-sixth of the nearly 6 billion people on the planet. Many are added to this total daily as ethnic strife drives them from their local habitat into areas incapable of, or unwilling to, accommodate them. Opportunities for the spread of disease are increased by rapid, fairly inexpensive global travel, the global economic marketplace, antibiotic-resistant strains of disease organisms, and other factors (e.g. Garrett, 1994). Once spread, transmission of disease from one individual to another is facilitated by urbanization and the frightful conditions under which illegal immigrants usually exist. Flies, rodents, and other disease-transporting organisms are extraordinarily difficult to control, especially when there are conditions of societal disequilibrium. On April 6, 1999, the *Chicago Tribune* reported that physicians worry about diseases invading Balkan refugee camps (reprinted in the *Roanoke Times*, A-4). This is an old and venerable argument against immigration. In 1851, Britons worried about the impact of foreigners from the continent coming to the International Crystal Palace Exhibition. Not only would they bring diseases of the body, but also Catholicism! More recently, First Lady Hillary Clinton was discouraged from visiting Ft. Dix to see refugees because of possible contamination. Twenty thousand refugees may be coming to the United States, and many thousands are being sent to other countries. What an opportunity for disease transmission!

But, imported diseases are only part of the problem. Our own *Pfisteria* is a particularly interesting organism since it seems to thrive in bodies of water that are organically enriched by runoff from poultry, hog, and cattle facilities, where animals are closely packed and waste products per unit area are substantial. It is well to remember that some species thrive on the altered environmental conditions produced by human society and their presence may often be harmful to humans. Humans and natural systems are co-evolving and selective pressures work both ways (Cairns, 1994, 1997b). It is ironic that humans are creating conditions favourable to species that are harmful to humans.

THE BIOSPHERIC THEME PARK

I recently attended a discussion group (about 25 people) on ethics. Only twice was the relationship between humans and the biosphere mentioned. Predominantly, the discussion focused on relationships within the human species – ‘do unto others’, etc. The two brief allusions to the relationship with nature focused on *respect* and *enjoyment*. But respect and enjoyment are optional. Furthermore, respect can also apply to such things as private property, which at one time included slaves. Enjoyment somehow carries the connotation of a theme park (hence the heading of the section), which does not adequately describe a deep relationship involving profound ethical responsibilities. In my view, humans are a recently arrived species (in geologic time) embedded in the biosphere from which they arose and upon which they depend. Respecting the worth and dignity of other humans makes no sense if their practices cause serious harm to the ecological life-support system. Expressing respect for the interdependent web of life is meaningless unless backed by daily deeds. The Institute of Eco-Ethics has the following guiding principles.

> The working principles of ecosystems are cyclic. Ecosystems do not remove or isolate resources, nor do they transform these into materials foreign to nature. They transform old resources into new resources, using naturally available energy: a network of multi-sided processes that support life and provide it with evolutionary power.
> What are the consequences for eco-ethics?
> (1) We must, as much as possible, reharmonize our human world with the world around us and reduce our detrimental impacts on nature. (2) We must increasingly replace linear resource degradation by cyclic resource re-utilization. (3) We must learn more about the working principles of ecosystems and use the insight gained for reconstructing our economies and societies accordingly. (4) The number of people on Earth and their per capita use of energy and matter must be reduced in accordance with the carrying capacities of ecosystems.

Ethics is usually defined as the rules of conduct recognized in respect to a particular class of human actions. Unfortunately, in practice this seems to be relationships within our own species. This is certainly commendable since our relationships within our species have much room for improvement. But, the quality of human life, arguably the survival of human society, depends on developing rules of conduct for our relationship to the biosphere and the 30+ million other species with which we share the planet. Neither the biosphere nor most other species communicate verbally. But there are ways to determine the effects of human actions upon them. Humans have benefited from ecosystem services since the species appeared on Earth, so enlightened self-interest mandates a concern that their actions not cause irreparable ecological damage or extinction of other species. Beyond that, however, humans should have a reverence for life in all its manifestations. This does not mean attempting to remain apart from natural systems, but rather avoiding disruption of natural cycles, not isolating resources from other species, and limiting displacement of natural systems by human artifacts (e.g. highways, shopping malls, and filling or draining of wetlands).

I am gradually coming to believe that reestablishing taboos (anything proscribed by society as improper or unacceptable) is they key to protecting the planet's life-support system. About 200 years ago, when Malthus' seminal publication on population appeared, Captain Cook returned to England with the news that Pacific islanders in the South Seas had stable, functioning societies based on sever penalties (e.g. death and loss of family possessions) for breaking a taboo. Taboos depend on a common social value system, ethos, or cosmology. To break a taboo puts the offender at risk of death or exile. In the present world, there are fewer places left to go. Reason, intelligence, and education should be given every chance, but, if they fail to protect the integrity of the planet's ecological life-support system, taboos seem to be an alternative worth considering. As for changing individual behaviour patterns: why have US citizens changed their cigarette smoking habits so rapidly, yet not alcohol consumption? These damage humans more than the environment, so what chance is there of altering environmentally damaging behaviours without taboos? Why adopt such Draconian measures today when murderers often avoid death penalties because they were 'victimized' as children? Tanton (1994) posited, the dry land areas of the planet have all been discovered and occupied. Except for a few countries such and the United States and Canada, the age of welcome to mass international migration is rapidly coming to an end. We are rapidly moving into an era of unwelcome immigration, and most people will have to 'make it' where they are. Creating severe ecological damage and moving on is no longer an option except for the very wealthy. Damage to an ecological life-support system affects everyone to some degree, but the local inhabitants most severely. When resources are finite, increased numbers of people mean a lower standard of living and, for those now starving or at subsistence levels, this is a life or death matter. For the wealthier countries, it is initially a decreased quality of life matter with prospects of further deterioration if trends continue. As the Kosovo tragedy in 1999 illustrated, international refugee migration is increasingly viewed as destabilizing to host countries, and most countries insist they only intend to be temporary hosts. Destabilization often leads to revolution or war, both of which decrease carrying capacity, which contributes to both human and biological impoverishment.

CULTURAL, RELIGIOUS, AND DEMOGRAPHIC SHIFTS

As Tanton (in press) notes, within a human lifetime, the Holy See is fated to become a Christian island in a Muslim sea The cause is the dramatic decline in replacement level fertility of Italian women from 2.1 average births per woman to 1.2 – one of the lowest birth rates in the world. Italy is adjacent to rapidly growing Muslim populations of North Africa, the Balkans, Albania and the

Middle East. Workers will be needed to support Italy's aging population so an outright military invasion by the Muslims is unnecessary. Illegal immigration will be difficult to stop, given Italy's coastline and the need of employers for cheap labour. Given the intensity of ethnic and religious conflict in the world at present, this could be a very destabilizing factor, likely to be unfortunate for both humans and the biosphere. Arguably, Marseilles – a north African city in southern France – is already there.

CONCLUSIONS

1. Peace enhances sustainable use of the planet – war impedes it.
2. Birth rates below replacement in most developed countries and above replacement in most developing countries will create some extraordinary demographic shifts, most of which will not enhance prospects for sustainable use of the planet.
3. Even if peace prevails, a new eco-ethics must be developed, which protects ecosystem integrity and consequent long-term dependable delivery of ecosystem services.
4. The most probable crisis years appear to be between 2000 and 2050, although episodic events or development of new technologies could alter this range.
5. Arguably, the major obstacle to peace is militant ethnicity and the major obstacle to sustainable use of the planet is the addiction to exponential economic growth.

After writing the conclusions, I felt that the manuscript should end with a set of guiding beliefs based on the desire for world peace and sustainability. Doubtless others will expand and refine this tentative list.

DECLARATION OF WORLD PEACE AND SUSTAINABILITY

1. Peace among humans is a necessary precursor to sustainability.
2. A harmonious relationship between humans and the biosphere is essential to sustainability.
3. Robust sustainable use of the planet requires human acknowledgement of dependence upon ecosystem services (e.g. maintaining atmospheric gas balance).
4. Ecological damage and repair must be in balance (as a minimal condition).
5. Anthropogenic biotic impoverishment (i.e. species extinction) must cease.
6. Absence of certainty is not synonymous with absence of risk – what we do not know can hurt us badly.
7. No species endures forever – we have an ethical and moral obligation to ensure that efforts to make the planet sustainable for our species do not preclude sustainable use by other species with which we share the planet.
8. Peace with nature requires that humans cease displacing natural systems by constructing artifacts. Failure to do so will destroy our ecological life-support system.
9. Nothing is more important than understanding the consequences of human society's destructive potential for both our own and other species and to change our behaviour accordingly.
10. Changing existing paradigms requires that concerned individuals confront both policy-maker and the general public with scientific information and reasoned argument. Additionally, they must expose them to the vision and ethos required for both peace and sustainability.
11. We must recognize the inappropriateness of the economic growth paradigm for sustain-

able use of a finite planet and the concomitant importance of limiting resources consumption per individual to enable allocation to future generations.

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Article 19

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Topics for Public Debate: Immigration, Sustainability, and the Precautionary Principle

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Many people in the United States profess a respect for natural systems, sustainable use of the planet, and immigration. The ability to compartmentalize these issues so that they are not assessed concomitantly represents an incredible denial of the obvious relationships among them. The only way to maintain these issues in isolation is to forbid or repress holistic discussions of them. However, refusal to discuss problems freely and openly does not eliminate them and, in fact, exacerbates them. This discussion is a preliminary exploration of some factors that require a free and open exchange of ideas on natural systems, sustainable use of the planet, and immigration.

We are human not so much because of our appearance, but because of what we do, the way we do it, and, more importantly, because of what we elect to do or not to do.
– René Dubos, 1981

Introduction

Even at the beginning of the twenty-first century, a free and open exchange of ideas on the issues of immigration, population stabilization, and planetary carrying capacity for humans is not forthcoming. Carrying capacity is the concept that people seem to fear most in any discussion of population issues. However, Abernethy (2001) has published a current analysis of Earth's carrying capacity for humans. Four factors are significant in any discussion of immigration, population stabilization, and sustainable use of the planet: (1) a finite planet holds only a certain number of individuals; (2) some individuals will acquire more resources than others; (3) individuals having fewer resources than others will migrate, to the best of their ability, to the areas perceived to have more resources; and (4) intelligence is of little use if used primarily to satisfy perceived short-term "needs" in ways that are deleterious to long-term use.

The Ecological Perspective

From an ecological perspective, immigration might be viewed more accurately as migration (i.e., wholesale movements of populations) from one ecoregion to another. Significant migrations may occur because a particular ecoregion has become inhospitable due to famine, war, or other causes or because significant numbers of the population believe that more abundant resources are available in other locations. These migrations may even be encouraged because the immigrants could provide cheap labor and/or because the present occupants of the area perceive their location as virtually unlimited in carrying capacity. Mass movements within a political boundary are as ecologically important to occupants outside the area as to those within the area. The Irish potato famine is a classic example of migration as a quest for better living conditions. However, creating peace and economic and biological resilience in each ecoregion will help limit migrations from one ecoregion to another.

In general, migrations for ecological reasons result from: (a) an open niche in another area, (b) seasonal or cyclic patterns, and (c) impoverishment in the home range. From the perspective of global sustainable use of the planet, mass migrations of any kind are likely to result in temporary or, worse yet, permanent ecological disequilibrium. Most humans are accustomed to thinking in terms of political boundaries and economic growth, rather than ecosystem health and integrity, and will almost certainly not shift this perspective until one or more ecological catastrophes compel them to do so. However, when the consequences of ecological recklessness become more apparent, time for remedial action may be short!

Although Zlotnik (1998) remarks that migration flows are relatively small on a global scale, the effects on population can be enormous. In the United States, about half the current annual population growth of 1.6 million is from natural increase and half is from immigration. By the year 2020, almost all net population growth in the United States will be from post-2000 immigrants and their descendants (Poster Project for a Sustainable U.S. Environment, undated, www.NumbersUSA.com). Without further immigration, the population of the United States (281 million in 2000) would peak at approximately 290 million by 2025. With immigration continuing at current rates, it will grow to 335 million by 2025 (Bouvier and Grant, 1995; Population Reference Bureau, 1999).

Recent evidence indicates that humans spread over the planet more rapidly than was previously thought. One speculation for the rapid expansion, primarily along coastal areas, is that humans, even in earlier eras, rapidly depleted the resources suitable for their use and for which they could be competitive. This view indicates that the impetus for rapid expansion of humans over the entire planet was due to their inability, even in those early days, to live sustainably where they were. In other words, emigration was due to a depletion of resources, and immigration was due to either the knowledge or perception that resources were more abundant and more easily obtainable in other areas. If this speculation is accurate, it refutes the widespread feeling that ancient tribal cultures lived sustainably and in a harmonious relationship with natural systems. However, some cultures, such as the Australian aboriginals, apparently were able to live sustainably with natural systems for as much as 60,000 years.

The Source Sink Model

Pulliam (1988) has developed an ecological source sink model for a species of bird at the Savannah River Site in South Carolina in the United States. In this model, some habitats become sources from which surplus population migrates to less suitable habitats that act as sinks for the surplus populations. In Pulliam's model sources can become sinks and sinks can become sources if the area is large and if a sufficiently large temporal span is studied. To a certain degree, some countries (e.g., Italy) with a human reproductive rate below the replacement rate are serving as sinks for countries (especially those nearby) with expanding populations and increasingly scarce resources. Clearly, sources are producing more humans than the sinks can absorb; hence, the global increase in human population. If Pulliam's model is applied to humans, then individuals unable to find suitable habitat will perish, or at least will not reproduce. Consequently, in a sense, nature is pruning the surplus growth (as Tertullian would have stated it). As Diamond (1994) and others have shown, the carrying capacity of a particular area, such as Easter Island, can diminish significantly if the ecological life support system is seriously degraded. In the absence of some form of population control and protection of the ecological life support system, the human population is likely to turn sources into sinks through salinization of arable land, depletion of groundwater aquifers, global warming, and a variety of other destabilizing events.

Immigration is not likely to be a satisfactory solution to the problems of overpopulation and resource allocation, however lenient the United States and other countries might become. The planet simply cannot cope with an exponentially growing population, even if the doubling time is a half-century or more. Immigration at best is a way to avoid solving the planet's most pressing problems. Immigration to the United States, which has a vastly disproportionate consumption of the planet's resources, only hastens the time when the nation can no longer serve as a population sink. In this sense, the United States is already vastly overpopulated if all the immigrants require as much per capita resources as those who are already residents.

Ecological Footprint Size

The concept of an ecological footprint (Wackernegel and Rees, 1996) provides a persuasive and reasonably simple way for measuring and visualizing the resources required to sustain households, communities, regions, and nations. The complex issues of the planet's carrying capacity for humans (e.g., Abernethy, 2001), sustainability (e.g., Hawken et al., 1999), and resource use are interrelated. The ecological footprint in hectares per person is 4.3 in Canada, 5.1 in the United States, 0.4 in India, and 1.8 for the world as a whole. The average immigrant to the United States would increase his/her individual ecological footprint size by 3.3 hectares (from 1.8 world average to 5.1 United States average).

Wackernegel and Rees (1996) note that small ecological footprints do not necessarily imply a low quality of life. Kerala, a southern state in India, has a per capita income of about $1/day (less than 1/60 of North American incomes). However, life expectancy, infant mortality, and literacy rates in Kerala are similar to those of industrialized countries, and the inhabitants have good health care and educational systems and a fairly stable population size. Wackernegel and Rees (1996) conclude that Kerala's exceptional standard of living, coupled with a small ecological footprint, is based more on accumulated social capital than on manufactured capital.

Some of the attributes that most societies profess to value, such as literacy, good health, and social capital, are not closely correlated with the size of the ecological footprint, either per capita or as a society. It is ironic, as Cairns (2000) notes, that people in the United States and many other cultures prize longevity while they continue to despoil the environment. One would think that they would be interested in sustainable use of the planet so that a longer life would not be subjected to a quality of life that has deteriorated dramatically during this period. Increasing the size of the per capita or societal footprint virtually guarantees that the quality of life will deteriorate from more polluted air, water, noise, and all the other factors associated with rapid growth on a finite planet.

If Americans were willing to decrease their per capita ecological footprint to that of Kerala's per capita footprint size, the immigration process in the United States could continue for longer than half a century. Ultimately, immigration would have to stop to avoid diminishing those attributes the United States professes to prize. Immigration is only viable on a long-term basis if the inhabitants of a country are not reproducing at replacement rates or are willing to reduce their per capita ecological footprint so as to share resources with the newcomers. Immigration is a threat if it increases the size of the per capita ecological footprint and pushes a population beyond the carrying capacity for the desired quality of life.

The Immigration Paradigm

As Kuhn (1970) noted, a paradigm is a belief so strongly held that, even when contrary evidence appears, the evidence is rejected. Paradigms bring a sense of reality to a chaotic world. However, they are not reality, merely models of it. Paradigms are extraordinarily durable and humans cling to them tenaciously. So, paradigms are not only models, but tenaciously held beliefs.

A quotation from George Washington (Ellis, 2001, p. 7) depicts the United States as a fount of unlimited resources that is available to enterprising individuals of whatever background.

> *The Citizens of America placed in the most enviable condition, as the sole Lords and Proprietors of a vast Tract of Continent, comprehending all the various soils and climates of the World, and abounding with all the necessaries and conveniences of life, are now by the late satisfactory pacification [Peace Treaty of Paris], acknowledged to be possessed of absolute freedom and Independence, They are, from this period, to be considered as Actors on a most conspicuous Theatre, which seems to be peculiarly designed by Providence for the display of human greatness and felicity.*

Unremarked here but understood and made explicit elsewhere in colonial writings (e.g., Ellis, 2001) is the idea that, even though the citizens had had access to these resources for a length of time, they had "done" nothing to them: the rivers remained unharnessed, the timber uncut, etc., so that the commercial value was not realized. A modern example is the idea that oil in Alaska is no good in the ground when Americans are paying "high" prices at the gas pump. In short, the paradigm of limited or finite resources is un-American. And if resources are viewed as infinite, why not invite the less fortunate to immigrate and share them?

A poem by Emma Lazarus entitled "The New Colossus" is engraved on a tablet within the pedestal on which the Statue of Liberty stands and is an eloquent statement of a paradigm that clearly has outlived its usefulness, but that United States citizens are extremely reluctant to abandon. The poem reads in part: "Give me your tired, your poor, /Your huddled masses yearning to breathe free, /The wretched refuse of your teeming shore. /Send these, the homeless, tempest-tost to me, /I lift my lamp beside the golden door!" This nation must consider if these words are still valid today.

In addressing this statement, everyone should remember that all Americans are former immigrants or descendants of immigrants. Persuasive archeological evidence indicates that humans only recently arrived in the Americas, in geologic time. Since all humans are similar genetically, no particular group of immigrants, as a category, is superior to any other group. Altering immigration policy should be neither characterized as racist nor prejudiced in other ways. However, it is legitimate to inquire whether present immigration practices are ecologically sound – that is, are they sustainable for an indefinite period?

Leo (2001) notes for the United States immigration policies that "under the Immigration and Naturalization Act foreigners are eligible for asylum if they face the risk of persecution on the basis of 'race, religion, nationality, membership in a particular social group, or political opinion.'" Leo also notes that the term *social group* "has been stretched to include disabled people, women who fear genital mutilation, and homosexuals who fear persecution. The compassion is admirable but identity politics and ideology are creeping in."

While the criteria for entrance into the United States are continually being weakened, or made more inclusive, many citizens of the United States, including large numbers of children, lack adequate medical care and medical insurance. The educational system badly needs strengthening at all levels, and the infrastructure of the country, including such things as the water delivery systems for many large cities, sewage treatment plants, and the like, are badly in need of modernization. Clearly, if the nation is unwilling to provide medical care for the huge numbers of people who are already citizens and a better education for the young, the United States is not likely to be willing to share resources with immigrants. In short, the immigration policy seems to be a political statement with no substance or intention to treat immigrants any better or as well as some of the presently needy and homeless already present in the United States as lawful citizens.

If human society is truly interested in sustainable use of the planet and leaving a habitable planet for its descendants, there is an ultimate test of these aspirations and that is to ask, "Is the present practice sustainable for an indefinite period of time?" Present immigration practices and policies are probably not sustainable for even another century or less (e.g., Lutton and Tanton, 1994). If the United States were to continue increasing its population at the present rate and maintain per capita resource consumption at its present levels, the American society would be using an even more disproportionate share of the planet's resources than it now does.

With one billion people already receiving substandard nutrition globally and billions more only modestly better fed, it seems unlikely that these people will cheerfully relinquish already inadequate resources so that those in the United States can have still more to increase the per capita ecological footprint size of immigrants to that of the average present American citizen.

Politics aside, the United States tends to encourage immigration by those with particular technological, scientific, or engineering skills, who are ambitious for upward mobility economically, who are entrepreneurs, and, above all, who are apparently willing to risk their lives to achieve their goals. In return, the immigrants expect to enjoy the same material blessings as present American citizens.

As an aside, Charles Kennedy (personal communication) has commented on the era when the state of India was organizing itself after independence. The large estates of the nabobs and maharajahs were to be broken up into holdings for individual citizen-farmers. The question then arose, what size should these parcels be? A sociological study was carried out by sending interviewers into the villages and asking the farmers how much land they could handle. The response average was four hectares and the number explained this way: "I can live on one hectare with my family and lease out the other three as a landlord." Clearly, allocating resources will not be easy.

Sustainability in an Information Age

Bhutan became the last country in the world to have its own television station (Guha et al., 2001) when the Bhutanese government's long-standing ban on television came to an end on 2 June 1999. At present, the new station broadcasts only to the capital city of Thimphu, using English and Dzongkha, the national language. Although television can be a great educational tool, its dominant message, particularly in the United States and many other parts of the world, is materialistic. Without doubt, the degree of materialism is highly correlated with human impact on natural systems.

Immigration and the Precautionary Principle

The precautionary principle (Raffensperger and Tickner, 1999) states that, when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically. Essentially, the precautionary principle challenges individuals and society collectively to use common sense and to act wisely and well. This rephrasing of an old rule ("an ounce of prevention is worth a pound of cure") shifts the burden of proof for the consequences of a particular course of action to those espousing it rather than those trying to prevent it. The quest for sustainable use of the planet involves assessing all of the multiple dimensions likely to affect the outcome in an aggregate or holistic fashion rather than individually, however important the individual issue might be. Further, sustainability requires studying highly complex, poorly understood systems for which the break-points and/or thresholds are not amenable to laboratory studies and may not be apparent until they have been crossed. Immigration policy seems a superb, though extremely challenging, test of the difficulties of implementing the precautionary principle! Certainly the precautionary principle is a *sine qua non* for sustainable use of the planet because sustainable use should be based on preventing mistakes rather than correcting them after they occur.

Too many countries have unsustainable practices, and, without public participation in decision-making, taking preventative action in the face of uncertainty would be extremely difficult, arguably impossible. This situation is especially true when economic growth is needed while simultaneously protecting the integrity of natural systems. Some publications have explored these difficult issues (e.g., National Research Council, 1996; Nattrass and Altomare, 1999; Hawken et al., 1999).

The immigration problem would be diminished if all countries had more sustainable practices, including the United States, which is a magnet for immigrants because of its disproportionate use of the world's resources. The average Mexican making thirty-five pesos (U.S. $3.60) per day is well aware of the disparity in affluence as are anti-globalization demonstrators world-wide (e.g., Carl, 2001). The central issue is, how compatible are present rates of immigration and concomitant demographic changes with political stability and sustainable use of the natural resources of the United States?

Unquestionably, the precautionary principle is one of the crucial keys to facilitating sustainable use of the planet and, concomitantly, the key to the badly needed feedback relationships between scientists and policymakers. The American Association for the Advancement of Science has taken a major step by establishing the Program in Scientific Freedom, Responsibility and Law/Court Appointed Scientific Experts, http://www.aaas.org/spp/case/advisory.htm or http://www.aaas.org/spp/case/panel.htm). It is important for scientists to maintain their objectivity and integrity while carrying out their research, but they must be increasingly aware of the policy implications of what they do and their concomitant social responsibility to contribute to the protection of human health and the interdependent web of life.

My own preliminary assessment follows on some of the issues important in implementing the precautionary principle with regard to immigration policy.

1. Barring some tremendous increase in mortality in the present population of the United States, immigration cannot continue at its present level for an indefinite period without serious damage to the integrity of the ecological life support system and the quality of life of individual citizens.

2. Immigration to the United States does not appear to have helped donor countries in markedly progressing towards sustainability nor in reducing the problems that prompted individuals to leave the country. Clearly the United States could not reasonably accept even one-fourth of the one billion or more people presently on the planet whose living conditions are dramatically substandard (i.e., living on less than U.S. $1 per day per capita). The precautionary principle might be best implemented by helping other countries to make conditions more attractive for their inhabitants and to live more sustainably than to create problems in the United States by accepting only a tiny fraction of the world's migrating inhabitants.

3. Given the pulsating paradigm eloquently stated by the Odums (1995), one of the non- ecological pulses under human control is the rate of immigration. The fewer pulses policymakers must

contend with, the more likely they are to achieve sustainable use of the planet. When other cultures have exceeded the carrying capacity of their territory substantially, it has not only resulted in famine, disease, and a lowering of the population, but also a lowering of the carrying capacity. The precautionary principle suggests that when environmental thresholds are uncertain and/or pulsating, it is prudent not to approach them too closely and definitely not to exceed thresholds such as carrying capacity.

4. Immigration is far less reversible than many other factors affecting sustainability. For example, the size of the country's ecological footprint can be reduced by using less polluting, more fuel-efficient automobiles or by consuming fewer resources, but it cannot, barring extreme acts of cruelty, reduce the size of the population substantially by means other than natural death, etc.

5. Immigration to the United States (or any other country) permits donor countries to prolong unsustainable practices by reducing their population size and, thus, their aggregate environmental impact.

6. Immigration frequently alters the demographics of a country and makes sustainable planning more difficult since demographics are extremely important when developing policies for sustainable use of a country or of the planet. For the planet as a whole, of course, the demographics are shifting, but, reducing immigration may achieve a local balance without affecting the global balance. Both sustainable practices and policies must be developed locally and changing the demographics seriously affects both.

7. Over the long term, if present rates of immigration into the United States are continued, resource availability per capita will almost certainly diminish, thus making the country less attractive to immigrants. The transition to sustainable practices requires more efficient resource use and concomitantly reducing the size of the ecological footprint of the average citizen as well as that of the nation as a whole. It is difficult to envision the circumstances under which the present immigration rate would facilitate this process. The quest for sustainability appears to mean putting other species ahead of humans and that there is a lack of compassion for less fortunate people elsewhere on the planet – a serious ethical problem.

8. The Durants (1968, pp. 19-21) list some biological lessons of history. The first of these is that life is competition. Competition is not only the life of trade, it is the trade of life – peaceful when food abounds, violent when the mouths outrun the food. The second biological lesson of history is that life is selection. In the competition for food or mates or power, some organisms succeed and some fail. In the struggle for existence, some individuals are better equipped than others to meet the test of survival. Nature loves difference as the necessary material of selection and evolution. Inequality is not only natural and inborn, it grows with the complexity of civilization. The third biological lesson of history is that life must breed. Nature has no use for organisms, variations, or groups that cannot reproduce abundantly. She has a passion for quantity as prerequisite to the selection of quality. She is more interested in the species than in the individual, and does not care that a high birth rate has usually accompanied a culturally low civilization and a low birth rate a civilization culturally high. Thus, to the extent that encouraging immigration is a form of egalitarianism and a drive toward equality, the lessons of history are that nature will frustrate this attempt. To the degree that the quest for sustainable use of the planet is a concomitant drive toward egalitarianism and equality within the human species, it will be frustrated by nature. If, however, the quest for sustainable use of the planet is an attempt to preserve and accumulate natural capital (as espoused by Hawken et al., 1999) and protect the planet's ecological life support system and the services it provides to humanity, it is not egalitarian but rather enlightened self-interest.

Reason to the Rescue

A reasoned discussion of immigration requires a high level of civility and a free and open exchange of ideas. Any environmental organization that places a taboo upon discussion of any issue affecting sustainable use of the planet has placed survival of the organization above protecting the biospheric ecological life support system and has essentially rendered itself ineffective. Employing reason is definitely not risk-free since it has cost some philosophers their lives, altered the careers of others who have attempted to employ reason when the societal norms were against it, and suffered severe sanctions when opening a discussion on a subject that was taboo in the society. It is regrettable that many colleges and universities in the United States and elsewhere are becoming increasingly unsuited to reasoned discussions with a free and open exchange of ideas because of their speech and behavior codes, zero-tolerance policies, and the like. Very possibly, the appropriate outlets for such discussions are CNN's *Crossfire*, CNBC's *Hardball*, and various other similar venues, together with some of the political forums and public policy conferences on C-SPAN, particularly the call-in programs and, of course, talk radio. Quite clearly, when the consequences of unsustainable practices become more apparent to the general public because of a recession or some other factor, more open discussions will occur. One hopes that the discussions will not be too late to be effective.

A Glimpse of the Future

The *East Sea*, a rusty freighter that was deliberately run aground in mid-February 2001 near the French Riviera (William B. Dickinson, personal communication), may be a common migration strategy in the near future. Turkish smugglers packed at least 910 Kurdish men, women, and children into the ninety-foot ship for what was clearly intended to be a one-way trip since the captain and crew fled by lifeboat with the ship facing land and the propellers turning. One day later, 400 Africans in four boats also landed in Spain.

Not surprisingly, a book (Raspail, 1975) predicted such events, on a much larger scale, over a quarter century ago. In this fictional drama, a flotilla of one hundred rusty ships departs from the Ganges, carrying hundreds of thousands of desperately poor people who are willing to risk everything in the hope of reaching the south coast of France and a better life. Five more fleets from Africa and Asia join them, and sheer numbers threaten to overwhelm both France's resources and culture. In an afterward to a second edition, Raspail (1995) describes the vision he had that led to the book:

> *They were there! A million poor wretches armed only with their weakness and their numbers, overwhelmed by misery, encumbered with starving brown and black children, ready to disembark on our soil, the vanguard of the multitudes pressing hard against every part of the tired and overfed West. I literally saw them, saw the major problem they presented, a problem absolutely insoluble by our present moral standards. To let them in would destroy us. To reject them would destroy them . . . So-called Christian charity will prove itself powerless. The times will be cruel.*

Both the quest for sustainable use of the planet and the precautionary principle would reduce the probability of this scenario becoming a reality. However, human migration, emigration, and immigration are the symptoms of a larger scale problem that is being ignored – exceeding the carrying capacity for humans of a particular ecoregion. Learning to live sustainably is the solution, and the precautionary principle is a major means of implementing sustainable use.

Ignoring the Early Warning Signals

Accumulating scientific evidence notes that a variety of global ecosystems are approaching, or may even have exceeded, dangerous thresholds producing ecological disequilibria that may be difficult, even impossible in some cases, to reverse. For example, the Arctic icecap has already thinned by forty percent, one-fourth of the world's coral reefs are sick or dying, and natural disasters caused by environmental degradation have cost the world $608 billion over the last decade – as much as in the previous four decades combined (Brown et al., 2001).

The choice facing political leaders is unquestionably historic: Should they lead human society in a paradigm shift to rapidly build a sustainable economy or risk the loss of the natural capital, which is the ultimate basis for the global economy (Hawken et al., 1999)? Environmental and subsequently societal catastrophes are inevitable if people continue to follow the infinite exponential growth paradigm and if they are close-minded enough to ignore the increasingly persuasive environmental warning signals. Such a paradigm shift (toward sustainability) is unlikely as long as President Bush is lauded for reversing his pledge on carbon-dioxide emissions, etc. (e.g., Chilton, 2001).

Conclusions

Immigration is, of course, only one facet of a complex, multidimensional environmental problem. In the present climate of political and economic uncertainty in the United States, it seems highly probable that elected leaders will roll back environmental laws and fail to complete key international agreements. Concomitantly, impoverished peoples the world over have access to information depicting, in no uncertain terms, the enormous disparity between their level of material affluence and that in the United States. Naturally, a very high percentage of them wish to come to the United States, and of these, a significant number will be sufficiently persistent, innovative, and skillful to do so. The well-documented literature on sprawl factors in large American cities shows that there are nearly equal roles played by population growth and land use choices in the loss of farmland and natural habitat to urbanization (Kolankiewicz and Beck, 2001). Immigration is only one of the components in this complex problem but, nevertheless, an important one. It does clearly illustrate that, even if there were no immigration, human society's relationship with natural systems would have to change dramatically. Still, immigration is clearly exacerbating the problem.

Time seems to be rapidly running out for a reasoned approach to developing human society's relationship with natural systems. Stubbornly clinging to old notions about immigration and exponential growth on a finite planet will surely result in disastrous consequences. Worse yet, the kinds of exponential growth to which society is still attached, have doubling times in social change that are virtually impossible for a democratic political system to accommodate.

It seems unlikely that the immigration problem will be resolved without correcting the maldistribution in resources. The maldistribution is seen not only among individuals but among nations as well. The United States has less than five percent of the world's population (281 million out of slightly over six billion) but a much larger share of the world's wealth, despite the fact that many of the 281 million citizens are desperately poor, lack adequate medical care, and may be malnourished. Accumulating wealth and material goods does not bring happiness, but it does bring problems which, if allowed to worsen, will bring much more discontent and unhappiness. If the wealthier American citizens were to reduce their consumption and make these resources available to other individuals both in this country and abroad, immigration pressure on the United States would surely lessen and all members of human society, especially the young, might have more hope for a sustainable future. This vision is almost utopian, but the consequences of not moving quickly toward sustainable use of the planet are so horrible to contemplate that it seems prudent to make an all-out attempt to do so.

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Article 20

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Opinion

The Role of Reservoirs in Sustainable Use of the Planet

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Attempts are being made to place nearly everything in a sustainability context, although implementation is thus far exceedingly rare. Most sustainability proposals act as if each component of human society were the only flower facing the sun. The consequence is titles such as sustainable transportation, sustainable agriculture, sustainable cities, sustainable energy, sustainable forestry, and the like, as if these were not interactive and as if events of one activity did not inevitably affect events in others. A critical component of sustainability programs will be the development of early warning systems to alert management that the system is not functioning as expected. Reservoirs appear to be ideal for this purpose. Since rain waters travel over land to reach streams, lakes, and reservoirs, they are influenced by anthropogenic activities on the land as well as airborne contaminants. In streams particularly, the hydrologic dynamics are influenced by the number of impervious surfaces, such as parking lots, found on the adjacent landmass. Movement of particulate material and its deposition as sediments are particularly important in reservoirs and, where persistent toxics are concerned, usually represent a substantial sustainability problem. The second major new initiative is industrial ecology where the boundary between industry and the natural world becomes less well defined. As human society moves toward sustainability, pure industrial systems will essentially disappear or become self-contained, and much of the remainder of the planet will be covered by hybrid industrial/ecological systems. Reservoirs are a prime example of such systems since they are not entirely natural and, in some cases, are primarily oriented toward solving societal needs, if one includes agribusiness, municipal water supplies, and the like. Reservoirs again should be leading indicators of the degree to which the boundaries between industrial and ecological systems become less well defined because each contains some components of the other. This manuscript focuses on these two newly developing and related initiatives.

Reservoir management in a sustainability context

Useful information on aquatic ecosystems (National Research Council, 1992) and reservoirs (Cooke et al., 1993) exists in numerous publications. However, two emerging and related areas of considerable significance to reservoir management, or resource management in general, are covered in this discussion: (1) sustainable use of the planet, and (2) industrial ecology. Boulding (1966) has stated, "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist."

Reservoirs are artifacts of human society that alter the hydrologic cycle in ways that endanger species that have adjusted to different ecological conditions. Both the dam and impoundment have a finite life expectancy determined by sediment deposition, nutrient accumulation, and structural integrity of the dam itself. Toxic substances may accumulate in the sediments, which may pose disposal problems if removal is part of a management strategy to prolong reservoir life expectancy. Although natural systems are self maintaining, reservoirs may incur considerable management costs that reduce their value. The term *sustainable* implies an indefinite period of use; reservoirs, as presently constructed and managed, do not qualify as candidates for sustainable practices. However, they do qualify as candidates if they are industrial/ecological hybrids, which do have a role in sustainable use of the planet. A major task will be to make reservoir management congruent with a comprehensive sustainability paradigm such as natural capitalism. This paper is a preliminary effort to explore these issues.

Although many publications preceded it, the United Nations World Commission on Environment and Development Report (1987) is arguably the document most responsible for the increased attention to the concept of sustainable development. *Sustainable development* is defined in the report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Alternative statements of this position include: (1) leaving a habitable planet for descendants and (2) intergenerational equity and fairness in resource allocation. Unfortunately, the word *development* is often associated with growth in artifacts of human society. The environmental newsletter *Current* of the UNESCO-UNEP (1996) notes: "economic growth – until recently synonymous with development – was once presented as the panacea to the ills of humanity: from poverty and disease to over-population and environmental degradation." Sustainability is of particular interest regarding reservoirs because they are more susceptible to aging than the rivers on which they are commonly built (e.g. Cairns & Palmer, 1993). From a human standpoint, reservoirs are of interest because, as soon as reservoirs are completed, human society often becomes seriously dependent upon them. Therefore, management of reservoirs in a sustainability context is an important management concern.

Sustainability requires focusing on long-term existence rather than on short-term economic benefits. Ecosystems become sustainable when their integrity is maintained, not merely by avoiding observable harm to a few "indicator" species. This mandate requires a landscape perspective with management practices suitable for large temporal and spatial spans. The simplest measures of ecological integrity may be indirect – i.e. the actions of human society likely minimize or markedly reduce negative impacts on natural systems (Cairns, 1995a).

Natural capitalism

The unifying theme of natural capitalism is the critical interdependency between the production and use of human-made capital and the maintenance and supply of natural capital (Hawken et al., 1999). Natural capital is the living systems of the biosphere which provide services that collectively constitute the planet's ecological life support system (e.g. Cairns, 1993, 1997; Costanza et al., 1997). The cornerstone of natural capitalism is using natural resources more effectively, which has two important benefits: (1) it slows resource depletion, thus lowering ecosystem damage, and (2) it provides more employment in naturalistic settings with employee satisfaction. Drastically altering hydrologic systems to attempt flood control or generate power is arguably not a viable means to achieve sustainable use of the planet.

Industrial ecology

Tibbs (1992) envisions a gradient with pure industrial systems at one end and pristine ecosystems at the other end with various combinations in between. His view suggests moving toward sustainability in a way that pure industrial systems essentially disappear or become almost self-contained and most of the planet will consist of combinations of industrial and ecological systems, while retaining as many as possible of the pure ecological systems to use as models. Although Tibbs does not emphasize or even mention reservoirs, they offer a marvelous example of the industrial/ecological combination. Reservoirs are definitely not lakes, but they do have many of the ecological attributes of lakes, including stratification, removal of some material from the water column and storage in the sediments, and the like. Industrially, reservoirs are major sources of hydroelectric power, water for agribusiness, and a major supplier of urban water, particularly in the arid areas.

Human society is greatly dependent upon reservoirs now in service. Reservoirs can become silted in, can trap hazardous substances such as pesticides (e.g. National Research Council, 1977; Colborn & Clement, 1992) that may appear in the biota or the water column, can have dams with finite life expectancies, and can incur demands now in excess of the supply.

The concept of sustainability acknowledges that technology and innovation on a finite planet can increase the carrying capacity of humans, but not indefinitely. There is also the question of quality of life, that is, should carrying capacity be determined by the number of people who can be crammed into a given area at a subsistence level or should quality of life will be the major determinant of ultimate carrying capacity? In instances where countries share waterways or where water is transported from one nation to another, sustainable use of the planet must be considered in terms of a bioregion, rather than entirely in terms of political boundaries.

Essentially, the goal in sustainable use of the planet is to manage the technological component of the life support system so that it does not impair the ecological component of this life support system (Cairns, 1996).

The scale of change caused by previous generations to natural systems is minuscule compared to the changes caused by present inhabitants, such as very large cities, shopping malls, an enormous transportation system with roads fragmenting the environment and, of course, reservoirs. Even though many present practices are unsustainable (infinite growth on a finite planet is simply not possible), abrupt transitions are neither good environmentally nor socially. Thus, in this new century, many hybrid systems will emerge with technological and natural systems in close coexistence and, in some cases, even hybrid technological/ecological systems will exist. One of the most notable hybrid systems is the reservoir, combining technology and many attributes of natural systems. In addition to being a hybrid industrial/ecological system of the type described by Tibbs (1992), reservoirs are also constructed ecosystems. Constructed or created ecosystems resemble those occurring naturally but are usually placed in locations where they were not previously found. For example, Atkinson & Cairns (1993) and Atkinson et al. (1993) describe wetlands that were constructed on surface mined lands after mining activities had ceased. Definite drawbacks can be identified to this type of activity (e.g. Cairns, 1994, 1995a).

1. Most ecological restoration is carried out to repair damage caused by human mismanagement. If management is the disease, how can it be the cure? Noss (1985) has said "This is the irony of our age: 'hands-on' management is needed to restore 'hand-off' wilderness character."
2. Some mitigative restoration is carried out on relatively undamaged habitat of a different kind. For example, created wetlands may replace an upland forest, or an upland forest may be destroyed to produce a 'replica' of the savannah that once occupied a particular area. Logically, this secondarily damaged habitat should be replaced by yet another mitigative action. Sacrificing a relatively undamaged habitat to provide mitigative habitat of another kind deserves more caution than it has been given.
3. At the current state of knowledge, restoration projects are likely to have unforeseen outcomes. Ecological restoration carried out by the most skilled professionals will occasionally, perhaps frequently, omit some very important variables. Episodic events may occur at inconvenient times. Some of these unforeseen results may offset any ecological benefits likely to result from a particular restoration project.
4. Well-meaning restoration efforts may displace the species best able to tolerate anthropogenic stress. By attempting to return an ecosystem to its predisturbance condition, ecologists may be hampering the evolution of those species capable of co-existing with human society. Attempts to manipulate the environment in such a way to promote the success of one or two species may impede both the natural successional process and also exclude other species that would otherwise be there.
5. Similarly, if ecological restoration is carried out on an extremely large scales, human-dominated successional processes could become 'the norm.'
6. Finding sources of recolonizing species for damaged ecosystems is increasingly difficult. Should one remove them from quality ecosystems and risk damaging that ecosystem, or use pioneer species, or, worse yet, exotics with the hope that the more desirable species will eventually colonize naturally?

All the above considerations will become important if reservoirs are either rejuvenated or replaced with an alternative type of ecosystem, including the pre-reservoir condition.

Reservoirs, of course, are unique since they have no ecological counterparts, excluding beaver dams because of both temporal and spatial scale differences and also the fact that beaver dams are made of biodegradable material. Regrettably, since existing reservoirs are likely to outnumber new reservoirs by a substantial margin, construction of new reservoirs with an ecological focus, while highly desirable, is not likely to be a common opportunity. When it does exist, reservoirs should be constructed with sustainable use in mind. The major question becomes how to modify existing reservoirs for sustainable use, including the delivery of a variety of ecosystem services.

Ecological health and the delivery of ecosystem services

Healthy ecosystems deliver services more reliably and of higher quality than damaged ecosystems. Therefore, measurements of ecosystem health, both structural and functional, become increasingly important. Cairns et al. (1993) have proposed a rather extensive framework for developing indicators of ecosystem health, which can be applied to reservoirs with modest modifications. Cairns & Niederlehner (1995) have also described ways that ecosystem health concepts can be used as a management tool. Finally, and possibly most important, Cairns (1995b) has proposed that ecological integrity, which is another way of describing ecosystem health or condition, might best be measured by determining whether the society associated with the ecosystem has environmentally friendly practices or abuses the environment. Among the many important features is the use of persistent toxicants, especially pesticides, in the hydrologic area that feeds the reservoir. Storage of persistent hazardous materials, or even non-persistent but moderately durable hazardous materials, in the reservoir sediments, the water column, or the bodies of organisms is something to be rigorously avoided if sustainable use is a major consideration.

Threats to sustainable use of reservoirs

Although the National Research Council (1992) report does not cover reservoirs, some comments on lakes apply to reservoirs. The report notes that, although lakes occupy a small fraction of the landscape, their extent belies their importance as environmental systems and resources for human use. Lakes are major recreational attractions and water-front property has a high economic value. Further, large lakes and *reservoirs* are used as drinking water supplies and for many commercial purposes, including fishing, transportation, irrigation, industrial water supplies, and receives waste water effluents. Of course, reservoirs are not natural systems, but they nevertheless have intrinsic ecological and environmental values. If reservoirs are sizable, they moderate temperatures and affect the climate of the surrounding landmass. Additionally, they store water, recharge groundwater aquifers, and moderate droughts. Reservoirs provide habitat to aquatic and semi-aquatic plants and animals, which in turn provide food for many terrestrial animals. In this regard, the ecological and environmental value of reservoirs is a function of the degree to which they are managed for this purpose. For example, pumped/storage reservoirs designed to meet peaking power demands have enormous fluctuations of water levels with their associated disturbances. These reservoirs are not suitable habitats for species that are dependent on shoreline stability.

Ecological stresses on reservoirs originate from both point sources, such as municipal and industrial waste water discharges, and from non-point sources, such as urban and agricultural runoff within the watershed and from more difficult to control long-range atmospheric transport of contaminants. The major categories of stresses for reservoirs are essentially identical to those listed by the National Research Council (1992) for lakes, including excessive eutrophication from nutrient and organic matter loadings; siltation from inadequate erosion control in agricultural, construction, logging, and mining activities; introduction of exotic species; acidification from atmospheric sources and acid mine drainage; and contamination by toxic (or potentially toxic) metals, such as mercury, and organic compounds such as polychlorinated biphenyls (PCBs) and pesticides. Hydraulic manipulation exists in lakes as well, but not nearly to the degree that it does in reservoirs.

As the National Research Council report (1992) notes, lake restoration is a relatively recent activity; in most cases, this activity should really be categorized as rehabilitation since only certain attributes are restored and the predisturbance condition is unlikely to be attained. For sustainable use of any system, it is essential to control the source of threats to the system. Nowhere is this more true than a hybrid industrial/natural ecological systems such as a reservoirs. In this particular case, the sources of the problems are in the larger drainage basin from which inlet or influent waters arrive and also from the ways in which the reservoir itself is managed.

Sustainability in the drainage basin context

One of the greatest physical threats to a reservoir is filling in with deposited suspended solids and becoming an alluvial plain. Establishment of ecological buffer zones along the streams contributing water to the reservoir is an important first step in avoiding deposits of suspended solids and can often be accomplished through simple voluntary behavioral changes by the people managing the stream area (e.g. Cairns & Pratt, 1995).

Another major concern is fluctuations in water level, particularly at a rapid rate, that are well beyond the variability of a normal lake. The fluctuations could be the result of demands upon the impoundment's water supply for irrigation, municipalities, evaporative loss of cooling water or from unexpectedly high runoff in the drainage basin area feeding into this system. Urban runoff may be particularly apparent and quite unlike any normal ecosystem runoff where the surfaces are not impervious. Urban runoff problems can be ameliorated (e.g. Cairns & Palmer, 1995; Cairns, 1995c). Societal demands can also be markedly reduced in times of need. Cities have reduced demand in extreme emergencies when literally no more water would be available if conservation practices were not put in place. The idea of putting conservation practices in place to protect ecosystem integrity may be a difficult task until a commitment to sustainable use and consequent maintenance of ecosystem integrity becomes an established societal practice.

Chemical stresses

Chemical stresses fall into two general categories – excessive nutrient loadings and chemicals at concentrations likely to produce toxicological effects. Agricultural runoff, of course, frequently includes both excessive nutrients and persistent chemicals that exhibit toxicological properties at rather low concentrations. Wastes from animal feed lots bordering streams and fish hatcheries and fertilizer runoff from farms, golf courses, and urban lawns are also not only sources of nutrients leading to eutrophication, but also are likely to contain herbicides and other pesticides. Use of an active chemical, such as chlorine in paper mills or for disinfection in municipal sewage treatment plants, can produce a wide variety of chemicals through combination and transformation. Many of these chemicals are persistent and can cause harm at extraordinarily low concentrations (e.g. Colborn et al., 1996), but precise predictions of the entire range of effects on humans and the environment are still problematic. For reservoirs, the consequence of increasing the temporal and spatial scale of environmental management is an increase in the uncertainty of the predictions of environmental outcome and consequences. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made. However, they are linked – acting with an intolerance of uncertainty often demands a high tolerance for risk. If the consequences are severe, one should be willing to act even in the face of high uncertainty. Impairment of ecosystem services certainly seems to fall in this category.

Traditional health and industrial monitoring systems produce both false positives and false negatives. In an environmental monitoring context, a false positive is a signal that some deterioration has occurred in the system when, in fact, it has not. A false negative is the absence of a signal when unacceptable changes in quality have occurred. The earlier use of sentinel species yielded false positives if the sentinel species was more sensitive to a particular toxicant than were the resident species and false negatives for some other toxicant for which the relative sensitivities were reversed. Furthermore, the correspondence between invertebrate chronic laboratory toxicity tests and *in situ* macrobenthic community endpoints is not always consistent (Cairns et al., 2000). Reductions of errors can be accomplished by a better understanding of the system being monitored and by multiple lines of evidence. Integration of environmental monitoring programs will provide both. In addition, some attempt is being made to re-address the balance between false positive and false negative errors in risk assessments. Traditional scientific approaches control false positives at the expense of additional false negatives; this tactic may be inappropriate in a risk assessment context (Schrader-Frechette, 1993). Often these uncertainties can be substantially reduced by robust information (e.g. Wlosinski et al., 1997).

Severe limits exist to what can be done with ecotoxicology, particularly with persistent complex organics in the environment. Even the chemistry and toxicity of in-place pollutants in sediments (e.g. Baudo et al., 1990) is daunting! Many of the 30-50 million species on the planet are still unnamed. Those that are named are relatively unknown in terms of their life cycles, etc., so it is not surprising that there is no substantive information on their response to toxic materials. Add to this situation the roughly 76 000-100 000 chemicals in more or less daily use and the possibility of interactions and transformations among these chemicals (e.g., Cairns et al., 1978) and the problem is daunting. With research being de-emphasized at many major government-supported institutions (or if not de-emphasized, the emphasis has switched to teaching), governmental budget cuts, and industrial downsizing, the information base is not likely to increase dramatically. Even if funding were available, the number of skilled professionals to generate persuasive evidence is inadequate. Therefore, the focus must be on diminishing the utilization of systems that create by-products that have deleterious rather than enhancing effects upon ecosystems. Private landowners who use products that damage public systems through runoff, airborne transport, and the like should be held accountable for the damages produced and for the cost of repairing the damaged ecosystems. As Hawken (1993) notes, “those who assert that we need to stop the engine of industrial growth in order to garner the resources to clean up our environment do not see that the industrial system itself is flawed in both its design and emphasis.” This request is not unreasonable – Hitachi (date unknown) is making substantial efforts to improve the environment, both through disassembly strategies and use of hybrid ecosystems for transforming various societal wastes for benign reincorporation into the environment.

Making distinctions

Kimball (1999) addresses the problem of overdosing on non-judgmentalism in society and the onerous task of making distinctions. As Kimball notes, neglecting important distinctions is one of the great temptations facing modern, affluent societies. In many discussions, it is fashionable to say that there is no objective truth, only clashing perspectives without true moral knowledge. Avoiding any judgments about how the world should work may postpone irritating clashes with those holding different views, but is not likely to result in sustainable use of the planet. On a finite planet, with severe pressure on nearly all resources, some judgments are inevitable. Reservoirs will probably be a flash point in this regard as water becomes more scarce, particularly quality water.

The hydrologic cycle

Sustainable use must always be considered, at least in a landscape context (the hydrologic cycle) and sometimes in a global context (greenhouse gases). The important issue is how much natural systems (in this case, the hydrologic cycle) can be altered without impairing the delivery of ecosystem services and damaging the ecological integrity of the systems that provide the services. Reservoirs definitely alter the hydrologic cycle and the ecological integrity of riverine systems. Initially, they may improve the human condition in a variety of ways. However, present management practices may not be sustainable over a multi-generational period (e.g. 20 generations). Rejuvenating senescent reservoirs may involve financial and ecological costs that are presently unacceptable to human society, especially during periods of economic uncertainty. For example, where should sediments with toxic substances be placed when removed from the reservoir and who pays for the removal, transportation, and placement site? What risks and ecological disequilibrium will result from this action, which presumably must be carried out periodically over a large temporal span? Is the reservoir to be managed for purposes other than flood protection of downstream areas where buildings and other human artifacts have been built on the floodplain? If sustainable use of the planet is to be achieved, the integrity of the entire hydrologic cycle must be given much more attention.

Balancing values

Reservoirs and other hybrid industrial/ecological systems require a balancing of societal and ecological values in a sustainable use context. Neither scientists nor managers are accustomed to developing and implementing these, but hybrid systems require judgments on a continual basis. Although episodic events will almost certainly require adaptive management, short-term goals should never override long-term goals if doing so impairs delivery of ecosystem services or damages ecosystem integrity. This situation is a major source of vulnerability to hybrid systems – namely that mitigating short-term emergencies will override long-term goals. To offset this possibility, constant reminders of the importance of the planet's ecological life support system are essential.

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Article 21

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Speculative Scenarios: Is There a Way to Use and Sustain Our Planet?

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The great fault of all ethics hitherto has been that they believed themselves to have to deal only with the relation of man to man.
—Albert Schweitzer (as quoted in Wallace, 1998, p. 412)

The nations of the region will act rationally once they've run out of all other possibilities.
—Abba Eban (as quoted in Postel, 1999, p. 133)

Literature on sustainable use of the planet is beginning to accumulate at a fairly rapid rate, although the general public and politicians, with some notable exceptions, have given the issue little or no thought. On a finite planet, human population size is clearly a central issue, yet most countries have no population policy and some use tax breaks to subsidize large families. Arguably, quality of life is an equally important issue, but is discussed mostly in economic and material terms. In addition, industries that are harmful to human health and the environment will fight vigorously to continue their present practices. Exponential growth of all kinds (economic, technological, urban, etc.) produces problems at a rate for which the social system is woefully unprepared. Finally, individual interest in any problem is markedly diminished if it is perceived as distant in time or space or both. Still, humans have proven amazingly adaptable when the consequences of not showing an interest in a problem are made clear. However, history shows that such a recognition does not often happen in time to prevent major human suffering. I remain optimistic about what could be done to achieve sustainable use of the planet, which is why the first scenario discussed here is a "soft landing" — regrettably a paradigm shift rarely occurs without devastating consequences preceding it. Therefore, I remain pessimistic about will be done, as is evident from the other five scenarios.

Scenario #1: The Soft Landing

One might easily justify a view of gloom when speculating about the future of human society. Much of the developed world has a large number of elderly compared to productive workers (e.g., Longman, 1999). Economic news from most of the world is not good; terrorism is increasing, as are the devices used by terrorists; ethnic strife is rampant. Even in this setting, Brown (1999) makes a persuasive case for an environmental awakening. Fossil fuel subsidies in developing and former eastern bloc countries have dropped from $202 billion in 1990-1991 to $84 billion in 1995-1996. Global average price for wind power has dropped from $2,600 per kilowatt in 1981 to $800 per kilowatt in 1998. World production of ozone-depleting chlorofluorocarbons was 1,260,000 tons in the peak year of 1998 and only 141 tons (excluding black market) in 1996 (all the examples are from Brown et al., 1999). Despite biotic impoverishment, continuing global deforestation, water shortages, and the like, human society might find enough of the natural world remaining to rehabilitate it to some semblance of its former integrity.

In the soft landing scenario, Earth's carrying capacity is exceeded but the duration is short; natural systems have not lost their resilience and human-assisted ecological restoration is remarkably successful. Brown (1999) sees signs that the world may be approaching the threshold of a sweeping change in the way society responds to environmental threats. He believes that this social threshold, once crossed, could change the outlook as profoundly as the one, which in 1989-1990, led to a political restructuring in Eastern Europe. Having worked with toxicological and ecological thresholds for a half century (e.g., Cairns, 1992), I am cautious in both determining thresholds and extrapolating the results. Still, compelling evidence shows that thresholds exist and are useful in making a variety of decisions despite both false negatives and false positives (e.g., Cairns, 1999).

One practical consideration in using thresholds is that their existence is often not known until they have been crossed (e.g., Cairns, 1998). What if human society crosses the threshold but gets back to the right side in time – then what? Society must realize that it cannot jump back and forth across the threshold. The first "then what?" would be an early warning system. Society should become acutely aware of when the threshold is too close, and retreating to more sustainable practices should become automatic. Sustainable practices should not have to be the consequence of losing a legal battle.

The second "then what?" should prompt society to recognize that environmental thresholds oscillate, and society should become aware of why and when thresholds change. The third "then what?" is the hardest! Human society must acknowledge dependence upon an ecological life support system and alter human practices and behaviors to protect the life support system's integrity. Carrying capacity – the maximum number of organisms of a given species that can be supported in a given habitat or geographic area – is a crucial limit or threshold. The quest for sustainable use of the planet is focused on the "cost" of maintaining healthy ecosystems and the services they provide in the context of the costs of growth in human population size and per capita level of affluence. The assumption of ecological limits is a *sine qua non.*

Discussions of limits to growth are described by detractors as "gloom and doom" prophecies. However, science makes no moral or ethical judgments since scientists merely report evidence on the probable consequences of a particular set of circumstances. One rarely hears gloom and doom accusations about carrying capacity signs on elevators, airplanes, bridges, and the like. Ecological systems are continually adjusting to the chemical/physical/biological limits they encounter. Is it asking too much of human society to do so as well? Unless adjustments are made, a "soft landing" seems quite unlikely. Human society should not behave as if the survival of *Homo sapiens* has been preordained. Individuals who do not value a comparable quality of life for their descendants and the descendants of others are unlikely to devote time, resources, and energy to the quest for sustainability.

Scenario #2: The Hard Landing

All species have an upper limit or threshold on population size that is determined by resources, space, predators, disease, and competition from other species. Technology has enabled humans to modify the factors that govern population growth, but not abolish them. In the absence of predators, herbivorous mammals will overexploit resources. They will first rise to an extraordinary population size and then crash to well below previous levels as a consequence of damaging the integrity of the resource base. How large might the crash be? Individuals with poverty level incomes are not economically situated to meet major emergencies, and this segment of society constitutes a sizable portion of the approximately 6 billion people now on the planet. Adding 4 billion people in the next century will definitely worsen the situation. However, barring a major nuclear exchange, extinction of the human species seems unlikely since small groups of hunters/gatherers still exist in various parts of the world. These people could probably adjust to living off the natural systems since they are already fairly adept at doing so. Even if the carrying capacity of the region is temporarily reduced, sustainable practices will almost certainly increase it over time spans that may not benefit the individual but should benefit the species.

The book *Beyond the Limits* (Meadows et al., 1992) estimates a world human population crash about 2030. Such a crash has happened before on a smaller scale on Easter Island, Mangareva Island, and a number of other areas of the world. I find the island examples particularly forceful since the inhabitants were intimately associated with their resource base and could personally witness its use by the people dependent upon it. Is an unexpected crash more or less likely in a situation where inhabitants are more removed from witnessing the sources of their food, energy, etc.? If a hard landing occurs, it will almost certainly be due to a number of factors rather than a single major cause. A few illustrative factors follow.

(1) Failure to grasp the rate at which exponential growth changes circumstances from acceptable to unacceptable.

(2) Attempts to get just a bit more profit before the system collapses (e.g., ocean fisheries).

(3) Overexploitation of resources by countries or corporations with headquarters well outside the area being damaged (e.g., chip mills).

(4) Denial or distortion of the evidence by those engaged in unsustainable practices (e.g., production of greenhouse gases).

(5) Cumulative effects of a series of actions seemingly harmless individually but disastrous in the aggregate (e.g., loss of wetlands and forests exacerbating the damaging effects of floods).

(6) Attempts to resolve scientific issues within a legal system unsuited for this purpose (e.g., are the scientists who testify in the judicial system qualified to serve on a National Research Council scientific evaluation committee?).

Any reader who doubts that society is too clever to make a series of foolish judgments should read Will Rogers' column "No Tax on Optimism – Yet" (pp. 408-410 in Sterling and Sterling, 1982). As usual, Rogers goes unerringly to the truth and even makes it humorous.

Scenario #3: Selective Soft and Hard Landings

As Wallace (1998) notes, Blacksburg, Virginia, U.S.A., a town of 30,000 persons, maintains 400 miles of streets – about 2,500 acres of asphalt pavement; Beaune, France, a city of 20,000 persons, is smaller than 500 acres, including *houses, shops and streets* (emphasis mine). Which of these cities has the smallest "ecological footprint" and is thus able to maintain a quality life on fewer resources? Kerala (a state in India) has a very small per capita ecological footprint, yet it compares well in attributes, such as life expectancy, with areas that have large per capita ecological footprints (United States and Canada). Clearly, it is unreasonable to expect Kerala to assist areas with large per capita ecological footprints to make the adjustment to resource limitations. What about the relationship between, for example, the United States and Haiti? The former has a large per capita ecological footprint and the latter a small one. Should the United States, as a matter of policy, reduce per capita ecological footprint size and send more aid to Haiti, even if this results in further population growth in Haiti without concomitant growth in resources? Haiti now has 42.6 percent of its population under age 15 and only 4.1 percent at 65+ (New York Times, *The World Almanac 1999,* p. 795). Major shifts in Haitian societal practices will be needed to achieve sustainability.

In addition, Haiti has no significant military capability. What happens if some country with military capabilities experiences a population collapse as a consequence of exceeding some resource threshold? Acquisition of additional resources by military means will undoubtedly occur to some political leader as it has to others in the past. War, of course, lowers carrying capacity through both diversion and destruction of resources.

Exemptionalism

Both Scenario #2 and #3 are likely to result from excessive optimism about “exemptionalism” – the belief that humans are exempt from the laws of nature that limit population growth and per capita affluence of other species because of their creativity, technology, and ingenuity. If resources are infinitely substitutable, they are not limiting and the human population can continue to grow in both numbers and affluence far into the future (Simon, 1981). Others (environmentalists) believe that there are limits to growth on a finite planet, although science and technology have increased Earth’s carrying capacity for humans beyond the limits identified by Malthus over 200 years ago. Arguably, the best single point-counterpoint debate on this topic is the Myers and Simon (1994) book, now regrettably out of print but available in many major libraries.

Wilson (1998) notes that, for the committed exemptionalist, *Homo sapiens* has in effect become a new species. Wilson even provides a new name — *Homo proteus* or *shapechanger man* — with the following description (p. 278) of this hypothetical species:

> *Cultural. Indeterminately flexible, with vast potential. Wired and information-driven. Can travel almost anywhere, adapt to any environment. Restless, getting crowded. Thinking about the colonization of space. Regrets the current loss of Nature and all those vanishing species, but it’s the price of progress and has little to do with our future anyway.*

Cairns (1998) has discussed some aspects of the risk/uncertainty paradox regarding exemptionalism and some illustrative ethical considerations (Cairns, 1999) regarding our relationship with other species if the exemptionalist’s assumptions proved robust.

However, another important consideration is the devastating effect that reliance on exemptionalism might have on human behavior. For example belief in infinite substitutability of resources might cause humans to become even less sensitive to the limiting effects of resource depletion on other species. It is already abundantly clear that other species have neither the technology or ingenuity to replace their exhausted resources. Their only hope is that human society will become more compassionate with respect to their needs or, alternatively, they will disappear.

The "point of no return" is an important planning strategy for explorers, airplanes, ships, and other situations where resources are finite and cannot be replaced without returning to a supply or resource base. Earth is transporting human society through space, but there is no supply base to replenish resources when they are depleted. Human society’s point of no return is when the natural capital that renews resources has been so degraded that it can no longer do so at an adequate rate. There is no reliable gauge to measure this endpoint as there is for a fuel supply. Undoubtedly, those engaged in reckless exploitation of Earth’s resources are unaware of the exemptionalist hypothesis or of infinite substitutability of resources. These reckless individuals deserve far less respect than the exemptionalists who have considered the resource base for future generations, despite a total disregard for the factors that limit other species and, arguably, humans even if to a lesser degree. The point of no return must permit some testing of the exemptionalist hypothesis while permitting a shift to sustainable use of finite resources if the exemptionalist hypothesis proves invalid.

It is regrettable that neither exemptionalists nor ecologists have given serious consideration regarding their course of action if the other side is correct. The Myers/Simon debate (1994) clearly shows the polarization that exists. The public is unaware of the reasoning supporting each viewpoint, although the profligate use of resources might suggest, to uncritical people, that there is stronger support for the exemptionalist position than may actually exist. Until a public debate occurs that goes beyond slogans and platitudes from both sides we can only speculate about public views. One hopes that this debate will occur before a point of no return has been passed.

Alteration of the First Three Scenarios by Episodic Events

There is a persistent tale about a plane that experiences "mechanical difficulties." As it descends for an unscheduled emergency landing, one passenger remarks "And I gave up smoking last month!" Other versions of the same philosophy are "When on the Titanic, you might as well go First Class," or "In the long run, we are all dead." Along the same lines, a large object from outer space could collide with Earth and cause mass extinctions or the Antarctic ice cap could shrink as a result of natural cyclic events or through anthropogenic effects or both.

A major catastrophe might not occur, and human society could still suffer enormously as a cumulative result of a an extended series of "small" decisions that in isolation seem beneficial. Or, as some of my friends have noted, "It makes no sense for a person who is 76 years old to be concerned about these things!" But, surely, it is comforting to envision that others will have the opportunity to experience the things that gave us pleasure! One must ensure that the precautionary principle is involved, which espouses the imposition of controls to protect the environment even when there is an incomplete understanding of the relationship between anthropogenic practices and their effect on the environment. Inevitably, some precautions will subsequently prove unnecessary, and others will be negated by events beyond the control of society. However, many of the principles will work, and some will have unexpected benefits. Carefully studied and effectively communicated efforts to help others benefit both giver and receiver and should bring joy to both.

Scenario #4: For Humans There Are No Limits or Thresholds

Although ecology and economics are related (both refer to the home – eco-logy is the study of the home and eco-nomics is the study of its management), a casual observer might assume they have no relation. Nowhere is this more apparent than in the debate between Myers and Simon (1994): Myers believes in carrying capacity for humans while Simon did not. If human ingenuity and technology can free the human species from the thresholds and limits that affect other species, sustainable use of the planet by humans has been achieved! However, much environmental damage is done under the economic growth banner and usually no other justification is needed. Many people who ravage the environment claim they are environmentalists. Every special interest group, from logging to highway construction, declares that its practices are sustainable. So where is the problem?

One big problem remains: What is the ethical and moral obligation to other species? Elsewhere (Cairns, in press), I have discussed this issue in more detail, but it can be summarized briefly: do humans drive other species to extinction just because they are not needed? This question leads to the next scenario.

Scenario #5: Humans Are Subjugated on Earth by a Technologically Advanced Species from Elsewhere

In the United States, the idea of humans being subjugated to an alien species was brought to national attention by a famous radio drama. The plot of the drama is that extraterrestrial invaders with vastly superior technology quickly subdue and enslave humans. The invaders are superior to humans in ways that permit dominance, and they have no compassion for "lower life forms." Ultimately, a lower life form saves the humans by infecting and killing the invaders. But, what if this result were not the ending of the drama? Humans do not enjoy this drama or premise because another species has views similar to humans toward "lower" forms of life.

Scenario #6: Sustainability is Achieved Because the Little Creatures that Have Always Run the World Take Full Charge

It seems unlikely that humans could destroy all life on Earth. Forms of life similar to those that preceded humans billions of years ago could take full charge again and the planet would operate sustainably. Of course, music, art, theater, radio talk shows, war, and other activities associated with humans would vanish. If humans damage their ecological life support system, intelligence (as humans define it) will join the long list of other evolutionary failures. This disaster does not mean the end of life on Earth – just the extinction of another species (humans).

Concluding Statement

A particularly encouraging sign for sustainable use of the planet is the significant shift in the viewpoints of theology and "hard science" in recent years. This shift has resulted in a substantive degree of consilience between the two. The often bitter disputes of the past are diminishing somewhat, and a few interactions may even approach camaraderie. Even physics has evolved from a deterministic view to the non-deterministic perspective of quantum theory and uncertainty. In the larger scientific community, there is increased willingness to accept some principles where hard data are difficult to generate on the basis of consilience with related hypotheses with more robust data. On the other side of the narrowing divide, theologians are using scientific evidence when reexamining their doctrines and religious affirmations. Arguably, the most important shift is the acceptance of limits to what their theologies can accomplish.

Scientists can now speak more freely of compassion and theologians of biotic impoverishment. Surely, this is a promising trend, albeit not without risks to both groups!

However, as Dobyhansky (1945) notes:

> *We like to believe that if we secure adequate data bearing on a scientific problem, then anybody with normal intelligence who takes the trouble to become acquainted with these data will necessarily arrive at the same conclusion regarding the problem in question. We like to speak of conclusions demonstrated, settled, proved and established. It appears, however, that no evidence is powerful enough to force acceptance of a conclusion that is emotionally distasteful*.

This makes Scenario #1, the soft landing, less likely than it would be if the evidence for limits to growth on a finite planet could cause the paradigm shift toward sustainable practices more rapidly. Most of us who share Dobzhansky's view would welcome being proved wrong. But, even optimists can be wrong so there should be plans B and C for coping with Scenarios #1 and #2.

Sustainable development is often described in terms that suggest a stable framework of practices will ensure success. For example, Murray and Powell (1999, p. 2) state:

> *Sustainable development is a concept in which communities seek economic development approaches that also benefit the local environment and quality of life. Sustainable development provides a framework under which communities can use resources efficiently, create efficient infrastructures, protect and enhance the environment and quality of life, and create new business to strengthen their economies. Where traditional approaches can lead to congestion, sprawl, pollution and resource overconsumption, sustainable development offers real, lasting solutions that will strengthen our future*.

Note the words *lasting solutions* (emphasis mine) in the final sentence. This implies a stable, biospheric environment, which is unlikely. A more realistic view is given by Odum et al. (1995):

> *While the steady state is often seen as the final result of development in nature, a more realistic concept may be that nature pulses regularly to make a pulsating, steady state – a new paradigm gaining acceptance in ecology and many other fields.*

A harmonious relationship with a pulsing system requires constant monitoring of the system's condition. Nothing less will make sustainable use of the planet possible! Yet, while every change in the economic system is given much attention and is widely reported in the news media, the condition of the ecological life support system is almost ignored. Until this situation changes dramatically, Scenarios #2 and #3 are highly probable, and Scenario #1, which is most attractive, is highly improbable unless human society becomes: (a) less recklessly opportunistic in the use of natural resources, (b) more concerned about the world left for future generations, and (c) more concerned about biospheric health and its corollary – not damaging ecosystems to achieve temporary competitive economic advantage. Our economic system may have once favored individuals that were recklessly opportunistic, but it has not produced many practices that are sustainable over large temporal or spatial spans. Sustainable use of the planet, as it is usually envisioned for humans, requires more long-range planning to avoid the societal disruptions and discontinuities that result from the aggregate tyranny of spur of the moment decisions.

What Are Some of the Steps that Can Be Taken?

There is persuasive evidence to justify optimism that there is much society can do to achieve a soft landing in the transition to sustainable use of the planet (e.g., Myers and Kent, 1998). There are many steps that would markedly enhance the possibility of a soft landing. These are easy to state – difficult to implement. Some illustrative examples follow.

1. Stabilize human population size until there is robust evidence that further expansion is possible without diminishing quality of life for humans and having even more adverse effects upon the ecological life support system.

2. Require solutions for each local environment that enhance both local and global sustainability. In short, solutions must be consilient with a mosaic of other local sustainability initiatives.

3. Become aware that each local sustainability initiative can have either beneficial or adverse effects upon other components of the sustainability effort. Mass movements of people to new regions of residence does not facilitate the sense of place or of community needed for exemplary local sustainability projects. On the other hand, ecotourism (at its best) should enhance an awareness of global sustainability needs as well as a global environmental ethos.

4. Have a sense of equity and fairness in resource distribution so that the enormous disparity in per capita ecological footprint size (e.g., Rees, 1996) can be reduced. The citizens of Kerala (a state in India) have a tiny ecological footprint compared to citizens of the United States and Canada, but their life expectancy is not greatly different. Menzel (1994) depicts material differences with a series of memorable photographs and demonstrates that material wealth is not essential to a quality life. Disparities in resource consumption produce social unrest, and this disruption is not conducive to sustainable use of the planet.

5. Allocate more space to other species so that future generations will remember what was preserved rather than what was destroyed. Sustainability is achieved by "leavers" rather than "takers."

These and other steps to enhance the prospects for sustainable use of the planet should foster a great sense of community. Societies that neglect to leave a habitable environment for future generations decay or perish. Intergenerational connectedness as well as a feeling of kinship with nature are powerful contributors to personal well being. This scenario is truly a win-win opportunity!

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Article 22

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Environmental Monitoring for the Preservation of Global Biodiversity: The Role in Sustainable Use of the Planet

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Key words: biodiversity, environmental monitoring, sustainable development, sustainability, global biodiversity

SUMMARY

Biological monitoring is surveillance undertaken to ensure that previously established quality control conditions are being met. Surveillance is a systematic and orderly gathering of data, preferably using standard methods and procedures so that comparison between bioregions globally is facilitated. Biological monitoring should be closely linked and integrated with chemical/physical monitoring, otherwise the cause of biological deviation from the norm may not be reliably associated with chemical/physical deviations from the norm. Since biota may differ dramatically from one ecoregion to another, a universal biological monitoring system should use species with a cosmopolitan distribution so that multi-regional comparisons can be made, large-scale stress patterns will emerge, and biotic impoverishment of an indigenous biota can be confirmed using the biotic impoverishment of organisms with a cosmopolitan or, at least, a very wide distribution. When intimately associated with chemical/physical monitoring, the causes can be more readily identified. Finally, organisms with a cosmopolitan distribution tend to be relatively small and have better recolonization rates following disturbance than organisms with more limited distribution and can be assessed in large numbers because of their small size. These attributes enhance statistical validity and the assessment of structural and functional changes. Functional changes are particularly important in the determination of ecosystem services, which, in turn, are becoming increasingly linked with sustainable use of the planet. This method is in no way intended to denigrate biological monitoring of larger organisms or ones with more limited distributions, but rather to show how the linkage between the two will provide more persuasive evidence of change should it occur. Additionally, because of short life cycles and the larger numbers that can be monitored, smaller organisms provide early warning systems that might prevent harm to the larger organisms with more restricted distribution. There is no robust evidence on what level of biodiversity is essential for sustainable use of the planet. Furthermore, not all the species on the planet have been given taxonomic names; for the many that have been named, their life cycles and habitat requirements are poorly understood. Worse yet, there are too few adequately qualified professionals to carry out these tasks even if human society deemed them important. As a consequence, the monitoring effort should initially concentrate at the systems level (landscapes, ecoregions, habitat) with the hope that a healthy ecosystem will retain most of its component species. Monitoring at the species level should accompany systems level monitoring to see if the assumption is correct.

> *I seek acquaintance with nature – to know her moods and manners. Primitive nature is the most interesting to me. I take infinite pains to know all the phenomena of spring, for instance, thinking that I have here the entire poem, and then, to my chagrin, I learn that it is but an imperfect copy that I possess and have read, that my ancestors have torn out many of the first leaves and grandest passages, and mutilated it in many places. I should not like to think that some demigod had come before me and picked out some of the best of the stars. I wish to know an entire heaven and an entire Earth.*
>
> Henry David Thoreau, *Journals,* March 23, 1856

DOES HUMAN SOCIETY REALLY NEED SO MANY SPECIES?

Any count of the number of species inhabiting the planet results in considerable uncertainty (e.g., Wilson, 1985, 1988). For example, Erwin (1983) notes that previously unknown insects in the canopy of the Peruvian Amazon rain forest are so numerous that extrapolation from estimates of local diversity to all rain forests of the world yields an estimate of 30 million species. Of the approximately 266,000 plant species known (Raven and Johnson, 1992), about 5,000 are used as food plants and 2,300 are domesticated; of these, a mere 20 provide most of the food for the planet's human population (Frankel and Soulé, 1981). Diamond (1997) places the number at 27, but he includes some species (e.g., goosefoot) not widely used. Erosion of genetic variability, high density, and large area populations make domesticated plant species increasingly vulnerable to disease and pests (e.g., Hoyt, 1992). In the context of this clear and present danger, new plants are not being domesticated on a wide scale and have not been for some time (the last 2,000, perhaps 4,500, years; Diamond, 1997).

Homo sapiens has, for most of its existence, lived as a hunter/gatherer with an almost encyclopedic knowledge of the environment. Domestication of both plants and animals began over 10,000 years ago and for large mammal species ended about 2500 BC (Diamond, 1997). Domestication required not only a sophisticated knowledge of potential candidates, since so few were selected from so many, but also some knowledge of the habitat requirements of the selected species. Human society still obtains valuable medicinal materials from natural systems and some food from ocean fisheries and the like, as well as wood and other fibers. However, human society's perception of its dependence upon natural systems is not particularly great, except, of course, in the few remaining hunter/gatherer societies.

Undoubtedly, many humans value natural systems for their own sake, as is evident from the rise in ecotourism, but this recognition is not appreciation for values associated with a life support system. Although ecosystem services have been recognized in the literature for many years (e.g., Westman, 1978), only recently has their monetary value been explored in any depth. In addition, the quest for sustainable use of the planet and sustainable development indicates a widespread (in geographic terms) interest in the possibility of sustainability but not yet a widespread commitment to it. Human artifacts continue to increase systematically on the planet (e.g., shopping malls, power line right-of-ways, roads, housing developments, etc.). The rate of ecological destruction still vastly exceeds the rate of ecological repair. Per capita affluence in terms of material goods is still increasing, as is the global human population. Humans continue to compete with other species not only for space but for increasingly scarce resources such as water.

Even though Costanza *et al.* (1997) discuss the economic value of biodiversity and Lawton (1991) indicates the need for evaluating biodiversity and its economic significance, this aspect has not yet been given significant attention to change the well established economic growth paradigm to a sustainable use of the planet paradigm. Both maintaining and enhancing the delivery of ecosystem services is essential for economic development, but the degree of biological diversity necessary to do so is not clear. In short, thresholds and breakpoints for major ecosystem malfunction and disequilibrium that would impair delivery of ecosystem services are not easily identified. The identification of such crucial thresholds has not dramatically improved since the introduction of the rivet-popping analogy (Ehrlich and Ehrlich, 1981): an aircraft can lose a single rivet without danger, but, if rivets continue to be lost, the aircraft will collapse and endanger its passengers. While high uncertainty about the consequences of change is almost invariably associated with complex systems (Cairns, 1999), the risks are still present even if the occurrence of unfavorable consequences cannot be predicted precisely. Unquestionably also, since human society has had a long influence on ecosystems that predates the agricultural revolution, each region's biodiversity has evolved toward a greater resistance to anthropogenic activities (e.g., Cairns, 1997). Nevertheless, this coevolution is not necessarily in human society's favor, as antibiotic-resistant disease organisms and agricultural pests indicate. The only way to determine these thresholds is by monitoring biodiversity in as many areas as possible, using ecosystem services (i.e., functional) endpoints, and to determine when such thresholds have been crossed. With the enormous number of human activities on the planet and the continual encroachment of human society upon areas previously occupied by natural systems, study sites should be easy to identify.

RELATIONSHIP WITH THE ECOLOGICAL LIFE SUPPORT SYSTEM

Arguably, the weakest component of human society's quest for sustainable use of the planet is its relationship with the ecological life support system. The biodiversity of the system is a heatedly debated topic of environmental politics. Despite the importance of natural capital (e.g., Hawken *et al.,* 1999) and the ecosystem services it provides (e.g., maintaining a habitable atmospheric gas balance), no feedback loop or quality control system is available to provide an early warning of the biodiversity on which sustainable use of the planet depends. Despite the importance of biodiversity, it seems abundantly clear that neither finances nor personnel will be available to monitor individual species on the planet. After all, many species have not even been given taxonomic names. If resources are not available to name species, how can resources be available for extensive monitoring? One strategy would be to monitor the integrity and health of ecosystems and to assume that, if they are robust, most species are protected. This approach does not preclude monitoring the condition of any particular species of exceptional interest to human society.

No information is available on just how many of the planet's species can be lost and still permit sustainable use of the planet as now envisioned. Even if this calculation were known, which particular species are essential would not be available, although arguably most are necessary. Not all the essential species will be charismatic and will unlikely acquire human protection for some reason other than the ecosystem services they provide (e.g., the whooping crane). Some groups, such as amphibia, are currently suffering extraordinary declines (e.g., Matton, 2001), but what effect this might have on the quest for sustainable use of the planet is unclear.

BIODIVERSITY AND THE PRECAUTIONARY PRINCIPLE

In essence, the precautionary principle (PP) proclaims that, when an activity raises threats of harm to human health or the environment, precautionary measures should be taken, even if some cause-and- effect relationships are not fully established scientifically (Raffensperger and Tickner, 1999). The PP is shown in such old sayings as "a stitch in time saves nine," "an ounce of prevention is worth a pound of cure," or "better safe than sorry." This resurrection of a series of old commonsense rules shifts the burden of proof to those who exploit uncertainty and benefit financially from it. The PP challenges citizens, scientists, corporations, and governments to act prudently and sensibly when risks are enormous. The quest for sustainability requires protection of the health and integrity of the planet's ecological life support system and that, in turn, depends on retaining a sufficient number of the components of the interdependent web or life for it to function effectively. Both natural capital and ecosystem services are crucially dependent on the maintenance of biodiversity and will be adversely affected, arguably placed in severe ecological disequilibrium, if the present rate of biotic impoverishment continues.

Virtually every human activity has some effect on biodiversity, and the rates of biotic impoverishment and loss of biodiversity are exceedingly well documented (e.g., Wilson, 1988; Woodwell, 1990). Natural systems have rebounded from tremendous extinctions in the past, and they could do so in the future. However, no robust evidence indicates that human society could survive the ecological disequilibrium of a massive extinction. Furthermore, re-diversification occurs over temporal spans that are many orders of magnitude greater than the human life span; therefore, while of great interest in evolutionary theory, re-diversification is of practically no value in formulating sustainability strategies.

Ecological systems are dynamic and change is the norm. Furthermore, as the Odums (1995) note, ecological systems are pulsing rather than steady state systems. Despite enormous change over significant spans of time, species richness remains remarkably constant (MacArthur and Wilson, 1963). New species are continually displacing established species, and the equilibrium process is dependent on a combination of invasion pressure and displacement of established species. In order to maintain this dynamic equilibrium, sources of colonizing species must be sufficiently near to a particular ecosystem so that colonizing organisms reach it at some particular rate. As a consequence, not only must global biodiversity be maintained but bioregional biodiversity as well. Species in nature preserves, zoos, gene banks, and the like are not useful if they have no way of reaching the areas requiring a certain level of invasion of species that would lead to colonization of some. Furthermore, it is difficult to predict which species will be successful colonists at which particular times. A species that invaded but was unable to colonize successfully at one time period might do so at another time period. Thus, from an ecosystem services standpoint, it may not be operationally effective to merely save a few representative components of a particular species in some part of the planet but, rather, a number of such sources would be needed to colonize a large number of areas; the number of invaders will be considerably larger than the number of successful colonists at any one point in time.

A few illustrative examples of precautionary steps that might be taken follow.

(1) Damaged ecosystems no longer being used by society could be ecologically rehabilitated to provide additional habitat for a large variety of species (e.g., National Research Council, 1992).

(2) Wildlife corridors could be established between some wildlife refuges that are reasonably close together, effectively increasing their value in retaining biodiversity.

(3) Individual citizens can support non-governmental organizations that establish and maintain wildlife refuges, such as The Nature Conservancy and the World Wildlife Fund.

(4) More affluent nations could support impoverished countries attempting to maintain wildlife refuges and national parks by paying for rangers, etc. to reduce poaching.

(5) More effort can be made to see that migratory species, such as songbirds, are not endangered by loss of habitat in wintering grounds, breeding grounds, migratory routes, etc.

BIODIVERSITY AND SUSTAINABILITY

Much of the literature extols the need to protect biodiversity or species richness (e.g., Woodwell, 1986; Wilson, 1988). A relationship exists between biodiversity and the delivery of ecosystem services, but what is not clear is the risks involved with the types of reductions currently occurring and the delivery of ecosystem services (e.g., Costanza *et al.,* 1997). Ecological disequilibrium (e.g., Garrett, 1994; Cairns and Bidwell, 1996a,b) can cause problems for human society. The Polynesians were responsible for the extinction of many species when they landed on various islands in the Polynesian system. Essentially, the Polynesians brought propagules to raise their own food because the islands themselves did not provide a satisfactory level of edible material without an agricultural system. Evidence also indicates that many North American species were driven to extinction when Europeans colonized North America. The replacement of indigenous Bermudan species with exotics is also well known.

Even when the system approach is used, most of the data gathering will probably be handled by volunteer workers using methods and procedures selected by professionals. The personal involvement on a continuing basis of large numbers
of people should offset the difficulties of training, etc.

BIOLOGICAL MONITORING

Biological monitoring is a term long used in the field of ecotoxicology (e.g., Cairns *et al.,* 1977a, 1978, 1979), but the term has not been used rigorously and has often strayed far from the meaning long established in the medical practice. A simple, once-only data gathering has often been called biological monitoring, as has a systematic and orderly gathering of data through time – generally referred to in ecotoxicology and the medical profession as "surveillance." However, biological monitoring is essentially only an exercise in data gathering, however orderly and systematic, unless it is associated with previously established quality control conditions. The term has been used in this sense for a substantial period of time in intensive health care systems, in industrial quality control manufacturing plants, in public health monitoring of municipal drinking water supplies, in monitoring of condition of food, and in a variety of other situations. The requirement for pre-established quality control conditions transforms the data gathering from an intellectual exercise into a mandatory action statement that is immediately put into place when the previously established quality control conditions are not met. Absent the quality control component, there is no corrective imperative or action statement. Therefore, if one is serious about protecting any system, including one maintaining biodiversity, the quality control component of setting thresholds, break points, and the like is essential.

Establishing goals

At the outset of any monitoring effort, it is essential to define the goals clearly; otherwise, it is impossible to select appropriate quality control conditions (Pacific Estuarine Research Laboratory, 1990; National Research Council, 1992; Kendolf and Micheli, 1995; Sutter, 1996; Chapman, 1999; Ehrenfeld, 2000). Calling attention to goal setting may seem platitudinous, but a number of reviews of restoration projects have found that a lack of stated goals is astonishingly common (e.g., National Research Council, 1992; Kendolf and Micheli, 1995; Lockwood and Pimm, 1999). Explicit goals should cover both the structure and function of the system, its species composition, its cyclic phenomena, its rate of species succession, and the attributes that define its integrity. At an early planning stage, it is also essential to indicate how monitoring information will affect monitoring decisions. The fatal flaw in almost all environmental monitoring is the unwillingness of human society to modify its behavior when the quality control system shows that quality control conditions are not being met. U.S. President George W. Bush's pre-election campaign promise to reduce carbon dioxide emissions was quickly reversed when an energy crisis developed in the Unites States (e.g., Chilton, 2001).

Finally, monitoring will assist in determining whether specific endpoints have been reached or maintained, but will not necessarily explain the underlying causes of the result. For example, if ecosystem services are not being delivered as expected, the causes may be other than biotic impoverishment. Determining the reason for not reaching an endpoint requires carefully designed experiments (e.g., Sutter, 1996).

False negatives and false positives

The *sine qua non* of all biological monitoring is the determination of the probability of the system to produce false negatives or false positives. A false negative is a signal indicating no deviation from the quality control norms when, in fact, change has occurred. A false positive is a signal indicating a definite deviation from the previously established norms, when there has been none. Almost all quality control norms of biological systems include normal variability. In some cases, there may be diurnal variability such as in the respiratory rate of certain fishes, or certain functional attributes such as transforming methane or carbon dioxide into oxygen. Chemical/physical norms in aquatic ecosystems include variable rates of flow, particularly in head water streams, where transpiration decreases at night and, therefore, stream flow may increase. Also, for aquatic ecosystems with substantial plant densities, the pH may change depending on the amount of CO_2 processed by the system. Colonization rates of aquatic insect larvae are, especially on artificial substrates, affected substantially by drift, which, in turn, is affected by a number of other factors such as darkness and stream flow. For computer-interfaced monitoring systems (e.g., Cairns *et al.,* 1977b; Cairns and Gruber, 1980), establishing response variability even for individual organisms is relatively easy (Gruber and Cairns, 1981). Robust statistical analysis can document variability at different periods of the day or other cyclic variations and chemical/physical attributes measured simultaneously and amenable to computer interfacing (Case *et al.,* 1978; Almeida *et al.,* 1978). However, extrapolations from one level of biological organization to higher levels in biological monitoring and other assessment systems should be viewed with extreme caution. Ideally, monitoring should be carried out at different levels of biological organization so that information redundancy can be determined and correlation coefficients and similarity indices developed.

Early warning systems versus long-term trend analysis

Early warning systems are an extremely important part of biological monitoring because they provide nearly real-time information and enable remedial quality control measures to be taken as soon as significant deviation from established acceptable conditions has been determined. However, rapid biological information systems (e.g., Cairns *et al.,* 1970) are also generally accompanied by a high degree of variability. An early warning system, by definition, is one of considerable sensitivity to attributes that may be signals of long-term damage if the stressor continues, but, ideally, it provides warning before serious damage has occurred to the ecological integrity of the system or to biological diversity. Early warning systems are particularly vulnerable to false positives, and, therefore, considerable judgment must be used in whether an immediate response is required. Nevertheless, at the very least, they should be the stimulus for an increase in both frequency of data-gathering and number of attributes monitored.

Trend analysis should be based on attributes that are not likely to demonstrate high variability, are not likely to disappear as a result of normal successional processes, have high predictive value for other attributes (i.e., informational redundancy), and are likely to be persuasive to both the scientific community and policymakers. Further, if one is measuring trends over years, decades, centuries, and longer, measurements must be based on attributes unlikely to disappear naturally or become inoperative during the temporal scales of interest. The selection of inappropriate or unstable attributes for biological monitoring of long-term trends is most unfortunate because each shift causes a “downtime” during which the monitoring system is ineffective, or partially so, which may be the time it is needed most.

Structural versus functional monitoring

Ideally, both structural and functional attributes of natural communities should be used in concert. It is possible to impair the performance of organisms without killing them, in which case the functional attributes are the most sensitive indicators of change. Alternatively, due to the functional redundancy of multiple species performing overlapping functions, it is possible to kill some but not all, thus reducing biological diversity without impairing the functional attributes of the system if the remaining species can increase numerically or increase physiological activity to counteract the loss. It is also quite possible that structure and function are so closely linked in natural systems that it is improbable that one will change without the other, but it would be prudent not to depend on this probability until robust, site-specific evidence is available to confirm this hypothesis. The biogeochemical monitoring in the Hubbard Brook system has produced thousands of papers that report functional changes in both terrestrial and aquatic systems, as have the Coweeta studies. Functional testing of aquatic biota for estimating hazard has been ongoing for years (e.g., Cairns and Pratt, 1989). Changes in species composition or other structural changes such as trophic relationships are too well known to need documentation. The problem, of course, in operating any quality control system, in this case one based on biodiversity, is the time necessary to generate information so that corrective action can be initiated in time to avoid further damage.

Cairns *et al.* (1972) developed a means of identifying and counting the number of individual species of diatoms using coherent optical spatial filtering, which, if operated properly, would indicate rapidly the species diversity of diatoms. Quite a variety of organisms can be collected on artificial substrates (e.g., Cairns, 1982) and used for monitoring of various types, including biodiversity. Despite a large number of papers on computer-interfaced monitoring systems developed in various parts of the world and summarized in a variety of books and journal articles, such systems have seen only minor use. Professor Shen Yun-Fen, of the Institute of Hydrobiology in Wuhan, People’s Republic of China, has trained a large number of professionals in the use of protozoan colonization of artificial substrates to indicate environmental quality. However, this method is a time-consuming effort requiring substantial professional training, which is almost certainly one of the major reasons why it has not been used more widely throughout the world.

A major effort should be initiated to convince policymakers of the value of various types of biological monitoring, including biodiversity. Trends already in place should make this effort possible, although it may make ecologists and biologists uncomfortable.

Indicator, representative, and sentinel species

If the suggestion were made to pick a stock that represented an aggregation of other stocks or a category of humans that represented all other categories, the reaction from most people would probably be uproarious laughter. Yet, this strategy has been used for years with regard to the environment where otherwise cautious people accept the assumption that there are indicator, representative, or sentinel species.

The indicator species idea in the field of environmental pollution arose from well established ecological associations where certain types of soil and other types of environmental conditions resulted in fairly clearly identifiable aggregations of species. In these circumstances, the association of species to environmental conditions and to each other is fairly robust. Consequently, the affiliation of a particular species with particular natural conditions is well established, although some species still exhibited wide ranges of tolerance and others narrow tolerance ranges.

However, environmental pollution is neither a single type of stress nor a particular chemical/physical attribute that fits this indicator species idea. Moreover, most stressors are chemicals to which the organisms have not previously been exposed or particular physical conditions existing only for a particular area. As Cairns (1974) notes, the presence of a species does furnish the assurance that certain minimal conditions have been met. However, determining the significance of the absence of a species is considerably more risky, since it may not be present because: (1) the environmental conditions are unsuitable, (2) the species has not had the opportunity to colonize the area but might well survive if it were introduced, or (3) another species has assumed the functional niche. Thus, the absence of a species is much less useful as an indication of environmental conditions than the presence of a species. However, as has been demonstrated for many years in the field that is now called ecotoxicology, there is no assurance that the presence of a species means that the pollutional level is tolerated by other associated species! Cairns (1983) explores some of the fallacies in this assumption.

As a caveat, I once believed not in a single representative species toxicity test as a means of predicting unacceptable conditions, but using a species from each of three different trophic levels (e.g., Cairns, 1956a,b; Cairns *et al.,* 1963) would be adequate. My research then used a diatom, an invertebrate (usually a snail or aquatic insect larva), and a fish as representative trophic levels. Invariably, one representative species was nearly always more sensitive than the other two, but the relative sensitivities varied enormously and not usually in a predictable fashion. Even for closely associated chemicals, one species might be more sensitive than the others and, definitely, even the most sensitive species was not representative of its group as a whole. As the National Research Council (1981) notes: "single-species tests, if appropriately conducted, have a place in evaluating a number of phenomena affecting an ecosystem. However, they would be of greatest value if used in combination with tests that can provide data on population interactions and ecosystem processes."

One comprehensive study of the ability of one species to predict the response of another is reported by Mayer and Ellersieck (1986). Using an enormous database in toxicology, they found no high correlation from one species to another of freshwater animals (they studied 66 species and 410 chemicals), although sometimes this did occur. Although the subject of their study was toxicants, the voluminous evidence from this study implies that organisms sharing the same habitat frequently have quite different responses to anthropogenic stresses, including chemicals. Surprisingly, this finding is often true for species with fairly close taxonomic relationships. Since, arguably, the most important cause of biotic impoverishment is stresses of anthropogenic origin, this point is extremely important. This highly variable response is both good news and bad news. It is good news because all the species are not likely to disappear simultaneously if the stress appears incrementally. It is bad news because it means the indicator, sentinel, or representative species assumption is not robust.

Cairns (1986) discussed a common fallacy of assuming that the response of one species could be used to protect an aggregation of species. The most sensitive species concept hypothesizes that, if one could find the most sensitive species for laboratory toxicity testing and set acceptable concentrations of chemicals sufficiently low to protect it, all other species would be simultaneously protected. The problem is that the most sensitive species to one chemical is not necessarily the most sensitive species to other chemicals. As Lowe (1974) has shown, compiling substantive databases on individual species makes their utility in monitoring far superior to most species being used in monitoring. However, except for the few common test species used in laboratory toxicity testing, very little is known about the toxicological response of most species, and the ecological requirements of some are still unknown.

In summary, naturalists have made some very astute observations about the niches occupied by various species, their habitat requirements, and their likely association with other species with similar ecological requirement attributes. Unfortunately, these types of associations do not hold true when attempting to monitor anthropogenic stress to which the organisms have only a short history of exposure.

Levels of biological organization

As Odum (1996 and earlier publications) has noted frequently, as one progresses from lower levels of biological organization to higher levels, new properties are added at each stage that were not observable at the lower levels. However, individual species are dependent upon the ecosystem or, stated in monitoring terms, the well being of the entire system that they inhabit. A prudent society would attempt to study simulated exposures that might have adverse effects upon natural systems, including the indigenous species. However, substantial uncertainties are associated with extrapolating from toxicological responses in laboratory systems to the responses of natural systems (e.g., Cairns and Smith, 1996; Cothern, 1988; Smith and Shugart, 1994). Also of tremendous disadvantage is using threatened or endangered species in any laboratory or field experiments. As a consequence, some related species with similar physiology can be found and used (e.g., Hart and Gunther, 1989; Gunther, 1989). Many of the uncertainties are due to the paucity, until relatively recently, of: (1) ecotoxicological studies at different levels of biological organization, (2) validation of laboratory simulations in natural systems, and (3) validation of results at other locations in both similar and dissimilar ecosystems.

ILLUSTRATIVE EXAMPLES OF SUITABLE MONITORING ATTRIBUTES

One enormous difficulty in any kind of monitoring is finding professionals who are sufficiently skilled to perform reliably!

1. Structure and Function

Research from Zedler and her colleagues, which examines both structure and function of constructed salt marshes in Southern California, illustrates how complex these relationships are and the importance of monitoring a range of parameters to understand them (Langis *et al.,* 1991;

Zedler, 1993; Boyer and Zedler, 1998).

2. Species Richness

Species richness seems an obvious selection for monitoring biodiversity. For example, increased species richness might be equated with successful restoration of a damaged ecosystem. However, for ecosystems that have naturally low species richness, using species richness as an endpoint would not be as useful as the kinds of species present and their condition.

3. Colonization Rate

Arguably, nothing is more important to succession than successful colonization which, in turn, requires perpetual invasion pressure which, in turn, requires a source of potentially colonizing species within adequate range. Artificial substrates are excellent for studying this process (e.g., Cairns, 1982). Regrettably, there is an erroneous impression that artificial communities of organisms are associated with artificial substrates when, in fact, there is a high correlation between the species present on the artificial substrate and those on natural substrates in the surrounding area. This correlation is especially true during the early stages of the colonization process for protozoans (Cairns *et al.,* 1969). Artificial substrates have a number of advantages for monitoring: (1) they can be positioned in a pattern of the researcher's choosing, (2) collecting specimens does not damage natural habitat, (3) determination of when the colonizing species arrived is easier, and (4) all the species have been collected since the entire substrate is removed; natural substrates may receive damage during collection.

Artificial substrates are particularly valuable in determining episodic fluctuations in such processes as aquatic insect larvae drift downstream. It is also possible, by combining artificial substrates and microchambers, to expose organisms to toxicants in natural systems without impacting the organisms in the natural systems themselves (e.g., Arnegard *et al.,* 1998). By associating artificial substrates with periodic chemical/physical sampling, information can be obtained about the range of conditions to which the organisms are exposed, the duration of exposure, and the aggregate conditions. Some chemical/physical measurements can be automated (e.g., dissolved oxygen concentration and temperature), thus increasing the information base available and providing a more detailed picture of the microenvironment to which the organisms are exposed.

4. Exotic Species

Exotic species are particularly likely to be pioneer colonists and, thus, to be quickly detected. Even if remedial measures are not immediately apparent for ridding the system of exotic species, important knowledge has been gained that makes changes in other species more understandable.

5. Desirable Characteristics of Quality Control Criteria

Numerous parameters could be mentioned for any ecosystem, and each would provide some useful information. However, financial constraints and time available make it mandatory to monitor selected parameters from a large, potential list of endpoints. Cairns *et al.* (1993) review the extensive literature of desirable characteristics of quality control criteria, depending on whether the goal is regulatory compliance (often the most compelling) or diagnostic (insight into reasons for failure to meet regulatory or other standards), or to provide an early warning that the ecosystem is deviating from the desired trajectory (Table 1). It may be necessary to monitor parameters that indicate maintenance of ecological integrity and assume that adequate biodiversity exists when integrity has not been impaired. Clearly, resources (both financial and personnel) are not adequate to track each species in a diverse system, so indirect parameters highly correlated with maintenance of biodiversity must be found and used.

ECOLOGICAL RESTORATION AND BIODIVERSITY MONITORING

The *sine qua non* of any type of monitoring is the development of an action statement. One of the most difficult, arguably the most difficult, aspect of developing a monitoring program of any kind is establishing the quality control conditions in advance, so that immediate action can be taken when there is a deviation from established norms, including normal variability. Absent quality control conditions, the activity is merely a data-gathering operation with a monitoring façade! Additionally, the ways in which the information will be used to make various decisions is an important component of the design of the monitoring system considered (e.g., Cairns *et al.,* 1992; Cairns and McCormick, 1992).

Remedial action will be more effective if considered in advance, at least in outline form (Bradshaw and Chadwich, 1980). Procedures and practices are important, even though both may be modified to meet the needs of a specific body of information. Essentially, however, the goal of any remedial action is to restore a quality that has been lost and, in this case, reduced species diversity. Generally, some sort of ecological restoration will be necessary to either remove contaminants or to restore lost ecological attributes, or both. Assuming that some species have been lost or their populations damaged, one must be assured that conditions are favorable for recolonization. This condition is particularly important if intervention is needed in order to reestablish the species, since the sources of colonizing species may be too distant to be effective. That is, propagules would either not reach the damaged area at all or not in time frames of interest to human society. Since microbial species are so important in energy flow, nutrient cycling, and other important ecosystem function, and, because their communities can be sampled in statistically significant ways without major disturbance of the communities, they provide a particularly persuasive first step in determining whether a damaged site has been sufficiently rehabilitated. In the absence of explicit predetermined quality control conditions, it is difficult to establish a model for ecosystem reconstruction or make an estimate of the likelihood of successful recolonization.

MULTIDIMENSIONAL MONITORING

Monitoring information is effective in decision making only if it arrives in time to take remedial measures when necessary. Therefore, continuous monitoring is advised, or, at least, information generated at frequent predetermined intervals. Monitoring for biological or ecological purposes should include both structural and functional attributes at different levels of biological organization. It should also be accompanied by or linked to chemical/physical monitoring so that, when changes in these characteristics are responsible for the change in biological attributes, a robust connection can be made and the type of remedial action deemed necessary should then be immediately apparent. Although quality control monitoring is not new to industry, especially pharmaceutical and other industrial products, when it is related to environmental conditions, it is something for which the public and its representatives are not well prepared. Monitoring is likely to be most cost effective and persuasive if a variety of purposes are being served and a substantial number of decisions influenced. Monitoring for biodiversity alone, although undoubtedly necessary for particular sites, should not be carried out in isolation from other types of environmental or ecological monitoring (Cairns *et al*., 1995) because there are obvious and close linkages between all of the components, at least to professionals in the field if not the general public.

Monitoring to protect the delivery of ecosystem services (e.g., Daily, 1997) is likely to be the most desirable for people interested in preserving biodiversity. Costanza *et al.* (1997) have persuasively documented the probable value of the ecosystem services to human society and their importance as a component of human society's life support system. Furthermore, a robust correlation between the maintenance of biodiversity and the reliable delivery of ecosystem services would almost certainly do more for the protection of the former than any other type of information, because the importance of maintaining the services is more readily apparent to most of the general public than is the preservation of biodiversity. Another economic value could easily be associated with biodiversity – namely, ecotourism and related activities, such as bird watching, whale watching, etc. In this case, the amount and intensity of tourism congruent with the long-term maintenance of an ecotourism capability would be an important and persuasive management activity.

BIODIVERSITY MONITORING AND THE LEGAL SYSTEM

The essence of quality control management is immediate and effective remedial measures undertaken as soon as previously established quality control conditions are not being met. This works well in the pharmaceutical industry, the paper industry, the automotive industry, and the like, because the entire process is usually under one jurisdiction. But environmental monitoring, whether conducted to ensure the maintenance of biodiversity or some other ecological attribute, is usually most effective at the landscape or bioregional level, which almost always involves different political jurisdictions, a mixture of private and public property, and the "rights" of each constituency within the landscape mosaic. Disputes are likely to be frequent and are invariably settled within the legal system at local, state, regional, or federal levels.

The process in the legal system is quite different from that in the scientific system, as has been evident in various situations. The legal system acts on precedent and is accustomed to long, often contentious trials with polarized views and, regrettably, often liberally laced with junk science. The scientific process is accustomed to probabilistic determinations based on scientific evidence and a process of validation or verification of a hypothesis that ultimately leads to major support by mainstream science. However, the court system tries to hear all sides of a question in science, even when some views are held by a tiny minority of scientists whose positions have not been validated by the peer review system.

A good example of such a situation are the chip mills that are run by components of the lumbering industry. These mills can move into an area quickly because the equipment needed to turn a log into chips is fairly transportable, is operated by only a few people, and can harvest timber from private land. The legal system has not dealt effectively with these operations, now heavily located in the southeastern United States, because of the rapidity with which the mills appear, process the timber, and move on. However, the operation, even if on private land, will almost certainly have an adverse effect on water quality because of removal of vegetation, churning up of the soil profile, increased run off, and the like. Any effective, landscape level monitoring program must necessarily be able to regulate effectively such activities as chip mills or the whole monitoring effort is senseless. Therefore, a science court needs to be developed on which the burden of proof is on the organization or individual proposing a particular course of action – those proposing the course of action will provide evidence that no significant deleterious effects will occur and <u>simultaneously post a bond</u> for ecological and/or biological restoration should the evidence be faulty and the predictions inaccurate. Economists have long noted that no environmental laws would be necessary if the rights of adjacent property owners were such that they were compensated for damage incurred as a result of activities on adjacent or even distant private property. Unless these issues are resolved, it is unlikely that any monitoring program, however well designed, will achieve the

Table 1 Desirable characteristics for monitoring parameters (modified from Cairns *et al.,* 1993)

Characteristic	*Description*
Biologically relevant	Important in maintaining a balanced ecological community
Socially relevant	Of obvious value to and observable by shareholders or predictive of a measure that is
Sensitive	Sensitive to stressors without an all-or-none response to extreme or natural variability
Broadly applicable	Usable at many sites
Diagnostic	Helps explain the particular factor causing the problem
Measurable	Capable of being operationally defined and measured, using a standard procedure with documented performance and low measurement error
Interpretable	Capable of distinguishing acceptable from unacceptable
Cost effective	Inexpensive to measure, providing the maximum amount of information per unit
Integrative	Summarizes information from many measured indicators
Historical or reference data available	Data available to estimate variability, trends, and possibly acceptable and unacceptable conditions
Anticipatory	Capable of providing an indication of deviation from a desired trajectory before serious harm has occurred, early warning
Nondestructive	Causes minimal damage to ecosystem
Continuity	Capable of being measured over time as restored site matures
Appropriate scale	Appropriate for the spatial scale of the restoration
Not redundant	Provides unique information from other measures
Timely	Provides information quickly enough to initiate corrective management action before extensive problems have occurred

intended results. Some cases illustrate this point.

Yellowstone National Park's bison herd often left the Park during winter. Ranchers felt the bison would expose domestic cattle to brucellosis, a disease that can cause cattle to abort their calves. One of the ranchers, Tom Rafato, felt that Yellowstone is like a "big ranch" on public land that is adjacent to other ranches on private land and that the Park should manage the "livestock" as any big ranch would. Even though Rafato lives 300 miles from Yellowstone and his cattle are unlikely to be exposed, he was seriously concerned about transmission to nearer ranches and subsequent re-transmission to his. When nearly a third of Yellowstone's bison herd was slaughtered by the State of Montana, a substantial public outcry and heated debate followed. The commonly held belief from the livestock industry is that the bison leave the Park because the herd is too large and there is not enough forage. Wayne Brewster, deputy director of Yellowstone Center for Resources, maintained that the grassland in Yellowstone is in good condition and that the bison movement in winter is almost entirely dependent on snow depth and snow conditions, which prevent the bison from getting as much grass as they need. They head for lower elevations with less snow cover. Brewster admitted that the evidence shows some risk if cattle and bison are co-existing in a feed yard or feed lot, but, that under free-ranging conditions, the risk of brucellosis transmission is extremely low. Other wildlife such as elk could pose a more direct health risk to Montana cattle. A recent National Academy of Sciences study suggests that researchers must find a viable vaccine for both bison and elk before brucellosis can be eradicated. However, developing the vaccine will only solve the problem for this one disease, not for the relationship between an ecological refuge for species not common in most of the United States and adjacent commercial properties, some of which derive almost all their income from ecotourism. Simpson (1997) reports that one study recommends quarantine zones to stop brucellosis, but buffer or quarantine zones are also likely to create a hot debate without much likelihood of consensus. A consensus must be reached on quality control conditions at a bioregional or landscape level, and these conditions must both be monitored and acted upon when necessary to achieve quality maintenance.

Another example is the application to import rabbit calicivirus disease into New Zealand. Clark (1997) sums up the situation by asking whether New Zealanders can afford the risks of having, or not having, rabbit haemorrhagic disease (RHD) viruses. In this case, a non-native species, the rabbit, was out of control and the cost to farmers was high. Clark (1997) notes that one solution to the rabbit problem, the introduction of ferrets that subsequently spread bovine TB, was another ill-considered introduction. South Island, New Zealand, farmers admitted that they had been deliberately spreading the rabbit-killing calicivirus for months. This introduction constitutes an illegal arrival of an exotic species, and which the individuals who brought it had no hesitation in admitting. Farmers were being asked to report any suspected outbreaks of the rabbit calicivirus disease (Anon, 1997a,b) Clearly, monitoring by interested parties, some of whom admit to introducing the disease, is not the best way to carry out surveillance. In addition (Anon, 1997c), if the rabbit calicivirus disease continued to spread, the government would let it run its course. In short, not only was the surveillance carried out by a group, some of whom caused the problem, but no remedial action was urged. Once the material was introduced illegally, it would persist as other exotics have done.

Reports (Washington Post, 2001) indicate that foot-and-mouth disease of livestock is spreading rapidly in England. The Associated Press (2001a) recounts the seizure of some Vermont (USA) sheep that were suspected of being infected with "mad cow disease," which has killed almost 100 people in Britain and other European countries since 1995. In addition, the Associated Press (2001b) reports a mass burial (up to 500,000 head of sheep) in an old airbase in Britain alone. Environmental consequences are assured, some possibly favorable (more stringent measures to avoid the spread of the disease, which might also reduce invasion of exotic species) and some unfavorable (possible contamination of groundwater). These events are important in a biodiversity context because societal energy and resources are diverted to solving short-term problems while neglecting the long-term problems that could easily impede sustainable use of the planet.

CONCLUSIONS

Species (biodiversity) are the components of the ecological life support system (the interdependent web of life) that furnishes both natural capital and ecosystem services, both of which are essential to sustainable use of the planet. All forms of capital are either derived from or dependent on natural capital, yet the basis of natural capital, biodiversity, receives little protection from human society and is being destroyed by human society at a rate unprecedented in human history. If biotic impoverishment and habitat loss continue at their present rates, severe ecological disequilibrium will occur, as well as a new ecological dynamic equilibrium state far less favorable to humans than the present one. At the very least, loss of natural capital and diminished ecosystem services will have direct adverse effects on both global and regional economies. Since it is impossible to predict when this disequilibrium will occur and when the extinction of species reaches an extraordinary critical threshold because these events have not occurred in the centuries when science made such measurements, it will be well to take precautionary measures to avoid crossing these critical thresholds until more is known about the planetary ecological life support system in terms of its structure and function.

Some precautionary measures are fairly straightforward, can be carried out with existing methods and procedures, and will not disrupt the economic or social system. Given biodiversity's key role in both natural capitalism and delivery of ecosystem services, it should be receiving much more attention than it has. One of the most striking reasons for this lack of attention is that no complete inventory has been made of the species existing on the planet, nor is there likely to be one completed in the next two or three decades. Even when species are given taxonomic names, their life cycles and functional roles in complex ecosystems will probably not have been determined, and these cycles and roles are important to understanding the delivery of ecosystem services. On a worldwide basis, such problems as global warming, acid rain, persistent chemicals that disrupt endocrine systems, and the like are all undoubtedly having effects that are likely to become more severe at some time in the future. Furthermore, stresses are often interactive and synergistic (i.e., their combined effects are more than additive). It is well known that ecosystems are complex, multivariate systems capable of collapsing rapidly once the stresses are more than they can tolerate. In this regard, ecosystems are much like the stock market or the economic system, which may decline suddenly for reasons not always apparent.

On the fruitful side, ecosystem recovery from damage can be quite rapid, although often much slower than the collapse. A slow recovery is especially true when there is a dramatic event such as an oil spill or short-term episodic events such as droughts or floods. Long-term damage, such as that occurring in coral reefs in many parts of the world, may be a series of incremental effects, which in the aggregate are devastating but not always readily apparent at the time. By merely restoring a percentage of the damaged ecosystems not serving any purpose for human society; by connecting ecological preserves with wildlife corridors when possible; by accelerating the inventory of the planet's species; and by taking precautionary measures with greenhouse gases, ozone depletion, ubiquitous distribution of life-threatening persistent chemicals, human society may buy time to gather more information about the restoration and accumulation of natural capital, delivery of ecosystem services, ecosystem dynamics of the planet's ecological life support system, and the like. A further advantage would be the likely generation of excitement and interest in the younger generations, since it would give them more hope for a habitable planet for their lifetime.

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Article 23

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Sustainability, Exceptionalism, and Exemptionalism

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ABSTRACT

Sustainable use of the planet is based on the assumption that social evolution and changed human behavior can produce a sustainable society. This paradigm is vastly different from the notion that humans possess a common set of rigid, genetically specified behavioral predilections that are unlikely to be altered by circumstances. This manuscript examines two beliefs that are arguably a root cause of the present human predicament.

Exceptionalists believe that some humans are vastly exceptional to most humans and, as a consequence, are entitled to a markedly disproportionate share of the planet's resources. In addition, humans are regarded as entitled to a vastly disproportionate share of the planet's resources than other species, for the same reason. Exemptionalists believe that human ingenuity, technology, and creativity free them from the iron laws of nature that limit and control other species. Both views constitute major obstacles to achieving sustainable use of the planet and require rigorous reexamination if sustainability is to be achieved.

> Brains exist because the distribution of resources necessary for survival and the hazards that threaten survival vary in space and time. There would be little need for a nervous system in an immobile organism or an organism that lived in regular and predictable surroundings . . . brains are buffers against environmental variability.
>
> – John Allman (1999, pp. 2-3)

INTRODUCTION

The term *sustainability*, as used in this paper, is a mutualistic relationship between human society and natural systems that preserves natural capital (e.g., resources, living systems, and ecosystem services and can, theoretically at least, continue indefinitely. In the context of this discussion, the term describes a relationship between two dynamic, multivariate, complex systems – human society and natural systems. Other authors may use the term *sustainability* to describe an ongoing harvest of wood, water catchment protection, wildlife conservation, transportation, energy supply, cities, and the like. These views are worthwhile "bottom-up" approaches while the system-level approach is "top-down." Another way of viewing sustainability is that of compassion for both human descendants and the millions of other species with which humans share the planet. While achievement of sustainability is not assured, at worst the quest should improve the quality of human life while simultaneously reducing degradation of natural systems markedly, i.e., it should improve both human and ecosystem health. Only perfect hindsight will confirm that sustainability has been achieved.

However, there is a debate about the degree of malleability of human behavior as it relates to sustainability. Ehrlich (2000) remarks that "human nature" as a singular concept embodies the erroneous notion that people possess a common set of rigid, genetically specified behavioral predilections that are unlikely to be altered by circumstances. If this notion were true, I am wasting my time writing about sustainable use of the planet (e.g., Cairns 1997a) as are all others who are hoping to improve the relationship of humans with natural systems. However, Ehrlich (2000) believes that the human behaviors now undermining the biospheric life support system can be changed to produce a sustainable society. These unsustainable practices elicited extraordinary policy statements by the United States National Academy of Sciences (1993) and the Union of Concerned Scientists (1993), which received astonishingly little attention by the news media.

When humans existed primarily in small tribal units as hunters and gatherers, the disparity in worldly goods between the least fortunate member of the tribe and the highest position in the tribe was relatively minor. However, the domestication of plants and animals, which occurred in some places approximately 10,000 years ago, made possible both the accumulation of worldly goods and a significantly disproportionate acquisition of these by a relatively few people. The Industrial Revolution increased the disproportionate acquisition of material wealth to a dramatic degree, permitting the so-called "robber barons" of industry to live in unprecedented circumstances regarding material wealth, while the vast majority of humans lived in marginal, arguably brutal, conditions. The relatively recent emergence of a sizable global marketplace has increased disparity in material wealth to an even greater degree. Individuals may now have assets exceeding $50US billion in a world where approximately a billion people exist on an income of $1US per day per capita or less.

Exceptionalists believe that some humans are vastly exceptional to most humans and, as a consequence, are entitled to a markedly disproportionate share of the planet's resources. Without question, the super wealthy are different from the ordinary citizen in some regard, having contributed to a sizable technological advance or having exceptional financial acumen, or both. The Durants (1968) conclude that a concentration of wealth is natural and inevitable and is periodically alleviated by violent or peaceable partial redistribution. It is worth noting that, despite widespread abject poverty among humans, *Homo sapiens* has been simultaneously acquiring a disproportionate share of the planet's resources (e.g., Vitousek *et al.* 1986), including space, to the detriment of the estimated 30 to 50 million other species with which it shares the planet. This unequal distribution of resources is rationalized by assuming that some humans are vastly exceptional to most humans and, therefore, entitled to a disproportionate share, however enormous, of the planet's resources. The same rationalization is invoked when humans displace other species, destroy natural systems, and drive numbers of other species to extinction, that is, humans are an exceptional species and, therefore, entitled to act as they do.

Exemptionalism is arguably the most important subset of exceptionalism. Exemptionalists believe that human ingenuity, technology, and creativity free humans from the laws of nature that limit and control other species (e.g., Cairns 1999). Some economists (e.g., Simon 1981, see also Simon's portion of Myers & Simon 1994) believe that resources are infinitely substitutable and exhaustion of one will inevitably lead to the appearance of a substitute when there is enough economic incentive to do so. Thus, humans are the ultimate resource and the species is not limited by finite natural resources. In short, the human species is not limited to a particular carrying capacity as are other species. Although the word *exemptionalism* is rarely used, the proponents of perpetual and infinite economic growth on a finite planet are clearly operating under the assumption that resources are not limiting. Conspicuously absent from this rationalization is the ethical question:

Just because humans have the power to accumulate wealth disproportionately, should they do so?

However, to some degree, both exceptionalism and exemptionalism are embodied in major religious and/or secular philosophies. This concept is far too broad a subject for this limited space; a number of authors have discussed the idea elsewhere (Passmore 1974; White 1967; McNeill 2000; Torrance 1998; Ehrlich 2000; Tucker 2001). Secular philosophies are especially important, given the literature on “political religions” and their doctrines of superior groups of people (e.g., Goldhagen 1996; Burleigh 2000).

ENTER TERRORISM FROM STAGE LEFT

A lesson drawn from the Gulf War and terrorism is that people will fight for limited resources and that this fight can be prosecuted with terrorism as well as with conventional weaponry. Viewed from this perspective, the problem is one of resource limitation, and the means of prosecuting the conflict simply relate to opportunity. The general consensus seems to be that no nation or organization can approach the technological prowess of the United States at the present time and that any attacks will be with low-tech methods. The United States has already seen notable examples of these methods in the explosions that demolished the World Trade Center in the United States and the explosions that caused personal injury and death at United States embassies abroad.

In addition to the horrible injury and loss of life, mostly affecting innocent bystanders, terrorism impedes dialogue that may result in an effective solution to the problems, albeit a solution that would be somewhat satisfactory to all parties but not entirely satisfactory to any party. Terrorism in Northern Ireland, and in other places such as London related to the Northern Ireland disputes, and comparable terrorism problems in the Middle East are good examples of terrorism’s impairment of a meaningful dialogue among the parties that might resolve the issues.

The inability of high-tech weaponry to stabilize the situation in the former Yugoslavia is another ongoing demonstration of the problems of terrorism. The situation in the former Yugoslavia is particularly poignant because of the large number of lives lost and the enormous damage to the technological infrastructure, personal housing, the agricultural system, and, in general, the delivery of a variety of life support services, such as electricity, potable water, and medical needs.

DIALOGUE AND SUSTAINABILITY

An effective dialogue, i.e., an exchange of ideas, is difficult to achieve between a person or organization with great power and a comparably powerless person or organization. This imbalance of power can be seen in dictatorships and in organizations where differing with organizational policy can have damaging effects on a person’s career. A continuing effective dialogue is essential to sustainable use of the planet. Terrorism, ethnic and religious conflict, and the like are formidable obstacles to engaging in dialogue. Yet there are some promising signs. For example, as this manuscript is being written, China and Japan are close to completing negotiation of an agreement to protect the sustainable yield of an oceanic fishery upon which both depend and which either is capable of depleting so that its yield is not sustainable (Radio Japan International Short-wave in the USA, February 27, 2000). Predictably, fishing organizations on both sides are upset with some aspects of the agreement. They are distressed by the fact that the ecological boundaries of the fishery do not coincide with the boundaries of the waters under political control as a result of international convention rather than ecological evidence. Without in any way denigrating the importance of this agreement, it is worth noting that the scientific evidence for the sustainable fishery yield was robust and the problem relatively straightforward.

Scientific evidence for other problems is nowhere near as robust. How can developed and third world countries engage in a meaningful dialogue on the production of greenhouse gases when the consumption of fossil fuels per capita is so disproportionate? When some of the issues of global warming became the cover story of a major United States weekly news magazine (Petit 2000), it was clear that attempts to plead ignorance of the problem are increasingly difficult! Even with the inevitable uncertainties of complex, multidimensional problems such as global warming, the potential consequences to the biosphere and human society are so daunting that immediate, significant precautionary measures are the only prudent course.

Although Antarctica is a remote area visited personally by only a tiny fraction of the planet's inhabitants, the melting of ice and snow there is a persuasive early warning to the remainder of the planet. Melting ice inevitably causes a rise in sea level globally, which would create hordes of environmental refugees in many nations in the world, such as Bangladesh. Alex Kirby of the BBC interviewed Mrs. Sajeeda Choudhury (Kirby 2000), the environmental minister of Bangladesh. She expressed concern over the probable effects upon her country of global warming:

> 'Approximately 20 million people will become ecological refugees. Where shall we move such a large population? It's an incredible task. People will try to move into upland areas. But there is not enough space to accommodate them. So I would request the developed countries of the world to rethink their immigration policies, for the survival of refugees from various small island states and low-lying coastal states like Bangladesh.' Asked which countries she had in mind, Mrs. Choudhury replied: 'America, the other big countries, Britain and Europe.'

The environmental minister's extraordinarily calm remarks focused on some ethical issues that deserve global attention. Is the United States exempt from the responsibility of accepting environmental refugees when its profligate use of fossil fuels has almost certainly exacerbated the global warming problem? Are countries, whose use of technology affects other countries, exempt from responsibility for those people lacking the technology?

From a cultural standpoint, other questions are even more daunting. While population numbers of specific cultures may be quite small in terms of the overall global population, some represent unique cultures. Their preservation should be a concern for the rest of the planet, particularly when other countries are major contributors to the cause of their problems.

IRRIGATION WATER

Most irrigation-based civilizations fail, yet new irrigation systems are persistently under development, based on the belief that this new trial will be an exception to history and that technology, creativity, and ingenuity will exempt the new ideas from the weaknesses that caused previous failures. Postel (1999) describes this situation by noting that modern society may have inadvertently struck up a Faustian bargain with nature. In return for the short-term gains of transforming deserts into fertile fields and redirecting rivers to suit human needs, nature is exacting a long-term price in a number of ways. One of the most crucial is the accumulation of salt in irrigated lands. Another is the depletion of fossil water (groundwater aquifers) at rates far in excess of the recharge rates. Postel (1999) documents extensively the loss of irrigated lands and makes a persuasive case for the inevitable future losses of irrigated lands. All irrigation systems, if successful, temporarily increase the food supply, and human population expands accordingly. When the food supply diminishes or disappears, another source of environmental refugees emerges. It is certainly within the realm of possibility that both global warming and irrigation failure could act simultaneously on many systems.

FAILURE OF DAMS

Another common disruption of the hydrologic cycle results from the construction of dams. Arguably, the most publicized ecological failures and the subsequent effects upon human society have been best documented for the Aswan dam, although other illustrations exist in the United States and other countries as well. Some early descriptions of failures are given in Farvar & Milton (1972). As silt-laden water enters a dam from a river or stream, the velocity of flow decreases and silt is deposited. Thus, all dams have a finite life expectancy based on a variety of factors, including the rate of erosion in the drainage basin (catchment area) above the dam. Deforestation in the catchment area above the dam usually markedly increases erosion and, thus, shortens the life expectancy of the dam.

Dams are becoming structurally unsound in various areas in the world, and this deterioration will surely continue. Those dams that remain structurally sound long enough to fill with silt and become alluvial plains pose an entirely different problem. Where will the deposited sediments be placed, many of which, if not all, containing persistent toxic chemicals? Arguably, the disposition of these contaminated sediments poses a greater threat to human society than the possibility of the structural failure of the dams. Damaging as the ensuing floods might be, a reliable early warning would allow people to evacuate the flood plain while attempts were being made to reduce pool level in the dam by increasing the discharge rate below to reduce the flood's impact.

LONG-TERM ECOLOGICAL DEBT

Financial debt receives much attention globally, even in the United States. Excessive indebtedness is becoming increasingly common at all levels of organization worldwide, from individuals to governments. Human society globally is evading its environmental debt by passing it on to future generations without ensuring that they have the means to pay it and maintain sustainable use of the planet. The problems of economic indebtedness, which are also being passed to future generations through federal deficits and the like, can be extremely severe. Ecological debt, while not nearly as well understood, can be even more threatening as the ecological collapse of many ancient civilizations has shown.

Navajo mythology includes a view of aging. When the first people came up from below into this white world, they found it inhabited by many dangerous monsters, including one named Old Age. Two twin brothers became heroes after slaying most of the monsters. They deliberately left Old Age so there would "be enough room for the people and their cornfields." Clearly, the Navajos had a concept of carrying capacity. They did not feel that they were exempt from the limiting aspects of nature's laws; they did not feel they were so exceptional that they could disregard the welfare of future generations; however, they did require a dangerous monster, Old Age, to ensure appropriate behavior (Reichard 1963).

Modern medical technology has enabled individuals to battle the Old Age monster successfully, as have technologically improved forms of agriculture, sanitation, and the like. Even despite the dramatic increases in human longevity over the last century, it is beginning to decline in some parts of the world due to AIDS, drugs, cigarette smoking, toxic chemicals, and the like. Also worth noting is the existence of some modern "monsters" – famine, disease, salinization of agricultural lands, depletion of underground aquifers, excessive flooding due to a combination of poor land management and unusual weather, and, arguably the worst monster of all, denial of reality.

THE FATAL FLAW

Most species that once existed on the planet are now extinct. Only a small percentage of the planetary total remains. Of those now alive, large numbers are reaching extinction at an unprecedented rate in human history. Those species that have become extinct have at least one fatal flaw; some have more than one. The fatal flaw for large numbers of species is the inability to survive the present practices and behaviors of human society. Arguably, the worst of these practices is the destruction of essential habitat and replacement with human artifacts. Even when habitat is not directly destroyed, it is reduced in ecological value by fragmentation (e.g., roads, superhighways, urban sprawl, canals, telephone lines, power lines, clear-cutting, and agricultural development). Migratory species are particularly vulnerable since they may breed in one area (e.g., North America), overwinter in another area (e.g., South America), and need stopover points along the migratory route. Impairment or destruction of any of these has serious deleterious effects upon the species, as studies of some birds have persuasively shown in the Americas.

Although the exact number will almost certainly never be known, it is highly probable that well over 100 million species have existed on Earth, most now extinct. Each had to adapt to new circumstances resulting from natural change (e.g., increased glaciation) or anthropogenic changes (e.g., over harvesting the passenger pigeon). Some species have adapted to the changes wrought by human society. Some have benefitted not only from the elimination of their competitors and predators but have also flourished because the habitats provided by humans are eminently suitable to them (e.g., the cockroach, the Norway rat, the white-tail deer).

It is interesting to speculate on what fatal flaw *Homo sapiens* might have, given the incredible present success of the species. It inhabits virtually every landmass of the planet and, arguably, all parts of the planet ("land, water, or air") are affected significantly by the species. Exponential growth in numbers has been especially pronounced during the last century, when the human population doubled for the first time within the life span of a single individual. This growth has been accompanied, for many people in developed countries and a few people in third world countries, by a concomitant increase in material affluence. To use the terminology of Wackernagel & Rees (1996), the per capita "ecological footprint" has become astonishingly large in the past century for many individuals. However, many individuals presently living on the planet have an ecological footprint that is not significantly different from that of their distant ancestors. In short, the disparity in size of ecological footprint among living individuals is the largest it has ever been during recorded history. However, at least one-sixth of the world's present population is malnourished.

The Japanese have both identified a fatal flow in *Homo sapiens* and named it – the victory disease! Its two major symptoms are: (1) that WE are superior to THEM (in this case read all other species) and (2) that WE are exempt from all the limitations that affect THEM! As a consequence, WE have a "right" to the space THEY inhabit and to the resources that THEY require to survive. The Japanese inflicted a stunning defeat upon a complacent United States military system at Pearl Harbor and followed this with six months of ceaseless victories covering an enormous area of the Pacific Ocean and Asia. Lest this recounting be misconstrued as a denigration of the Japanese, I hasten to add that Napoleon was afflicted with the victory disease, as was Hitler and the United States during the Vietnam war. History provides numerous other illustrations of the same sort. Is it possible that this dangerous disease, which has in the past only affected particular societies at particular times, has now spread over the entire planet?

Discussion of the "victory disease" can be broadened to link environmental resource issues with human aggression. Expansionist wars (e.g., Imperial Japan, Germany under Hitler, the USSR under Stalin, France under Napoleon, and Imperial Rome) all appear to have exhibited a robust economy when resources were acquired by aggression, but this era was followed by a rapid decline when overextension prevented further aggressive successes. Even great military successes ultimately consume more resources than they deliver, and the state collapses. Cairns (2000) speculates that, although world peace is probably an essential condition for achieving sustainability, world peace is not a guarantee that sustainability will be achieved.

Not surprisingly, Greek mythology includes a narrative particularly appropriate for the present situation. Daedalus, an architect and sculptor who wished to escape the Labyrinth (a prison he himself had built for the Minotaur and where he and his son Icarus were kept), constructed wings with feathers held together with wax for himself and his son. Daedalus escaped to Sicily, but Icarus flew too close to the sun; the wax melted; and he fell into the Aegean Sea where he drowned. Icarus gave little heed to the well being of his life-support system – in this case, feather wings held together with wax. Through heedless destruction and impairment of the planet's ecosystems, human society is also placing its life-support system in jeopardy!

Hawken *et al.* (1999) refer to the life support system as natural capital and assert that all economic benefits presently enjoyed by human society are ultimately based on natural capital. In addition to being the source of a wide variety of raw materials, ecosystems provide a wide array of services with tremendous economic value (e.g., Costanza *et al.* 1997). However, unhealthy or damaged ecosystems are unlikely to deliver these services in either the quality or quantity desired (e.g., Cairns 1997b). Ironically, much ecological damage is subsidized by governments (e.g., Myers & Kent 1998), although there are some indications that such subsidies are being reduced because they are not cost effective. Arguably, until recently, up to half the ecological damage was subsidized either directly or indirectly through such things as supply of irrigation water (e.g., Postel 1999). Even if subsidies were entirely eliminated, the amount of ecological damage done in the name of economic development would threaten sustainable use of the planet. The basic problem is an unwillingness to admit that present behavior, with regards to human society's relationship to the environment, cannot continue indefinitely on a finite planet.

The ecological life support system viewed from a tolerable stress standpoint is a multiple array of thresholds or breakpoints. The terrible reality of ecological thresholds is that one is unaware of their exact location until they have been crossed. This crossing was the central theme of Carson's paradigm-shifting book *Silent Spring.* Laboratory studies of thresholds, particularly toxicological ones, are fascinating. However, an experiment carried out with the entire planet may produce results that are fatal to the human species that would put human society in severe disequilibrium! In such cases, where the stakes are enormous, it is prudent to exercise the precautionary principle (e.g., Raffensperger & Tickner 1999) – and take precautionary action even if there is uncertainty that present behaviors and practices will or will not produce dire consequences. Icarus could have increased his distance from the sun when the first tentative softening of the wax occurred; he would have survived. If he had followed the precautionary principle, the risk could have been dramatically lessened. So, too, human society might well develop a policy on greenhouse gases before there is coastal flooding in 17% of Bangladesh and other comparable low-lying areas of the world.

Implementing the precautionary principle will not be easy (e.g., Calver 2000). Successful application will be a complex process involving a wide variety of professionals, organizations, and citizens. Still, with only one planet, precaution guided by wisdom is a prudent measure.

SUSTAINABLE USE VS. SUSTAINABLE DEVELOPMENT

It is curious that the word *development* is modified by the adjective *sustainable* in the report of the World Commission on Environment and Development (1987) because most people associate development with growth. But if the primary goal is *sustainable use,* why not be explicit in the wording? Sustainable use precludes abuse! Has human society become so addicted to development that it is in denial about the ecological abuse so commonly associated with development? Difficult times are already here for half the planet's population and, with the surge in automotive fuel and heating oil and gas prices in fall of 2000, it appears that all but the extremely affluent will be comparatively impoverished as the 21st century begins. As fictional detective Sherlock Holmes is reputed to have said (his apprentice quotes him on p. 300 of King, Laurie R., 1996), "When faced with the unthinkable one chooses the merely impossible." In this case, the unthinkable would be driving still more of Earth's species to extinction in order to increase the affluence of a few while billions lack the basic needs (i.e., food, shelter, warmth, water). The merely impossible is changing the behavior of the affluent so that death of countless species and loss of irreplaceable natural habitat are not the inevitable price of their affluence.

It is easy to identify the problems with regard to implementing sustainability. For example, Lackey (1996) has highlighted the institutional and societal problems associated with implementing sustainability. Many are important, arguably critical, managerial problems that must be addressed. Exceptionalism and exemptionalism are attitudinal problems that require a quite different approach. The ways in which society addresses them or chooses not to address them is a special attribute of the human species and will have enormous impacts upon the lives of future generations.

What should the basis of the new paradigm be? It should be the human tendency to relate with life and natural processes. In short, to use Wilson's (1984) term, *biophilia*. The question should not involve how much of the biosphere can be destroyed before it affects economic development; the question should be "why isn't human society stopping the destruction now?" Sustainability requires this halt to destruction, and exceptionalism and exemptionalism are the primary obstacles.

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Article 24

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ARTICLE

Ethics in Environmental Politics and Sustainable Use of the Planet

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ABSTRACT: Environmental politics, especially regarding sustainable use of the planet, must be based on a shared set of ethical values. Although there is a fundamental conflict between ecological doctrine and human cultures, naturalistic assemblages of plants and animals can co-exist with human society in a mutualistic relationship. Numerous environmental practices of human society have ethical implications and are serious obstacles to the quest for sustainability. Continuing them will probably result in crossing one or more important ecological thresholds, which may result in new ecological conditions less favorable to human society than those that presently exist. Some of the probable conditions (e.g., global climate change) could be characterized as paradigm-shifting catastrophes. Motivational ethics may triumph initially, but consequential ethics may eventually emerge in environmental politics, which would then produce some interesting conditions in a sustainability context. Since humans have only one planet on which to experiment, speculation about possible future scenarios seems prudent, as does precautionary action to avoid undesirable outcomes.

KEY WORDS: Sustainability · Ethics · Biosphere · Life support system · Humanization of earth · Paradigm shifts

I have set before thee life and death, blessing and cursing:
therefore choose life, that both thou and thy seed may live.

Deuteronomy 30:19

During nearly all the history of our species man has lived in association with large, often terrifying, but always exciting animals. Models of the survivors, toy elephants, giraffes and pandas, are an integral part of contemporary childhood. If all these animals became extinct, as is quite possible, are we sure that some irreparable harm to our psychological development would not be done?

G. Evelyn Hutchinson (1962, p. 74)

ETHICAL CO-EXISTENCE

The ethical obligation of human society to the biospheric life support system is easily stated. Human society benefits from natural capital and the services it provides, but gives little in return and is damaging the system in a variety of ways. Attempts to protect habitat (e.g., wetlands, tropical rain forests) encounter strong political resistence. However, even exemplary protection does not meet fully human society's ethical responsibility for the condition of the biospheric life support system. Human society must actively care for the health and ecological integrity of the system. As Dubos (1980) remarks:

> 'Since the humanization of Earth inevitably results in destruction of the wilderness and of many living species that depend on it, there is a fundamental conflict between ecological doctrine and human cultures, a conflict whose manifestations are most glaring in Greece'.

In my view, naturalistic assemblages of plants and animals can co-exist with human society in a mutualistic relationship. The quest for material wealth has impoverished the biosphere, and still over half the humans on the planet exist on the equivalent of a few US $/day per capita. A society with automobile bumper stickers that claim 'He who dies with the most toys wins!' clearly needs to reexamine its ethics.

ETHICS IN SCIENCE AND SOCIETY

Successful implementation of sustainability initiatives requires that human society have trust in both its leaders and its scientists. Trust requires both faith and some degree of understanding of how the interdependent web of life (i.e., the ecological life support system of which humans are a part) works. In addition, environmental politics must be based on a shared set of values – an environmental ethos (Cairns 2001)! Human society is presently far from trusting the motives of those espousing sustainability. Bartlett (1997-98) notes that, at one end of the spectrum, the term *sustainable* is used with precision. In the middle of the spectrum, the term is simply added as a modifier to the names and titles of beneficial studies in efficiency, etc. that have been around for years. At the other end of the spectrum, the term is used as a placebo. In some cases, the term may be used mindlessly (or possibly with the intent to deceive) in order to shed a favorable light on continuing activities that may or may not be capable of continuing for long periods of time. In the United States, the term *environmentalist* has almost lost its meaning since persons who clear cut forests, build highways through natural systems, etc. now often claim this title.

Soulé (2001) states that a growing chorus of critics now believes that the popular *sustainable development paradigm* has done more harm to nature than good, having set back conservation by a decade or more, particularly in rainforest areas of the tropics. In contrast, Salafsky et al. (1993) believe that a process they refer to as *sustainable exploitation* generates local income without compromising biodiversity values. Sustainable exploitation includes such activities as bird watching and other wildlife viewing, local artisan production or value-added wood products, harvesting of natural products (e.g., Brazil nuts), and carefully managed safari hunting. However, Terborgh (1999) and Oates (1999) note the drastic decline in the creation of nature reserves and wildlife parks while many others have essentially ceased to exist. Brandon (1998) describes the problems with multiple-use *biospheric reserves* and notes that they are unlikely to succeed in preserving biodiversity unless users agree to: (1) different use levels in different zones and (2) the enforcement of sanctions against those breaking the rules. McDonell and Vacarin (2000) espouse the participation of local people in such efforts, including both management and benefits.

THE ETHICAL DILEMMA

The ancient Greeks were an extraordinary culture as far back as 6^{th} century BC. Yet even during its modest beginnings, Greek philosophy touched on many veins of Western scientific thought (e.g., astronomy, law, political science, physics, psychology, medicine, etc.) without access to most of the implements on which modern science depends (e.g., electricity, computers, telescopes, microscopes, chemical analyses, etc.). Einstein once stated: 'I did not come to my understanding of the fundamental laws of the universe through my rational mind.' Einstein's seven years as a minor civil servant in the Swiss Patent Office afforded him many hours for thinking about the universal laws in a less superficial way than present hectic society permits. In *The Republic*, Plato inferred that learning was actually remembering and that humankind is born into some form of amnesia.

PRACTICES OF HUMAN SOCIETY THAT REQUIRE HIGHER ETHICAL STANDARDS

To perform any tasks sustainably implies practices that can continue indefinitely. However, the term *development* implies growth (i.e., economic development) of material goods or human artifacts to most people. In this context, the ideas of *sustainable development* on a finite planet is an oxymoron. Sustainable use, without abuse, can probably be carried out indefinitely and is, thus, more ethically defensible.

An illustrative list of practices of human society that have profound ethical implications follows.

1. advocating exponential growth on a finite planet
2. displacing natural systems with anthropogenic artifacts (e.g., shopping malls) without seriously considering alternatives (e.g., neighborhood stores, Internet shopping)
3. not treating the biospheric life support system with the reverence that a system essential to life deserves
4. failing to recognize (or admit) that anything inherent in human nature is biologically based and, consequently, that humans have a kinship with other creatures
5. exploiting the common grounds (e.g., air, oceans, public land, and water) so that benefits accrue to a few and the losses are borne by many
6. failing to recognize that individual 'rights' (e.g., food, shelter, water) are based on natural capital and that each individual is a part of, not apart from, the interdependent web of life
7. depriving both present and future generations of ecosystem services through destruction of natural capital
8. dismissing rather than discussing the hazard cues that the environment provides, such as biotic impoverishment, endocrine disrupters, evidence of global warming
9. dehumanizing oneself by ignoring that compassion for all humans and other creatures is essential to sustainable use of the planet
10. downplaying sound scientific information, which is essential to sustainable use of the planet

THE TITANIC HUBRIS

Films such as 'A Night to Remember' and other stories of the ill-fated steamship Titanic enthrall people long after the event. Even people not yet born when the ship sank are fascinated by the story. Individual dramas are a significant component, but the larger scale events are the ones that are haunting! Arguably, they do so because the events on Steamship Titanic have remarkable similarity to present events on Spaceship Earth. The important components are:

1. an unshakable faith in the powers of technology to shield humankind from all sorts of natural forces.
2. a tendency to believe that human knowledge is sufficient to predict future events and allow time to be well prepared for them.

3. an extreme reluctance to change human behavior even when substantial evidence indicates it is no longer appropriate.
4. a slow and ineffective response to unexpected problems when precautionary action is needed.

The spatial and temporal scales for a sustainable planet far exceed those of the Titanic disaster, but the basic paradigms that influenced the outcome remain unchanged despite impressive technological advances and the emergence of the information age. Perhaps even more important are the many forms of exponential growth (economic, population, urban sprawl, loss of rainforests and other natural systems) that dramatically reduce the time to respond to trends and/or prevent ecological damage.

CROSSING ONE OR MORE MAJOR ECOLOGICAL THRESHOLDS

The Associated Press (2001a) has reported that bans on logging roads may be lifted under the new U.S. administration, and U.S. President Bush has told the U.S. Congress that he will not regulate carbon dioxide emissions from power plants because he does not believe the scientific evidence for the effects of anthropogenic greenhouse gases is robust (Associated Press 2001b). In addition, energy shortages in the United States indicate a high probability that supplies of energy will be sought more vigorously, even in environmentally sensitive areas. Also, U.S. Environmental Protection Agency chief Christine Todd Whitman is poised to relax a pollution standard involving reformulated gasoline (Wire Reports 2001). These considerations are important because the United States, with less than 300 million people of over 6 billion, uses approximately one quarter of the world's energy and is accounting for almost the same proportion of CO_2 emissions (Ehrlich & Ehrlich 2001). Furthermore, the same report indicates that, to reduce pressure on human life-support systems, the United States must set an example for other countries by establishing a population policy that halts rapid population growth (13% since 1990) and by initiating a national dialog on curbing runaway consumption while increasing quality of life for Americans.

As if the bad news already given were not enough, Schettler et al. (1999, 2000) note that the intersection between environmental chemicals and child development has produced evidence of the effects of environmental chemicals on a number of important processes such as developmental disabilities, including attention deficit/hyperactivity disorder; autism; and related neural developmental diseases, all of which affect millions of American children. Biotic impoverishment, the loss of biodiversity on the planet, is too well documented to require any references. Furthermore, the freshwater supply of the world is being mismanaged in a variety of ways (e.g., Postel 1999). These examples are just a few illustrations of adverse anthropogenic effects on both humans and their ecological life support system. Not only are these actions being tolerated, but governments are subsidizing them with tax monies (Myers with Kent 1998). As historian Mc Neill (2000) notes, humans have been reshaping the face of Earth for millennia, but the 20th century witnessed rates of environmental transformations at a scale never before seen – the consequences of which remain uncertain. Human society is often slow to adapt when their behavior and practices seriously threaten their ecological life support system (e.g., Diamond 1994, 1997). As a consequence, it seems highly probable, arguably almost inevitable, that human society will push its ecological life support system past one or more crucial breakpoints or thresholds. Odum (2001) shares this view. The increased globalization of the economic system also increases the probability that both the spatial and temporal scales will be vastly increased over the historic examples already available in the collapse of civilizations through history over a variety of geographic areas. It is important to note that natural systems do not have the homeostatic mechanisms that result in physiological stability in humans and other creatures. A natural system pushed over a crucial breakpoint or threshold may not return to its predisturbance condition or state, but rather to some new equilibrium condition which may or may not have existed in the past. With regard to the field of ecotoxicology, where these thresholds have been studied extensively, the problem is exceedingly complex (e.g., Cairns 1992). Several outcomes do seem highly probable: (1) the new ecological equilibrium conditions may not be as favorable to humans as the present ones, (2) invertebrates and disease-causing organisms have shown themselves remarkably adaptable in such areas as resistance to pesticides, antibiotics, and the like, and they are therefore likely to adapt to new conditions more rapidly than humans, and (3) as Cairns (1994) notes, human society and natural systems are coevolving and, while coevolution may appear beautiful in its final state, there are extremely harsh penalties exerted on those components or attributes that fail to adjust to new conditions with sufficient rapidity.

AFTER THE THRESHOLD HAS BEEN CROSSED

Ecological disequilibrium that follows the crossing of a threshold might well cause political disequilibrium as well. Conditions are likely to be markedly less favorable than they formerly were. Additionally, many areas already exist where political disequilibrium might be further exacerbated by ecological disequilibrium. Anarchy resulting from either ecological or political disequilibrium might well preclude a systematic, orderly, reasoned response to these new conditions. If humans survive such circumstances, it will probably be as a series of petty fiefdoms or tribal units. If some degree of societal integrity remains, there are a large number of possible outcomes, for which a few illustrative scenarios follow.

Scenario #1. An important ecological threshold is crossed but the system's integrity is not destroyed and sufficient ecological resiliency remains to enable a return to some semblance of earlier conditions

The assumption in this scenario is that the threshold is crossed, but there is a realization of the crossing before ecological integrity has been destroyed or severely impaired. Corrective actions are taken to remove anthropogenic stress, permitting the system to return to some degree of its predisturbance state. An example of this scenario is the work on the Kissimmee River in Florida, which was thrown into ecological disequilibrium by the construction of a canal by the U.S. Army Corps of Engineers. As noted by the National Research Council (1992), the ecological consequences of the canal construction were severe and apparent to the general public. Demands were made and implemented by the political system to restore at least some of the preexisting ecological conditions. Because prompt remedial action was taken and because recolonizing species were readily available, the restoration and recovery of the system were dramatic and, again, readily apparent to the general public. There are numerous other examples of the recovery and restoration of ecologically damaged regional ecosystems (e.g., Cairns et al. 1977), but, if the anthropogenic stress involves such characteristics as global climate change, these scenarios are unlikely to be common, especially with systems as large as the oceans.

Scenario #2. An ecological threshold is crossed, resulting in severe disequilibrium conditions followed by a new equilibrium condition substantially different from the one preceding the disturbance

In these cases, ecological restoration to the original equilibrium condition may not be possible for a variety of reasons, including: (1) no adequate sources of recolonizing species, (2) difficulty in restoring antecedent chemical, physical, and habitat conditions, (3) political will for restoration is not sufficiently strong, (4) political will is strong but financial and other resources are inadequate, and (5) exotic species have colonized the disturbed area and have become so firmly established that dislodging them would require an enormous effort and the outcome would be uncertain and problematic. Unless precautionary action is taken early in the 21st century to diminish present rates of biotic impoverishment and ecological damage, this scenario is likely to be the most common one. Ironically, had human society been sufficiently adaptive to build a harmonious relationship with natural systems before irreparable damage occurred, the even more drastic adaptations required after an ecological threshold has been crossed would not be necessary. Preventative adaptation is far more easily implemented than adapting to a new set of equilibrium conditions unlike the ones to which human society has been accustomed for most of human history.

Scenario #3. A crucial ecological threshold is crossed, reducing the carrying capacity of Earth for humans with a consequent severe and abrupt reduction in population size

The surviving humans selected for their adaptive capabilities and ingenuity might well build a more harmonious relationship with natural systems even in their new, unfamiliar condition

Scenario #4. A crucial ecological threshold is crossed and the new equilibrium conditions are unsuitable for human habitation

This scenario would resemble, in some ways, the great biological extinctions of the past in which some species survived and speciation resulted in a diverse but different biota over geological time.

THE PLANETARY CEMETERY

Although burial places for human remains are becoming increasingly scarce in urban areas, the entire planet is becoming a vast cemetery for non-human species without burial markers or even very many mourners. Worse yet, the space occupied for millions of years by myriad life forms is now increasingly covered by human artifacts such as shopping malls and highways. As motorists speed over these sacred grounds, talking on their cell phones and raging at other motorists, it is unlikely that they grieve about the role they have played in the disappearance of these other creatures. If the death penalty for individual humans is increasingly abhorrent in many societies, why is the anthropogenic death sentence for entire species not a colossal sin against life itself? If other species had the power to conduct a Nuremberg trial on planetary death camps for 'lower forms or life' executed with little regret by human society, what would humankind's defense be? It is indeed curious that destruction of the planet's ecological life support system, which supplies essential ecosystem services (Table 1) and is required for sustainable use, receives so little respect. As Wilson (1984) remarks, 'the one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitat. This is the folly our descendants are least likely to forgive us.' Dubos (as quoted in Piel and Segerberg 1990, p. 269) puts it somewhat differently: 'Although the earth is but a tiny island in the midst of vast reaches of alien space, it derives distinction from being a magic garden occupied by myriad different living things that have prepared the way for self-reflecting human beings.' If one assumes that natural capital (i.e., the ecological life support system) is essential to sustainable use of the planet, then the basic scientific question should be: 'What is necessary to preserve self-maintaining natural systems?' For those requiring information on natural capital and ecosystem services, the volume by Hawken et al. (1999) has numerous references and case histories.

Scientific inquiry requires more than a lofty generalization such as *sustainable development* or *sustainable use of the planet*. Moreover, the goals and conditions must be stated for the entire

Table 1. Illustrative ecosystem services

1. Capture of solar energy and conversion into biomass that is used for food, building materials and fuel
2. Breakdown of organic wastes, such as sewage, and storage of wastes that cannot be broken down, such as heavy metals
3. Maintenance of a gas balance in the atmosphere that supports human life; absorption and storage of carbon dioxide and release of oxygen for breathable air
4. Regeneration of nutrients in forms essential to plant growth (e.g., nitrogen fixation) and movement of those nutrients
5. Purification of water through decomposition of wastes, regeneration of nutrients, and removal of sediments
6. Storage of freshwater, retention and release of water after rains that provides flood peak reduction, and ground water recharge
7. Distribution of freshwater through rivers
8. Generation, maintenance, and binding of agricultural soils
9. Control of pests by insectivorous birds, insects, bats, and others
10. Pollination of agricultural crops by birds, insects, bats, and others
11. Development and archiving a genetic library for development of new foods, drugs, building materials, and waste treatment processes through both Mendelian genetics and bioengineering
12. Development and archiving a variety of 'replacement' species, preventing expected disturbances such as fire, flood, hurricanes, and droughts from disrupting the provision of other ecosystem services
13. Storm protection through physical dispersal of wind and waves by plants
14. Control of both microclimate and macroclimate
15. Recreation and aesthetic satisfaction

system (Cairns 1997), not just isolated components such as sustainable agriculture, although these are also essential. Finally, as Cairns (1997) notes, a single person can write an article about sustainability, but an organization, tribal unit, or society is needed to practice it.

Paradigm-shifting catastrophes. National Academy of Sciences (NAS) President Bruce Alberts (2000-2001) remarks that a fear of spreading irrationality is perhaps the strongest motivator for the NAS to giving a high priority to what undergraduates understand about science. The NAS has long been active in the battle for a more rational society, and this battle becomes even more important as globalization of human society, its economies, and its effects on natural systems become ever more evident. Just one major inappropriate or irrational decision on such things as global climate change and atmospheric ozone depletion will almost certainly have destabilizing effects on both natural systems and human society. Some months ago, two momentous events were given scant attention in the news media. The first was the discovery by an ice breaking Russian cruise ship steaming towards the North Pole during the Arctic summer that miles of open water has replaced previously evident thick ice. The presence of sea birds, where none have been seen before, was an indication that this open water had existed for more than a day or two. The second event, at the opposite end of Earth in Antarctica, confirmed that the hole in the ozone layer over the Antarctic continues to grow and is now three times the size of the United States. The casual way in which both events were treated by the new media suggests that nothing short of a major ecological/societal catastrophe will cause a paradigm shift into a series of sustainable use of the planet practices.

A catastrophe of this size could easily be irreversible. Hardin (1998) has superbly addressed the task of overcoming denial of the tough ecological issues of population, economics, and ethics. A central issue is the consequences of total freedom in a world of limits. Hardin further notes that, in the arrangements of nature, freedom is relegated to an operational position that is secondary in importance to survival and concludes that, in a competitive world of limited resources, total freedom of individual action is intolerable. Hardin (1998) remarks that scientists favor *consequential ethics,* which is less interested in historical origins and more concerned with the future consequences of present acts. Almost certainly, a major ecological/societal catastrophe would produce a system of consequential ethics. *Motivational ethics* might still triumph because, in times of societal disequilibrium, a return to past conditions can be very attractive.

Motivational ethics will probably create still more catastrophes and, ultimately, the survivors, if any, will turn to consequential ethics. It is interesting to speculate on what consequential ethics might emerge in environmental politics, if taken in a sustainability context.

1. The *free market* as now defined will almost certainly cease to exist, as will individual freedom as now interpreted.
2. Any actions seriously damaging the planet's ecological life support system will result in drastic consequences for the individuals or organizations causing this damage, even if they plead that they were unaware of the outcome of the actions or that there was uncertainty about the outcome.
3. Extravagant, disproportional use of the planet's resources, which is now characteristic of the United States and a number of other countries, will be considered aberrant and, therefore, unacceptable behavior.
4. There will be a systematic and orderly allocation of resources between the planet's ecological life support system and human society. It is not clear, and probably it will never be entirely clear, exactly how much space and protection is necessary to preserve ecological integrity and result in self-maintaining ecological life support systems. The precautionary principle advocates erring on the side of prudence or, stated another way, providing more than the minimal amount of resources in the event that the projection of resource needs of natural systems might be short of the mark.
5. The ecological life support system must be given the respect and reverence now accorded the economic system, as a very minimal requirement. The term *minimal* is deliberately used because the natural systems have been badly abused, and many of their components (i.e., species) have been extirpated. Thus, the ecological systems will be in recovery for at least a century and perhaps longer and, thus, need more protection and respect than if they were robust and normal.
6. It will be essential to improve ecological quality control monitoring to provide early warning signals of impending deleterious effects or the occurrence of deleterious effects or, if not an early warning, detecting the deleterious effects before they have had substantial impact. Ecosystems are dynamic, pulsing systems so both design of the systems and interpretation of the evidence they provide will require much skill and judgment. In the early stages of the development of these monitoring systems, false positives and false negatives will be a major source of irritation. As the systems become more robust, the frequency of false negatives and false positives will diminish but not disappear.

CONCLUSION

It is easy for most humans to forget that they are only one of millions of species in the ecological 'theater' and have not been on the 'stage' as long as many others, are not as numerous as many others, and do not have the biomass of many other species. As Gorbachev (2001) noted, 'nature will not wait', and environmental experts warn that many environmentally damaging trends are now too far advanced to achieve real sustainability by means of gradual change; they believe human society has 30 to 40 years in which to act. Time is short, and humankind is already lagging behind. However, the impetus for rapid change in human society is almost always a catastrophe as a consequence of inappropriate practices. The captain of the Titanic could easily have taken precautionary action, which would have made the crossing less memorable but less costly in lives. Human nature is prone to take risks and, when the consequences are literally unimaginable, the risks are taken more lightly than they should be. Nature will persist whatever humans do. It is human society that may not persist whatever humans do!

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Article 25

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EDITORIAL

Equity, Fairness, and the Development of a Sustainability Ethos

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To cure a disease, one must first acknowledge it exists.
American Folk Proverb

ABSTRACT: Estimates made just before the 21st century indicate that, by the year 2100, Earth may have between 10 and 11 billion people – not quite double the 6 billion population count reached in October 1999. Sustainable use of the planet requires that human needs be met without impairing the integrity of the planet's ecological life support system. This objective will almost certainly require equity and fairness in resource allocation among members of the human species and with natural systems upon which humans depend. For the first time in history, humans have the power to create serious disequilibrium in natural systems at a global level. Nature is not vengeful, but it is opportunistic; new 'equilibrium conditions' are likely to be far less favorable to humans than present conditions. To prevent disequilibrium, a new ethos or set of guiding beliefs regarding human society's relationship with natural systems is essential. The best descriptor of the new ethos is eco-ethics (www.eeiu.org) guided by ethical science and implemented by compassionate, reasoned environmental politics. ESEP, the publication organ of the Eco-Ethics International Union, should be a powerful integrating force in developing the necessary integration of science and value systems while maintaining the integrity of both.

KEY WORDS: Sustainability · Sustainable development · Carrying capacity · Limits to growth · Equity in resource use

ECO-ETHICS

A person reading the professional journals in the fields of economics and ecology might be forgiven for not realizing that both the words economics and ecology originate from the same Greek word. Human societies worship of economic growth has, in the 20th century, increasingly destabilized the global ecology. Clearly, a third component has been neglected – the ethical responsibility of human society to the planet's ecological life support system and the millions of species that inhabit its diverse ecosystems. As Berry (2000) notes: 'if we lack the cultural means to keep incomplete knowledge from becoming the basis of arrogant and dangerous behavior, then the intellectual disciplines themselves become dangerous.' The purpose of this editorial is to explore some of the ethical problems associated with the quest for sustainable use of the planet. The solutions must be based on ethics in science and environmental politics.

EQUITY, FAIRNESS AND SUSTAINABLE USE OF THE PLANET

Although intergenerational equity and fairness are the *sine qua non* of sustainable use of the planet, the related issues of equity and fairness for other organisms, the biosphere, and presently living humans have not received adequate attention. Does sustainability imply a greater degree of equity and fairness than now exists or merely maintaining the status quo? The poor consume less than the wealthy and many resources are becoming scarce (e.g., quality freshwater). At what point, if any, should society attempt to discourage over-consumption in order to increase planetary carrying capacity of humans or to achieve a greater degree of equitability or fairness? All too often, sustainability focuses on business activities (e.g., sustainable transportation, energy, agriculture, etc.) rather than attempting to develop a global ethos (a set of guiding beliefs) that would shift human behavior in ways that would protect the biospheric life support system and make better use of natural capital (Hawken et al. 1999).

Sustainable use of the planet is often discussed as if it were a new concept. However, some societies had a sustainable relationship with natural systems for thousands of years. From what remains of them today and from early reports of these societies, it is evident that most individuals had an encyclopedic knowledge of the ecosystems they inhabited. In addition, robust evidence indicates that now living individuals, in the Kalahari Desert for example, can accurately construct events of the recent past just by examining animal tracks, scat, and the like.

Another notable feature of sustainable societies was their small per capita ecological footprints [for details of this concept, see Rees (1996)] and the comparatively small differences in material goods and resources consumption per capita. The disparities in personal income (and, thus, access to resources), even in a comparatively wealthy country such as the United States, are not likely to be endorsed by the extremely poor. This situation is not conducive to a societal ethos or shared set of values. An ethos based on fairness and equity regarding human society's behavior within its own and other species seems to be the only possible unifying theme for sustainable use of the planet. Even then it might not happen—stochastic events do occur!

Societies that lived sustainably for thousands of years, presumably by not depleting natural capital, generally expressed a sense of 'oneness' with the universe or environment. This identification or oneness still exists in some societies today – for example, Bhutan (Tashi Wangchuck, personal communication). In contrast, individualism is arguably the dominant view in the world today, although not overtly expressed in some dictatorial societies. In some societies (e.g., United States), individual 'rights' are proclaimed much more frequently than individual responsibility for the greater or universal good. Surely, honoring and respecting the uniqueness of each individual can be achieved without endorsing uncivil, disruptive behavior. Technology and increased affluence cannot, of themselves, negate the bleak characterization of humans (Hobbes 1651) as being dominated by the will for self preservation. Hobbes states that the war of 'all against all' is continual and humans are condemned to a life that is 'solitary, poor, nasty, brutish, and short.' Profligate use of natural capital (including fossil fuels) plus technology have increased life expectancy, crowded the planet far beyond expectations of Hobbes' time, and provided unprecedented affluence to a minority of the world's population. Even so, humans still inhabit a finite planet and resources are not unlimited. Thus, the will for self preservation must now include a sense of equity and fairness in resource use, including intergenerational relationships. A sustainability ethos must also include preservation and protection of the planet's ecological life support system since no technology exists to replace it.

This desire for development of a sustainability ethos may seem unworldly and utopian. However, the Australian aborigines appear to have lived in a sustainable relationship with their environment for 50,000 years or more. The Bushmen of Southwest Africa have done equally well in a comparatively hostile environment—the desert in which they live (Thomas 1958). In addition, other species have lived sustainably in their environments for incredible spans of time. Tullock's (1994) very readable book on the economics of non-human societies provides some fascinating insights into economies that have existed far longer than human society's. Is it utopian to expect *Homo sapiens* to match the performance of species with tiny brains or no brains at all? To deny the possibility of doing so is to acknowledge that intelligence, as humans define it, has been an evolutionary failure.

Homer-Dixon et al. (1993) have produced a superb analysis of the role that scarcity of natural resources plays in violent conflict (also more recently, Homer-Dixon 1999). An opposing view is that resource scarcities are not limiting to the human species because human ingenuity and technology will provide substitutes (e.g., Simon's views in Myers and Simon 1994). However, no robust evidence exists that resources are infinitely substitutable and, until there is, the precautionary principle[1] mandates preservation and enhancement of natural capital. Even if humans were no longer resource limited, 30+ million other species are. Surely humans have some ethical responsibility toward them (Cairns 1999)! As Campbell (1991) comments about the first evidence of art found in French, Spanish, and North American caves – some dating back to 40,000 years BC – one finds that 'the mystery dimension of man's residence in the universe opens through the iconography of animal messengers.' As Wilson (1984) notes, humans have biologically based expressions of human dependence on nature for survival of their species. Wilson contends that this dependence is so widespread that it is a universal human characteristic firmly verifiable as innate to the human psyche. Also, Leopold (1949) describes this beautifully in discussing the value of a goose honk.

THE TYRANNY OF SMALL DECISIONS

Most people do not realize the cumulative effect that their personal decisions have on the biosphere. Many don't care! With over 6 billion people on the planet, the aggregate impact of millions of similar decisions can have devastating effects on natural systems and personal lives. Odum (1982) remarks on this effect from an ecological viewpoint and, earlier, Kahn (1966) comments from an economic viewpoint. Air pollution in major cities from automobiles is just one of many examples of this aggregate impact of large numbers of identical, individually insignificant decisions.

Human society's economic and technological prowess has engendered the dangerous belief that humans are increasingly free from natural laws that govern other species (simon 1981). Even in the improbable event that this assumption is valid, there is no assurance that political leaders will not make inept decisions regarding its use. In general, the scientific and technological literacy of political leaders is not high, and this, coupled with an unwillingness to relinquish power, virtually guarantees unfortunate, unadvisable consequences to the general public. Still, there are grounds for hope.

THE CO-EVOLUTIONARY BASIS FOR SUSTAINABILITY

Raven and Johnson (1986) define co-evolution as 'the simultaneous development of adaptations in two or more populations, species, or *other categories* (italics mine) that interact so closely that each is a strong selective force on the other.' Most people are aware that insects, hummingbirds, and a variety of other creatures are lured to plants in various ways (nectar, aroma, etc.) and transfer genetic material (pollen) to other plants. This co-evolutionary relationship has enormous economic value to human society, which becomes painfully evident when something happens to the pollinators and the major agricultural crops are diminished. Arguably, pests and pesticide manufacturers are in a co-evolutionary relationship since pests develop resistance and the manufacturers develop new products. Antibiotic resistant strains of germs are another example from the field of human medicine. The last two examples are important because an intelligent species (*Homo sapiens*) is forced to modify its behavior and practices as a result of changes in a less intelligent species. AIDS is a prime example of this issue.

The situation becomes even more interesting in the *other categories* (italics mine) part of the definition. For example, Schneider and Londer (1984) discuss the co-evolutionary relationship between human society and global climate. Cairns (1994, 1996, 1997) also discusses the co-evolutionary relationship between human society and natural systems. Natural systems are human society's ecological life support system and furnish services (e.g. maintaining atmospheric gas balance). Careless behavior will eliminate many species, but will leave those species that humans cannot control (pests). Humans cannot control the 30-50 million species on the planet, but other species are good at controlling each other. Sustainable use of the planet requires that humans live more harmoniously with all other species since they constitute the life support system.

ENLIGHTENED SELF INTEREST

No species willingly relinquishes resources without getting something in return. In some cases, such as the 'helper' of a mated pair of Florida scrub jays (a bird), what initially appeared to be altruism turned out to produce long-term material benefits that were not immediately apparent to observers. If the individual bird of the same sex as the helper dies, the latter acquires a territory at low cost. For some humans, such relationships may be based on survival of one's genotype or emotional satisfaction. How does the average human benefit from engaging in successful sustainability initiatives? Some illustrative examples follow.

1. Fair and equitable allocation of resources with the human and other species should reduce social unrest, including wars, and keep the planet's life support system functioning dependably.
2. Intergenerational equity and fairness in resource allocation should enhance hope for the future among the young and encourage them to participate in this endeavor.
3. A sustainable planet is the best legacy the older generations can leave for the young. Participation in sustainability initiatives can give more meaning to the lives of the elderly, especially those who have not remained engaged with life and the larger community.
4. Biophilia (love of nature) is basic to human nature (Wilson 1984). Protecting and enhancing the health of nature will simultaneously enhance human health.
5. Beyond a certain minimal level, material possessions do not enhance happiness. Feelings of love, affection, socialization, and compassion are more likely to bring about happiness. Acquiring, maintaining, and guarding material possessions reduces the time available for the activities just mentioned.
6. Compassion for the human and other species is based on a commitment to, respect for, and responsibility for all forms of life. Compassion is not possessive (but the human attitude toward material goods is). Sustainable use of the planet is based on sharing, which enhances societal integrity.

SUSTAINABLE DEVELOPMENT – UTOPIAN AND VAGUE

When the Brundtland Report (The World Commission on Environment and Development 1987) was first published, I was stunned by its widespread acceptance by some individuals and groups that an uncharitable person might call anti-environmental. On reflection, this acceptance was less surprising because the concept of sustainability is stated in such vague terms that it is more a challenge to the status quo than a well defined, implementable program. Inspired by the Natural Step Program, Cairns (1997b) developed a preliminary set of goals and conditions essential for sustainability. A greatly condensed summary, without discussion of any points, follows (reproduced with permission).

Goal 1

To assure that the machinery of nature has sufficient energy to deliver the necessary ecosystem services.

Condition: Human society shall not co-opt so much of Earth's energy that ecosystems can neither furnish services nor endure for substantial periods of time.

Goal 2

To avoid poisoning or impairing the machinery of nature by altering both the structure and function of natural systems by means of toxicants.

Condition: Substances extracted from Earth's crust or synthesized from raw materials must not be concentrated or dispersed in ways harmful to the biosphere (e.g., metals, oils, or pesticides).

Goal 3

To ensure that ecosystem services, such as the maintenance of atmospheric gas balance, favorable to human and other life forms continue at their present or, preferably, better levels.

Condition 1: The physical and biological basis for the services provided by nature shall not be systematically diminished (e.g., overharvesting whales or fishery breeding stocks).

Condition 2: Artifacts created by human society may not increase systematically on the planet.

Condition 3: A balance must exist between ecological destruction and repair – this is an obvious, almost platitudinous, statement; yet, this concept must be included in public policy.

Condition 4: Management strategies for sustainability must allow natural processes such as succession, evolution, predator-prey relationships, and the like to continue.

Goal 4

To devise a better balance in meeting short-term and long-term 'needs' of human society.

Condition: Short-term human 'needs' may not be met if doing so endangers the planet's ecological life-support system.

Subcondition 1. If a world food shortage develops, grains will be shifted from domesticated animals to humans, rather than conversion of more natural systems to agriculture.

Subcondition 2. Society must not depend on yet-undeveloped technologies to save it from the problems it has created.

Goal 5

To ensure most of Earth's population has the opportunity for a high quality life.

Condition: Human population over the long term must be stabilized at a point at which adequate per capita resources are demonstrably available.

Subcondition 1. When defining sustainable use of the planet, society should use quality of life as the primary criterion.

Subcondition 2. Human 'rights' may not be met if the ecological life-support system is endangered by doing so.

Subcondition 3. The majority of people and countries on the planet must accept a single paradigm on sustainable use of the planet.

Goal 6
To avoid a human-induced episodic environmental catastrophe that would cause much human suffering.

Condition: When employing environmental management strategies about which the precise consequences are still somewhat uncertain, large protective safety margins (i.e., either slowing development or carrying it out extremely cautiously) are essential until the outcome has been better defined and the consequences have been determined to be acceptable and not of significance to long-term sustainability.

Goal 7
To diminish the conflict between generations caused by the perception that future generations will lead impoverished lives because of present greed.

Condition: Older people must become deeply involved in sustainable use of the planet to demonstrate by deeds, not words, the older generation's concern for generations to follow.

Goal 8
To reincorporate all waste from human society into natural systems without damaging their integrity.

Condition 1: Materials that cannot be reintroduced safely into natural systems should not be produced.

Condition 2: Assimilative capacity of natural systems shall not be exceeded.

Condition 3: Robust predictive models must be developed regarding assimilative capacity, and these models must be validated and continually monitored to ensure that previously established quality-control conditions based on these two prior activities are being met at all times.

Goal 9
To develop equity and fairness in resources distribution within human society and with other species with which it shares the planet.

Condition 1: A sufficient majority of humans must acknowledge the reality of equity and fairness so that there is an incentive to preserve the ecological life-support system for sustainability.

Condition 2: Ethnic and racial strife must cease so that destructive energy can be rechanneled into constructive activities.

Goal 10
To develop a holistic sustainability initiative.

Condition: Each specific or targeted sustainability initiative (e.g., agriculture, transportation, energy, cites, fisheries) must not act as if it is the only 'flower facing the sun!' It will be difficult to orchestrate these special interests, but otherwise, holistic sustainability will fail.

Cairns (2000) restated these in a more abbreviated ethical context as a declaration of World Peace and Sustainability.

1. Peace among humans is a necessary precursor to sustainability.
2. A harmonious relationship between humans and the biosphere is essential to sustainability.
3. Robust sustainable use of the planet requires human acknowledgment of dependence upon ecosystem services (e.g., maintaining atmospheric gas balance).
4. Ecological damage and repair must be in balance (as a minimal condition).

5. Anthropogenic biotic impoverishment (i.e., species extinction) must cease.
6. Absence of certainty is not synonymous with absence of risk—what we do not know can hurt us badly.
7. No species endures forever—we have an ethical and moral obligation to ensure that efforts to make the planet sustainable for our species does not preclude sustainable use by other species with which we share the planet.
8. Peace with nature requires that humans cease displacing natural systems by constructing artifacts. Failure to do so will destroy our ecological life support system.
9. Nothing is more important than understanding the consequences of human society's destructive potential for both our own and other species and to change our behavior accordingly.
10. Changing existing paradigms requires that concerned individuals confront both policymaker and the general public with scientific information and reasoned argument. Additionally, they must expose them to the vision and ethos required for both peace and sustainability.
11. We must recognize the inappropriateness of the economic growth paradigm for sustainable use of a finite planet and the concomitant importance of limiting resource consumption per individual to enable allocation to future generations.

THE PRECAUTIONARY PRINCIPLE

The precautionary principle insists that policy makers move to anticipate problems before they arise or before persuasive scientific evidence of harm is available (Jordan and O'Riordan 1999). The Rio Declaration on Environment and Development (1992) gave the precautionary principle wider visibility to those making international agreements and national legislation. A crucial sentence reads: 'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.' The Swedish Chemicals Policy Committee (1997) took a precautionary approach in their chemicals management model, which focused on sustainability. The treaty establishing the European Community (1993; Article 130:297-299) also takes a precautionary stance. These and other examples direct attention to the need to identify threats to Earth's ecological life support system and to take steps to prevent serious or irreversible harm before it occurs. Given the lofty levels from which these exhortations are issued, one might reasonably expect more implementation to occur. However, the rate of implementation is far too slow in view of the magnitude and diversity of environmental threats likely to develop before 2050. Why is a paradigm shift toward precaution and sustainability not developing more rapidly?

THE TYRANNY OF PARADIGMS PAST

Mainstream science of the 20th century espoused a separation of value judgments and science following the teaching of Decartes and Bacon. Reductionist (primarily laboratory) science has been based on quantifiability, replicability, and statistical significance of results. However, problems at landscape, national, and global levels are multivariate and the outcome is strongly influenced by societal values. Government subsidies (Myers and Kent 1998) is just one of many possible examples. In the United States and many other countries, public policy and associated implementation are more likely, in practice, to protect economic health than environmental and public health. The continuing legal battles about the responsibility of tobacco manufacturers for a range of public health problems is a good example of the latter. The legal rights of property owners to disrupt the hydrologic cycle in various ways (e.g., dams, destroying wetlands) is another good example of the latter. Endocrine disrupters (Colborn et al. 1996) are a good example that covers both public and environmental health. Predictive ecotoxicology (Cairns and Niederlehner 1995) is still in early developmental stages and, even if it were more advanced, society lacks a philosophy of science that can cope with uncertainties and address issues of equity and fairness in society's relationship with the planet's ecological life support system essential to sustainable use of the planet. United States courts and many other courts of law favor reductionist science, but not integrative (multidimensional) science. Even in cases of reductionist science, such as evidence of harm from tobacco smoke, the burden of proof of harm is not on the manufacturer to any substantial degree, and questions of withholding incriminating evidence abound. The presumption of innocence is fine for humans, but misapplied to corporations and other artifacts of human society.

EQUITY, FAIRNESS, COMPASSION, AND AN ETHOS OF SUSTAINABILITY

The planet's dominant paradigm fosters technology and economic growth in ways that seriously threaten the health and integrity of the ecological life support system. Sustainability initiatives attempt to redirect economies and technologies in ways that are less environmentally damaging and ultimately enhance and increase natural capital (Hawken et al. 1999). Neither science nor law as presently practiced are likely to result in sustainable use of the planet, although they can contribute much toward this goal. The same comment applies equally well to technology and economics. Without a set of guiding values (ethos), all of these will fail! Central to these guiding values are fairness, equity, and compassion, not only for present and future generations of the human species but for the biosphere and fellow species as well. As His Holiness the Dalai Lama (1998) notes, the purpose of the human existence is to seek happiness (p. 16). He distinguishes seeking happiness from pleasure. He further believes that the pursuit and achievement of personal happiness, thus defined, does not lead to selfishness and self-absorption. Neither is happiness the result of an abundance of material possessions.

Human society may never achieve sustainable use of the planet. There is no universal law that ensures *Homo sapiens* will persist for any particular time span. Despite current paradigms, survival of the human species almost certainly depends more on compassion, equity, fairness, and an ethos of sustainability than it does on science, law, or technology. Humans lived in a long-term sustainable relationship with the biosphere when it had none of these as they are now known. At that time, they had no choice. Few humans could survive if returned to those earlier stages. However, there is much to indicate that present practices are mostly unsustainable. Making them so will require new values and behaviors, and exponential growth shortens the time to make the transition gracefully.

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Article 26

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EDITORIAL

Exceptionalism and Globalism

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ABSTRACT: Achieving sustainable use fo the planet will require ethical judgments in both sciences and environmental politics. The purpose of this editorial is to discuss two paradigms, exceptionalism and globalism, that are important in this regard. Exceptionalism is the insistence that one set of rules or behaviors is acceptable for an individual or country but that a different set should be used for the rest of the world. For example, the disparity in per capita consumption of resources and economic status has increased dramatically in the last century, but the consumers of great amounts of resources do not feel a proportionate responsibility for addressing this issue. Globalism is defined as individual and societal willingness to diminish, postpone or forgo individual natural resource use to protect and enhance the integrity of the global ecological life support system. Increasing affluence and the still increasing human population, coupled with wide dissemination of information and an increasing awareness that humans occupy a finite planet, exacerbate this already difficult situation. Increased interest in sustainable use of the planet makes open discussion of these issues mandatory because individuals cannot function in isolation from the larger society of which they are a part. Similarly, no country can function in isolation from other countries, which collectively form an interactive mosaic. This discussion identifies some of the crucial issues related to exceptionalism and globalism, which must be addressed before sustainable use of the planet can be achieved.

KEY WORDS: Environmental ethics · Globalism · Individualism · Exceptionalism · Sustainable development · Economic growth

SUSTAINABILITY

A commonly held belief is that, the more distant a problem is in time or space, the less attention it receives. However, sustainable use of the planet (more popularly referred to as *sustainable development*) requires serious attention to matters involving both large temporal and spatial spans. The dominant paradigm is perpetual economic growth, which is an oxymoron for inhabitants of a finite planet. Sustainability will require a major paradigm shift, which will be invariably painful during the transitional period. Denial that the problems exist will only make matters worse because serious issues will remain unaddressed. Globalism is defined as individual and societal willingness to diminish, postpone or forgo individual natural resource use to protect and enhance the integrity of the global ecological life support system and is the sine qua non of sustainable use of the planet.

ECOLOGICAL FOOTPRINT

Wackernagel & Rees (1996) have documented the grossly disproportionate per capita consumption of natural resources (ecological 'footprint' size). Public debate about the responsibility for this situation is remarkably muted in those countries with the highest per capita consumption. These consumers act as if they are exempt from responsibility, although they are well aware of the devastation of tropical rain forests and other natural systems. No political candidate would dare break the taboo and urge public discussion of this issue! Yet some politicians claim to favor 'smart growth,' 'sustainable development,' and other descriptors of sustainable use of the planet.

EXCEPTIONALISM

Exceptionalism is insisting that one set of rules or behaviors is acceptable for a particular individual or country but that a different set should be used for the rest of the world. For example, United Nations Secretary General Kofi Annan has noted that over half the world's humans have neither placed nor received a telephone call. At the same time, talking on a cellular phone while driving has become a major issue in the United States where ownership of automobiles is drastically different from much of the rest of the world's population. The ethical issue becomes: would humans be living in a sustainable world if the entire world replicated American ownership of automobiles, cellular phones, and other material goods? If not, should citizens of the United States and other developed countries cease to act as if they were entitled to exceptional treatment? Sustainable use of the planet almost certainly requires a universal ethos or set of guiding beliefs and values. Exceptionalism, as practiced, flaunts this requirement. It and exemptionalism (the belief that human technology, creativity, and ingenuity exempt humans from the biophysical laws that limit and control other species) are, arguably, the most formidable obstacles to sustainable use of the planet. Further, since the United States is the planet's only superpower, other nations will assume that its behavior is sustainable for other portions of the planet.

THE DEADLY DUO: EXCEPTIONALISM AND EXEMPTIONALISM

Exemptionalism (Cairns 1999) assumes that human technology, creativity, and ingenuity exempt humans from the iron laws of nature that limit other species. In this view, resource depletion is not a problem because an infinite number of substitutes can be found or created. The minority view of environmentalism asserts that leaving a habitable planet for future generations requires major attention to the health and condition of the ecological component of Earth's life support system and is concerned about resource depletion.

The planet is in the grip of a tyranny of small individual decisions, which in isolation appear insignificant but collectively may, at times, have severe and unpleasant consequences. This phenomenon was noted many years ago by economist Kahn (1966) and more recently by ecologist Odum (1982). Arguably, failure to appreciate the adverse impacts of multitudes of small decisions may be the cause of many acts that collectively harm natural systems and, ultimately, human society.

It is essential to emphasize also the positive power of aggregate individual decisions that, in isolation from others, seems futile. Sustainable use of the planet is based on the assumption that large numbers of environmentally sensitive small decisions will result in leaving a more habitable planet for future generations. The degree to which each individual modifies personal decisions because of eco-ethics, rather than deciding on purely self interest, will determine the fate of the planet's ecological life support system. This paradigm shift requires both a substantive improvement in environmental literacy and the development of a new societal ethos (or value system) based on an acknowledgment of human dependence on natural systems and an acceptance of an ethical responsibility for the fate of fellow species.

Exemptionalists make three primary assumptions: (1) humans are the superior species and their 'needs' transcend those of other species, (2) some humans excel in acquiring material resources and are entitled to as much as they can gather, and (3) resources are infinitely substitutable (e.g., Simon 1981) and, therefore, are available in unlimited quantities to those humans with the ingenuity, creativity, and energy to acquire them. Acceptance of these articles of faith obviates any ethical responsibility for one's fellow humans or fellow species. The word faith seems appropriate because as Dobzhansky (1945) noted 'It appears, however, that no evidence is powerful enough to force acceptance of a conclusion that is emotionally distasteful.'

Those who act on the assumption that humans are dependent upon an ecological or biospheric life support system do so as an act of faith. Sciences alone will not suffice! This concept is why a set of eco-ethical values is essential. Faith, not evidence, is the basis for each position – scientific evidence is used selectively to bolster each position.

Faith, however, is far from a perfect shield against unpleasant consequences. Wealthy exemptionalists (e.g., Lardner 2000) might well note the Durants' (1968) caution that concentration of wealth is natural and inevitable and is periodically alleviated by violent or peaceable partial redistribution at the biospheric level. Global warming, antibiotic resistant species, and anthropogenic environmental endocrine disrupters are illustrative of the unpleasant consequences of a paucity of eco-ethical values.

Economic growth is more popular than ever at a global level despite persuasive contrary evidence (e.g., Hodson 1972, Hardin 1992, Douthwaite 1999) that appears to have had little or no effect upon the economic/technological juggernaut. Obviously, restraining the materialistic 'good life' is so distasteful that contrary evidence is ignored or denied. Eco-ethics appears to be the best way to avoid the very unpleasant environmental consequences for which evidence is mounting rapidly.

THE CRIME OF EXUBERANT OPTIMISM

Tanner (1981) proposed the following regarding environmental education: (1) most people only want to hear good news, (2) they want to trust anyone who is speaking positively or bearing good news, and (3) the members of the general public decide on issues based upon their judgment/trust of the speaker, rather than on facts or knowledge. When confronted with massive evidence that predicts dire consequences if a present trend continues, a common response is 'I remain optimistic.' Usually no substantive supporting evidence is offered, nor is it generally required. The irony is that the speakers consider themselves to be intellectuals, although ignoring evidence is a decidedly anti-intellectual position. Ballantyne and Parker (1996) advocate constructivism, which emphasizes a qualitative change in the understanding of the learner, rather than increasing the amount of knowledge. A successful environmental education approach interrelates knowledge, attitudes/values, and behaviors. Cairns (1994, 1998) espouses recognizing that human society and natural systems are co-evolving, each affecting the other. Regrettably, most humans perceive themselves as separate from the environment and its problems and, therefore, are unable to connect personal responsibility to potential solutions (e.g., Gigliotti 1992). The National Research Council (1994) concluded that immediate and constant feedback may fail to optimize performance – an important observation in the quest for sustainable use of the planet. The National Research

Council (1991) notes that delayed and intermittent feedback may produce superior performance because it allows learners to detect and correct errors. These findings are important considerations in the development of an eco-ethic.

ECO-ETHICS AND THE PERCEPTION OF CLOSE CONNECTIONS

Sustainable use of the planet requires delaying or reducing use of resources to obtain gratification for the benefit of future generations as well as presently disadvantaged persons, that is, unless either the present disparity in natural resource use per capita is considered acceptable or one believes that per capita resource use for all can be brought to the levels of the presently advantaged without irreparable harm to natural systems. Present evidence indicates that environmentally responsible actions involve simpler living that places less pressure on natural systems. Wackernagel and Rees (1996) discuss this at considerable length and reach two important conclusions: (1) reducing the size of the human ecological footprint can increase the quality of life and (2) efficiency savings do not necessarily reduce ecological footprint size unless the savings are captured for investment in natural capital rehabilitation.

It is abundantly clear that there is often a substantial gap between professed beliefs and actual behavior. The integrated causal model of Barkow et al. (1992) and various social exchange theories propose that humans are more likely to behave altruistically when the recipient of the behavior is closely connected or similar (kin, peer) and when the potential for reciprocal altruism exists. Increased social status also helps, although an uncharitable person might not regard such an act as altruistic. However, present societal actions, with some notable exceptions, do not indicate feelings of closeness to either natural systems or future generations.

Cutler (1999) believes society has made a religion of materialism and property rights to the detriment of natural systems. In fact, much activity that results in environmental damage is subsidized by governments (Myers & Kent 1998). Naturally, special interest groups receiving these subsidies make every effort to suppress discussion of adverse effects upon human health and the environment. Failing that, attempts are made to denigrate those who point out the adverse effects. A classic case was the reaction to Carson's (1962) *Silent Spring*. This courageous woman, bravely describing her soon to be fatal illness as arthritis, was ridiculed as a 'gloom and doomer,' too emotional for a scientist, and, arguably worst of all, for venturing into subjects not suitable for a woman. The names of the denigrators have long been forgotten (except by those of us who witnessed the battle), but Carson is an icon of the environmental movement. Her efforts show that eco-ethics may yet prevail. Still, Ehrlich and Ehrlich (1996) illustrate well that the battle for an ethical relationship with the biosphere is far from over. In fact, there may well be a far more serious problem than well-funded special interest groups.

TOPPLING TABOOS

A taboo is a prohibition excluding something from use, approach, or mention because of its sacred and inviolable nature (*American Heritage Dictionary*). Many years ago, I naively became finance chair of a religious organization and found that frank discussion of individual contributions was taboo. Yet, most members were associated with (even owners of) business organizations where 'cash flow' was a dominant item in most discussions. Hardin's (1996) superb book on this subject should be required reading for everyone interested in eco-ethics. As Hardin notes, few, if any, objects are taboo for touching. However, in the United States at least, one's actions in touching another person, except for the traditional handshake, may be misunderstood and result in legal action. Touching another person has become more taboo in the U.S. than it was just a generation ago. It is now a matter of considerable legislation, despite abundant evidence of the health value of many forms of physical contact. Most other primates spend much time grooming each other, removing fleas, etc. Now that fleas are less common on humans and motives in touching others less obvious, a strong taboo is developing.

For eco-ethicists, Hardin's injunction to never tackle more than one taboo at a time is daunting. If one believes that everything in nature is interconnected, how can one focus on a single connection? If, as Hardin recommends, one diminishes the element of surprise (for example, by sending copies of a talk to the news media), a multidimensional approach would likely result in confusion and misunderstanding. The most important objective should be to identify the taboos clearly and stalk them in a systematic and orderly fashion. However, before this concept can be implemented, there is another obstacle to overcome.

DIMINISHING DENIAL

Homo sapiens has a tremendous capacity for denial despite the species description. Humans deny the death of a person important in their lives, or the existence of a terminal illness, or that cigarette smoking may cause health problems. In some societies (e.g., the U.S.), the aging process is denied with euphemisms such as 'senior citizens' and '80 years young.' Not surprisingly, denial is also a common means of avoiding the ethical issues concerning the relationship between human society and the biosphere. If issues are ignored or humans pretend they do not exist, perhaps they will go away. Or, more subtly, humans may preach respect for the interdependent web of life and acknowledge that they are a part of it, but practices continue to injure the relationship. Environmentalists jet all over the planet to espouse environmental sensitivity and meet in places quite distant for most (e.g., the Rio Conference) to discuss the best way to address environmental problems. Make no mistake, an honest self-appraisal will certainly reveal that everyone practices denial to some degree. Doubtless, Hardin's advice about taboos applies equally well to denial, that is, address only one form of denial at a time, both at a societal and individual level. As a society, would it hurt to admit that anthropogenic-induced global warming is a distinct possibility and to consider policies that diminish greenhouse gases? Or, at the individual level, is a petrol-guzzling sport utility vehicle (SUV) an environmentally sensitive way to visit natural systems?

Orr and Ehrenfeld (1995) have a splendid, concise analysis of the denial problem, and Hardin (1998) has produced the definitive book on this subject while simultaneously showing that society need not flow inevitably into environmental chaos. A great companion book is Douthwaite (1999) since it addresses the denial that economic growth, especially at the global level, can impoverish many humans and endanger natural systems at the same time.

Denial is such an attractive way of not facing problems head-on and is so socially and politically acceptable that it is difficult to imagine that it will be banished forever! However, diminishing denial is essential to both the survival of the human species and improving the quality of life in this new century.

HOPE FROM THE BUSINESS COMMUNITY

Hawken et al. (1999) link environmentally sensitive business practices with profitability and bolster this point with numerous case histories. Nattrass and Altomare (1999) espouse the idea that a company should take on the additional responsibility of social and environmental degradations, which they describe as the evolutionary corporation. These corporations are placed in a curious position because, arguably, business has been labeled the major source of most environmental problems. Yet, correcting problems at the source dramatically enhances the probability of success. Weston (1995) has produced an insightful book on the integration of ecological concepts into industrial operations. Clearly, some businesses would rather spend money on protracted legal battles than on addressing the problems. Regrettably, they are supported by politicians and citizens fearful of losing campaign funding, tax dollars, or jobs, and news media fear loss of advertising revenue. Worst of all may be the 'When on the Titanic, go First Class' attitude. However, a sense of community may yet triumph over exceptionalism, and ethical issues may yet become a dominant factor in societal decisions.

CONCLUSIONS

Exceptionalism is a major obstacle to a fair, equitable, and non-degrading 'use without abuse' policy for global environmental resources. Exceptionalism is socially acceptable and is primarily a consequence of the denial of the problems, both human and environmental, that it causes. When coupled with exemptionalism, the effects can be devastating. The situation is further exacerbated by the failure to accept that similar, seemingly insignificant small decisions, if sufficiently numerous, can exert a tyranny or enhance prospects for sustainable use of the planet, depending on their nature. Optimism is an essential attribute of the human condition; however, exuberant optimism that denies evidence and abandons reason is very dangerous. The development of an environmental ethos as a set of guiding eco-ethical values, a perception of connectedness between human society and the environment, and a concomitant perception of connections with future generations are essential to sustainable use of the planet. In order for a meaningful discussion to take place on these issues, many taboos must be toppled and denials diminished. There is every reason for optimism about what could be done to address these problems, but persuasive reasons for pessimism about what will be done.

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Article 27

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ARTICLE

Exuberant Optimism vs the Precautionary Principle

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ABSTRACT: Management of Earth's resources will not attain sustainability unless tough questions are asked and the merits and disadvantages of conflicting paradigms are rigorously examined. Two major conflicting paradigms are: (1) economic growth will solve all problems, including environmental ones; the free market has negated the dire environmental forecasts and relegated them to the status of myths, and (2) human society is dependent upon the planet's life support system – it assumes that the present rate of biotic impoverishment (e.g., species extinction, loss of habitat) will so alter the biosphere that it will be less habitable for humans. Dominant, global practices are based on the first assumption, which, if invalid, will have dire consequences for human society. For example, anthropogenic greenhouse gases causing a modest rise of global temperatures could produce 20 million environmental refugees from Bangladesh alone as a consequence of a sea level rise that would inundate 17% of the habitable land. Implementing the second paradigm would require major, mostly unpalatable, changes in human behavior. Since, at present, humans occupy only one planet, the precautionary principle suggests acting more cautiously with regard to economic growth until its effects upon the planet's ecological life support system are better understood.

KEY WORDS: Precautionary principle · Economic growth · Environmental protection · Ecological life support · Sustainability

Knowledge of what is does not open the door directly to what should be. – Albert Einstein

Man has lost the capacity to foresee and forestall. . . . He will end up destroying the earth.
– Albert Schweitzer

A prudent man sees danger and hides himself, the simple go on and suffer for it. – Proverbs 27:12

HUBRIS

Hubris kills, as countless myths and folk tales warn. During the 1999 football season, a traditional bonfire structure collapsed on the campus of Texas Agricultural and Mechanical University, killing 23 students. Collapses had occurred three times previously, one as recently as 1994. Officials at Texas A&M were well aware of the dangers and had produced a handbook after the 1994 collapse of guidelines and regulations to be followed by the engineers in charge of the annual project. The ecological ethics involved in such a public display on the campus of a center for higher education deserves a separate discussion. The important aspect for this discussion is that, as of early December 1999, Texas A&M administrators were still wondering what to do about a 90-year old tradition before rearranging their priorities. This indecision is almost certainly due to an uncertainty about long-term public opinion on this issue.

In a similar vein, but on a larger scale, Murphy (1999) links population growth and prosperity with densely populated Hong Kong as an example of hubris. If Hong Kong had a plastic dome over it, the air would soon become far less breathable, arguably fatal, unless human behavior changed dramatically. Hong Kong is livable because it is embedded in a larger ecological life support system – it is literally propped up by an ecological life support system orders of magnitude larger than it is. Weaken some of its props, and the area becomes unstable. Hubris is assuming the system is inherently stable. Except for the difference in scale, the ecological life support system is much like the Texas A&M log pile, except that the latter has been demonstrably unsustainable while the biosphere has not yet proven to be so as dramatically.

GLOBAL FALLOUT VS GLOBAL DIVERSITY

As Cohen (1995) notes, calculating Earth's carrying capacity for humans is virtually impossible. Uncertainties are too numerous and all predictions are conditional. Still, population projections, such as Frejka's (1973), are worthwhile even though some are outdated. In one scenario, Frejka's estimate is about 15 billion people between 2040 and 2045. A United Nations (1992) projection has a high figure of about 28 billion. These projections, nearly two decades apart, have a difference far in excess of the 6 billion global total reached in 1999. Some major considerations are related to these projections. (1) Will biospheric feedbacks modulate these projections? (2) Will conflicts over resources (e.g., freshwater) damage both technological and ecological life support systems? (3) Will allocation of increasingly scarce resources result in more authoritarian governments? (4) Will the quest for ever increasing per capita material affluence negate the ecological benefits of population stabilization if or when it occurs? (5) If a finite planet will support only a finite number of humans, how will society know when it is near the threshold, or worse yet has exceeded it? (6) What effects will further increases in human population size and affluence have on the already high species extinction rate?

ECOSYSTEM HEALTH

Arguably, exuberant optimism regarding sustainable use of the planet is most evident where ecosystem health is considered. An illustrative case (Casey 1999) notes that the city of Rio Rancho's utility director noted that the city is not convinced of the United States Fish and Wildlife Services claim that maintaining habitat for an endangered minnow would *require that the river have water in it the year round* (italics mine). In another case, the State of New Mexico (Taugher 1999) officials want a water dispute settled in state court where they believe it will be clear that *farmers own the water rights* (italics mine). The health of the riverine ecosystem is not to be a major consideration. Since most sustainability initiatives have a strong local/regional component and lack a strong commitment to ecosystem health, the prospects for sustainable use of the planet seem dim! The assumption that ecosystems will continue to provide ecosystem services essential to human well being, regardless of their treatment by society, is clearly an example of exuberant optimism.

Evidence of belief in economic growth paradigms abounds, but the belief in science and rationality appears far lower. Even though the evidence for deteriorating ecosystem health (i.e., biotic impoverishment, global warming) comes almost entirely from science, much of the evidence is being disregarded, often vilified, for reasons based on political expediency. With a frail national consensus (which seems to reflect the global view) about science, a prudent, rational approach toward ecosystem health seems unlikely. Severe deleterious consequences might shift this view, but then the options for remedial action will be severely restricted, possibly even non-existent. In this era of economic and technological dominance, the findings of science about global warming and other major environmental issues fall into the category of: 'I wouldn't believe it even if it were true.' Kuhn (1970) stated it more eloquently: 'A paradigm is a belief so strongly held that when contrary evidence appears, the evidence is rejected.' The present societal dilemma is that a significant body of scientific evidence indicates that global warming, resulting from anthropogenic greenhouses gases, should be taken seriously but would require a major shift in human behavior to abate. Accepting this evidence would require substantive changes in both economic and technological practices. Denial of the need to reject the dominant paradigms ('all economic growth is good,' 'there is a technological solution for every problem caused by technology') requires rejection of scientific evidence. If this assumption is correct, then still more confirming evidence will not alter the situation. There is an alternative to exuberant optimism, which is based on rationality to make wise judgments even in circumstances of moderate to high uncertainty.

THE PRECAUTIONARY PRINCIPLE

The precautionary principle (PP) has seven commonly occurring themes (Raffensperger & Tickner 1999, p. 24): (1) a willingness to take action in advance of formal justification of proof, (2) proportionality of response, (3) a preparedness to provide ecological space and margins for error, (4) a recognition of the well being interests of non-human entities, (5) a shift in the onus of proof onto those who propose change, (6) a greater concern for intergenerational impacts on future generations, and (7) a recognition of the need to address ecological debts. The rationale for the PP is fairly straightforward (Raffensperger & Tickner 1999, pp. 2-3).

> Decisions to take action to restrict potentially dangerous activities are often taken after science has established a causal association between a substance or activity and a well-defined, singular adverse impact. Proving causality takes both extensive time and resources. During this research period, action to prevent potentially irreversible human and environmental harm is often delayed in the name of uncertainty and the harmful activity continues. For a variety of reasons, it may not even be possible to demonstrate a causal association in complex human/ecological systems.

The PP does challenge overemphasis on reductionist science and the still prevalent belief that science will enable humans to transcend natural laws that restrict other species. However, the PP has been accepted by the Rio Declaration (Cameron 1994), the United Nations, and the European Union. The Swedish Chemicals Policy Committee (1997) concluded that PP is applied as much as it should be. Boehmer-Christiansen (1994) discusses the use of the PP in Germany. In the United States, the Toxic Substances Control Act (TSCA), passed in 1976, represents an attempt to establish a mechanism whereby the hazard of the chemical compound to human health and the environment can be assessed *before it is introduced into the environment* (italics mine). If the chemical substance presents an unreasonable risk of injury to human health or the environment, the administration of the U. S. Environmental Protection Agency (EPA) may restrict the use or ban the chemical substance. This requirement clearly reverses the burden of proof, which is one of the tenets of the PP.

These illustrative examples show support for the concept of the PP, although implementation, if it ever occurs on a significant scale, will be a contentious, no-holds-barred battle because it is perceived as a deadly threat to many financial interests. However, persuasive contrary evidence (Hawken et al. 1999) provides examples of environmentally sensitive, profitable industries.

Although Hawken and colleagues do not emphasize the PP, they do promote the protection and enhancement of natural capital, which is a primary goal of the PP.

Myers & Kent (1998) state that a number of goals of both the PP and natural capitalism can be achieved merely by eliminating perverse subsidies. Of course, this elimination will doubtless be fiercely resisted by special interests benefitting from the subsidies. Myers & Kent (1998) include a number of case histories where perverse subsidies have already been eliminated, although, in some cases, saving money was arguably more important that protecting natural capital.

BIOTIC IMPOVERISHMENT

Nowhere are the fatal consequences of exuberant optimism for endless economic growth on a finite planet more evident than in the extinction rates of both plant and animal species. In August 1999, over 4,000 scientists from 100 countries convened in St. Louis, Missouri for the International Botanical Congress (IBC) to discuss a variety of topics, including extinction rates. Dr. Peter Raven, President of IBC, predicted that between one-third and two-thirds of all plant and animal species, most in the tropics, will be lost in the 21st century. For internet data on plants in jeopardy, the following are useful:

- World's Biodiversity Becoming Extinct At Levels Rivaling Earth's Past 'Mass Extinctions' <http://www.sciencedaily.com/releases/1999/08/990804073106.htm>
- XVI International Botanical Congress <http://www.ibc99.org>
- An Action Plan To Conserve the Native Plants of Florida <http://everglades.fiu.edu/serp/action/index.html>
- Earthshots – USGS <http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents/>
- A Survey of the Plant Kingdoms <http://web1.manhattan.edu/fcardill/plants/intro/>
- Botanical Society of America (BSA) <http://www.botany.org>
- American Journal of Botany <http://www.amjbot.org>

An older but highly regarded source (Wilson 1988) with abundant references on both plants and animals will also be useful.

Ironically, many—arguably most—of the status quo economic growth advocates claim to be environmentalists and lovers of nature. At least some of them actually believe this. Whether the love of nature is a facade or a denial of the consequences of their actions is of little importance to the species already gone or those that will soon be driven to extinction by anthropogenic activities. An even greater irony is that the exuberant optimists are probably destroying the planet's ecological life support system, which will cause much human suffering and possibly extinction of their own species. *Homo sapiens* might have only a minor role, in geological time, in the ecological play in the planetary theater. Fossil records suggest that most species had one or more fatal flaws that resulted in their extinction. Perhaps the fatal flaw of the human speices is exuberant optimism for economic growth.

NATURAL CAPITALISM AND THE PRECAUTIONARY PRINCIPLE

Hawken et al. (1999) advocate another form of economic growth termed natural capitalism. This concept is based on growth in quality that is environmentally sensitive. The trials for this idea have been both temporally and spatially small, but they provide persuasive evidence that humans need not drive other species to extinction, at least not at the present rate. There are no conflicts between the tenets of natural capitalism and the commonly occurring themes of the PP (Raffensperger & Tickner 1999, p. 24). Natural capitalism seems worth a try, since it is far more defensible ethically than present practices. Any system that is based on practices that drive other species to extinction at rates unprecedented in human history is not sustainable.

THE QUEST FOR RATIONALITY

I remain optimistic about what can be done and pessimistic about what will be done. The gap between 'could' and 'will' appears to be the result of what Hardin (1999) terms 'the ostrich factor', based on the well known tale attributed to Pliny the Elder around 1 AD (as quoted in Bierens de Haan 1943). Is the refusal to acknowledge the existence of things unseen(e.g., global warming, species extinction) the fatal flaw of human society? Can humans morally and ethically not accept the fate they have meted out to countless other species in the name of progress? Such reflections as this question are usually brushed off as 'gloom and doom'. This denial has been true from Malthus (1798) to Carson's (1962) *The Silent Spring* to Colborn's research with endocrine disrupters (Colburn et al. 1996).

'SOFT' ECONOMICS/'SOFT' ECOLOGY

In science, the word 'soft' is usually used as a pejorative to mean assumptions that are not amenable to the experimental approach. In both economics and ecology, it is extraordinarily difficult to establish cause/effect relationships. Mechanisms are often established in both, but serious difficulties result in establishing their relative importance. Despite the common origin of the words 'economics' and 'ecology', there is little consilience in their dominant paradigms. In both economics and ecology, there are areas of massive ignorance. Still, areas exist where cause and effect are quite clear! For example, loss of habitat has deleterious effects upon the species that inhabit it. However, multidimensional synthesis is difficult but essential to both economics and ecology. There is, however, one enormous difference. Economics is associated by laypersons with material affluence and gracious living, while ecology is associated with 'human deprivation' for the sake of critters. Human society celebrates the former and is uncomfortable discussing the latter.

THE POSSIBILITY OF A PARADIGM SHIFT

Major paradigm shifts occurred in the 20th century that were 'unthinkable', often until the very time they occurred. If alternative paradigms are fairly clear, the probability of society making rational choices is enhanced but not assured. Sustainable use of the planet and a more harmonious relationship with the biosphere based on natural capitalism and the precautionary principle may well replace the exuberant optimism about perpetual economic growth and freedom from limiting factors. It is always well to have a PLAN B, just in case PLAN A fails! As Ehrlich (2000) notes,

> So here we are, small-group animals trying to live, with increasingly rare exceptions, in gigantic groups – trying to maintain health, happiness, and a feeling of connectedness in an increasingly impersonal world in which individual natures are based on even smaller fractions of society's culture.

If individuals do not collectively strike a balance between economic growth and sustainability, nature will make sure that the balance is achieved, regardless of the impact on individuals. In a very real sense, both those primarily concerned about the economy and those primarily concerned about the environment have a cautious and exuberantly optimistic component. Those favoring economic growth are very cautious about inflation, productivity, profitability, and the like. They often optimistically believe that the ecological life support system will not be irreparably degraded by economic growth. Those favoring the environment would like to see more concern about possible or probably adverse effects of economic growth upon natural systems. They optimistically believe that sustainable use of the planet is possible, although there is no robust, validated, working model fairly certain to achieve this result.

CONCLUSION

Clearly, further alienation of these groups from each other will not result in sustainable practices. Claims of each side to be rational and attributing irrationality to the other side are not likely to result in a viable new paradigm either. However, moderation in both optimism and caution by both sides just might result in a workable paradigm. The possibility is certainly worth exploring if only because the alternatives appear so dismal.

Optimism is a blessing if tempered by reason. A reasoned approach requires a free and open exchange of ideas in an atmosphere of civility. Demonizing those with opposing views impedes a free and open exchange of ideas and, worst yet, give zealots power far beyond that justified solely by merit. Paradigms can be valuable steps on the path toward enlightenment, but should never be regarded as the ultimate truth because this implies a climax to the process of reasoning. We should celebrate the multiplicity of human natures and the diversity of paradigms because we inhabit a dynamic world where judgment is a continuing requirement.

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Article 28

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Reexamining "The Inherent Worth and Dignity of Every Person" Paradigm in an Interdependent Web of Life Context

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> *Human beings have evolved a plurality of ways of engaging spirit, nature, and one another so as to enable their mutual flourishing; we need to be critically faithful to each of these ways, separately, and in interplay with each other, if we are to set our species on a just, sustainable, and spiritually fulfilling path of planetary evolution. This is the promise of the marriage of the ecological world view and the democratic ideal in our epoch*.
>
> Engel, 2000

> *What use is a house if you haven't got a tolerable planet to put it on?*
>
> Henry David Thoreau

Individual Connection to the Biosphere: The Noosphere Concept

This discussion of the paradigm of the inherent worth and dignity of every person within the context of the interdependent web of life begins with the concept of "noosphere." The word "noosphere" is composed of two Greek terms, "noos" or mind and "sphere" used in the sense of biosphere – the living envelope of Earth. The noosphere concept refers to an evolutionary stage in which humans become aware of their capacity to influence the course of biospheric evolution (personal communication from Vladimir Zolotarev, author, NooDigest noo@ibiw.yaroslavl.ru) LeRoy (1928, as quoted in Stokes, 1992) examined the reasons and practices of humankind's formidable power over the physical, and thus ecological, environment. He reflected on the power of the human intellect to transform the biosphere into the sphere of reason – the noosphere. Le Roy stressed that a profound philosophical analysis of *human activities* (italics mine) and, above all, of the role of reason on Earth is required. The great Russian philosopher V. I. Vernadsky expressed faith in the life of reason and was impressed by LeRoy's concept of the noosphere (personal communication from Vladimir Zolotarev). Vernadsky's materialistic concept of the noosphere refers to the part of space that experiences the influences originating in man's mind. Vernadsky writes "The development of the biosphere into noosphere is a natural phenomenon, more profound and powerful in essence than human history."

The concept of the noosphere was further expanded by LeRoy's colleague, Catholic theologian and paleontologist Pierre Teilhard de Chardin, in *The Phenomenon of Man.* Teilhard de Chardin's (1965, p. 31) concept of the noosphere is definitely spiritual: "The task of the world consists not in engendering in itself some supreme reality but in bringing itself to fulfillment through union with a preexistent Being."

In the United States, where economic growth, material possessions, and individualism are lauded by so many, a harmonious mind/biosphere relationship seems an "impossible dream." Yet, the cultural creatives described by Ray and Anderson (2000) care deeply about ecology and saving the planet, spirituality, relationships, and peace. They believe that a creative minority has the enormous leverage essential to cause a paradigm shift. They envision a new, saner, and wiser culture. Further, they believe that cultural creatives are the "invisible" third culture in a society perceived as consisting of only two cultures – moderns and traditionalists. The primary weakness in this postulate is that it fails to examine how each culture would respond to major catastrophes that might plausibly occur, given present exponential rates of human population increase and environmental change. A gradual transition may well favor the cultural creatives, but major global catastrophes may well favor the traditionalists or updated modern (technology, competitiveness, etc.) paradigm. Continued exponential growth could easily result in societal disequilibrium globally and different paradigms in different cultures at different times. Since there is now an unprecedented globally interactive system, these changes will have a major influence on the dominant paradigm in the United States.

Top-down/Bottom-up Ecology

The field of ecology has two compatible but different approaches. The "bottom-up" approach begins with a study of the components of a system (the interdependent web of life) or species with the assumption that some knowledge of component dynamics is essential to an understanding of the system. The "top-down" approach assumes that, without an understanding of the system in which the components are embedded, neither the component nor the system will be properly assessed. Actually, the high probability is that the components and the system are co-evolving , although a scientific test of this hypothesis is unlikely to be persuasive in time frames of interest to human society. However, Boff's (1995, p. 11) ecologico-social democracy, which accepts not only human beings as its components but every part of nature as citizens, might be regarded as a co-evolution of two interacting systems, each strongly influenced by the other. Daly and Cobb's (1989) book on redirecting the economy toward a common good might also be interpreted this way. Cairns (1994) notes that co-evolution between human society and natural systems can be either hostile or benign. If the former, human society may end up sharing the planet with species it cannot control – i.e., pests. A benign relationship would benefit both partners – i.e., human health is closely linked to ecosystem health.

Parton (1999) believes that the preservation of nature, by itself, will not become a mass movement, even though human survival depends on it, unless accompanied by a genuine sense of community and friendship within human society itself. Parton (1999) believes that mass appeal might be achieved by offering people the opportunity to belong to a genuine community in service to Earth. I agree "wooing" nature requires peace (Cairns, 2000) and peace requires friendship!

Convictions about Science and Its Social Role

Segerstråle (2000) documents in considerable detail such themes as the objectivity of science, the social use of scientific knowledge, human nature, political bias, and personality clashes using the sociobiology debate as a unifying theme. She notes that not only cognitive differences but also strategic interests come into play on both sides. She remarks that one could describe the situation between the two primary opponents (Lewontin and Wilson) in the sociobiology controversy as one of symbiosis. Segerstråle comments that it was in both parties' "interest to keep the controversy going, not to clear up misunderstandings, and not to examine too closely where the real differences lay but rather to retain the attention of the scientific community." Segerstråle (p. 50) describes the situation as an opposition between a purist, critical, logical approach with slightly negative overtones (Lewontin) and a practically oriented, opportunistic, speculative, and generally "positive" model-building approach, where judgement is postponed until later (Wilson). All of these elements and more enter into the debate about the individual worth and dignity of every person. Some use the "bottom up" approach using the individual as the basic unit (as some humanists do) and others use the "top down" approach using the interdependent web of life as the basic unit (as I do) and examine individual worth and dignity in that context. Both approaches have merit but generally lead to quite different conclusions.

Inherent Worth and Dignity

If humans acknowledge a dependence on the biospheric life support system (the interdependent web of life) or, at a minimum, a respect for the interdependent web of life, it seems reasonable to judge the inherent worth of an individual in the context of the individual's relationship with the interdependent web of life. Stated more brutally, is it a destructive or constructive relationship? If the relationship is destructive, it is difficult to visualize how any rational person could describe individual worth except as a potential rather than an actuality. As a caveat, it is wise to withhold judgment on destructive behavior until there is some evidence in the form of precedent, practices, or actions that support the decision being made. However, the tolerant approach carried too far will place natural systems at increased risk if a natural system ethic is rare. If the relationship with the interdependent web is constructive, leading to protection and accumulation of natural capital rather than its destruction, and there is evidence to support this judgment, the affirmation has substance. In the absence of this evidence, it is a platitudinous statement lacking any substantive ethical or moral value. Further, it is a disservice to both society and natural systems if it is used as a ritual substitute for effective action.

Humanity's Habitat

An individual in an inadequate or unsuitable habitat can sometimes achieve a semblance of dignity; however, one of the sources of dignity is the way in which an individual behaves in a particular setting. Most individuals require good conditions to achieve a significant portion of their potential. In addition, it is virtually impossible for a literate person to be unaware of the inadequate resources available to a large number of the world's humans. For example, Cassidy (2000) reports a World Bank statistic that almost half the 6 billion people on the planet live on less than US$2/day and more than 1 billion on less than US$1/day. By comparison, many sweatshop workers who produce apparel for American college students are comparatively well off.

In 1999, the global population of humans exceeded 6 billion. In only 12 years at the end of the century, 1 billion were added, the number of humans in India's population at the end of the century. During the last half of the 20th century, world population increased from 2.5 billion to 6 billion (Brown, 2000). Anyone interested in product quality control might reasonably ask: if human production rates are this rapid with such large numbers, how does one ensure acceptable quality of life that will enable the potential worth and dignity to be adequately expressed for a substantial majority of humans – certainly not by further damaging natural capital. Sharing and a less materialistic life among the affluent seems to be the most attractive solution.

Declining Per Capita Resources

Individual fitness (ability to achieve inherent worth) requires a continual expenditure of resources. In this regard, it is noteworthy that world grain production per capita dropped by more than 2% in 1999, extending a decline that has been underway since 1984 – one that has reduced per capita grain production worldwide by approximately 10% (Brown, 2000). These sobering figures do not tell the entire story. A small but growing share of the world's grain harvest is being produced through unsustainable use of land and water (Brown, 2000). Postel (1999) describes in considerable detail some of these practices involving irrigation of agricultural land. The *State of the World* published each year by World Watch, numerous United Nations reports, and the many publications of others have documented that resources are not infinite on a finite planet and that the problems of unsustainable practices will continue until human society faces them squarely.

Maldistribution of Resources

For those interested in increasing their literacy in the area of maldistribution of resources, an excellent book by Wackernagel and Rees (1996) illustrates the vastly different per capita impact ("ecological footprint") on the interdependent web of life (e.g., the biospheric life support system). Ecological footprint size can be determined by estimating the annual consumption of particular items from aggregate regional or national data and then dividing the total consumption by population size. This calculation is much simpler than attempting to estimate individual or household consumption by direct measurement, but this measurement can be taken as well. The next step in the calculation is to estimate the land area appropriated per capita for the production of each major consumption item. Wackernagel and Rees divide their areas of consumption into five major categories: (1) food, (2) housing, (3) transportation, (4) consumer goods, and (5) services. Energy is difficult to determine in this calculation because the fossil fuels currently available have been obtained from what Catton (1980) refers to as "phantom land" – the ecosystems that produced the fossil fuels are long gone, but society is still using their productivity today. Another way to determine the "energy land" component of the ecological footprint calculation is to estimate the area that would be required to grow fuel crops to replace the depleting stocks of fossil energy. This determination may be a superior method when considering sustainable use of the planet.

Wackernagel and Rees (1996) give comparisons of ecological footprints in hectares per person: Canada: 4.3, USA: 5.1, India: 0.4, the planet as a whole: 1.8. The *Netherlands fallacy* is the term commonly used when proponents of unlimited growth mention the population density of the Netherlands and the quality of inhabitant life. Blithely ignored is the fact that the per capita ecological footprint in the Netherlands is 3.32 hectares per capita, which clearly shows that the people in the Netherlands require more land than they actually occupy to maintain their quality of life, even though their ecological footprint per capita is dramatically smaller than that of an individual in the United States. I have worked with ecological numbers and figures for my entire professional career and find the calculations of Wackernagel and Rees (1996) very persuasive. Nevertheless, I have been mesmerized by Menzel's (1994) photographs in *Material World: A Global Family Portrait*, which shows representative families from a number of different societies posing before their dwellings surrounded by all of their possessions. Details accompany each family group photograph, such as the size of the family, income, and the like. Statistics for each country, such as the area, population size, population density, ethnic composition, literacy rate, infant mortality, life expectancy, and rank of affluence among United Nations members, are also given. However, the pictures are haunting. Regrettably, all too many of the wishes for the future of the participants being photographed involve material possessions.

Since the United States is clearly the world's leading automobile culture, it is instructive to examine the private car use per capita versus population density.

	Persons per acre	Miles driven per person
United States	36.3	6740
Canada	64.4	4307
Europe	123.3	2802
Developing Asia	402.1	999

Another instructive set of numbers is commercial energy per capita by gigajoules (one gigajoule equals 0.36 barrels of oil); these are 1995 figures (world average is 61).

Commercial energy consumption per capita, in gigajoules (1995 figures)	
Africa	13
Asia	31
South America	38
Central America	137
Europe	145
Pacific Islands	173
North America	317

If one expresses a belief in the inherent worth and dignity of every person, then, in view of these numbers, just how is it being expressed in today's society? As a worst possible case scenario, the assertion of a belief in inherent worth and dignity is a substitute for more active implementation of social concerns. Is it a denial of personal and institutional responsibility? Donella Meadows has calculated that to provide the American per capita level of material goods and resources to all of Earth's present population would require at least three planets comparable to Earth. At the present population growth rate of 1.7% annually, the doubling time of the current population is 41 years. Thus, without any increase in material goods per capita, another Earth will be needed in 41 years if the population continues to expand at its present rate. The only rational way to achieve equity and fairness in material resource distribution among humans is for the profligate users to reduce consumption to permit a more equitable distribution of finite resources. This change would still leave unaddressed the problem of equity and fairness in resource use with the millions of other species on the planet.

Resources and the Interdependent Web of Life

The classic paper of Vitousek et al. (1996) provides persuasive evidence that one species *(Homo sapiens)* of the estimated 30 million or more on planet Earth is co-opting approximately 30% of the sun's energy, which is converted by living material through photosynthesis to provide food and other resources used by all species. Decades ago, world-class ecologist Aldo Leopold remarked that "to be an ecologist is to live in a world of wounds." What he was noting then is still true today – the average, educated person has a low ecological literacy and is virtually certain to be strongly influenced by the barrage of propaganda designed to minimize the seriousness of environmental problems. In a society essentially oblivious to the ecological wounds, it is arguably a curse to be able to see them and recognize the inability to have any significant impact on the destruction of the web of life or its restoration when damaged. This situation is frustrating, and, although not admirable, many have chosen silence rather than endure a platitudinous response to serious inquiries. The same environmental slogans, essentially unchanged, have been used for over half a century. During this time, the situation has appreciably worsened. Two notable exceptions exist to this silence: responding to requests for help in situations where the established dogma is clearly not working, and writing for professional journals where the level of shared knowledge is substantial.

Multidimensional Wounds

The world's wounds are not only ecological. Any area of conflict – racial, economic, religious, ethnic, and even demographic – will cause wounds that the enlightened can see and the unenlightened cannot. To be fully aware of them all is emotionally shattering, and to even be fully aware of one category usually exceeds the tolerance of most people. Going beyond the platitudes is disquieting and virtually guarantees that one will be labeled a pessimist. However, a free and responsible search for the truth will inevitably disclose some unpalatable facts. The goal of a world community, including other species in the interdependent web of life, with peace, liberty, and justice for all, requires both acute awareness of inequities and significant efforts to diminish them.

Passive caring is arguably an oxymoron. Active caring, without an adequate level of literacy, may be more dangerous than apathy. These statements are offensive in a "feel-good" society, but I find a compassionate society infinitely more attractive! However, compassion, to be meaningful, requires empathy which, in turn, usually mandates significant changes in behavior.

Consilience

Wilson (1998) resurrects the word *consilience* (literally, a leaping together) to describe recombining the fragmented and diverse areas of knowledge in a holistic manner to meet the emerging challenges of the time. Some important interfaces in this web of knowledge that are important to this discussion follow:

1. the degree of linkage between human and environmental health.
2. the degree to which exercise of individual "rights" damages the integrity of the interdependent web of life.
3. the relationship between economic growth and the preservation and accumulation of natural capital.
4. the degree to which the concept of sustainable use of the planet is essential to the well being of all humans, including future generations.
5. the determination of the balance between developing the potential of each human (the human condition) and maintaining the condition of the interdependent web of life, which is composed of the human and millions of other species (the ecological condition).
6. the determination of the degree to which disparity of resource allocation, within the human species and between humans and the millions of other species, affects the prospects for sustainable use of the planet.
7. the determination of the degree of diversity that facilitates the cooperation essential to achieving a sustainable world for all species.

Designing a Life in Harmony with Nature

Human society's dependence upon the biospheric life support system (the living "skin" of the planet) is becoming rapidly more apparent in science, but society, as yet, does not cherish nature. Millions of other species vigorously seek space and resources just as *Homo sapiens* does. Human ancestors were comparatively small in numbers and had primitive technologies. For them, the world must have appeared either hostile (e.g., large predators) or at least reluctant to share food and shelter. No species willingly gives up resources without getting something in return (e.g., nectar attracts pollinators). To achieve even a modest improvement in living conditions, it was essential for early humans to subdue nature. Even in the last few centuries, animal and planet resources seemed unlimited in such places as Africa and North America. However, exponential growth of the human population and a concomitant exponential growth in per capita affluence in much of the population destroyed the balance that existed when humans were hunter/gatherers. Now, regional planners decide the degree to which nature can be tolerated without impairing economic growth. All too often, a token amount, which is not really a natural system in the eyes of a trained observer, is set aside with great difficulty. Communities may wage heated debates over whether land should be left as a nature preserve where other species can be respectfully observed or whether it should be used for recreation, etc. with a "natural" peripheral area around the human artifacts (Browder et al., 2000).

Nature's Trump Card

In this technological world with a global economy, it is easy to forget that natural systems are also the ecological life support system. Natural systems provide services, such as maintaining the atmospheric gas balance, for which there is no technological substitute (e.g., Hawken *et al*, 1999). The survival of human society, as it is at present, depends upon a healthy ecological life support system. Two choices are available: react before more damage occurs or react after the damage is so severe that all but the most intractable skeptics acknowledge it exists. The latter choice seems most probable since, when a major ecological threshold has been crossed, disequilibrium is quite common. However, it is prudent to advocate precautionary, preventative action for however long the option remains of reacting before damage occurs.

How Much Environmental Damage Is Tolerable?

Every individual in a technological society creates some environmental damage. Even hunter/gatherers appear to have driven some species to extinction. Comparatively low technological societies, such as the Polynesians, that colonized islands previously uninhabited by humans clearly drove many species to extinction (e.g., flightless birds). However, both the amplitude of the impact and the rate of change in the 20th century was unprecedented in human history (e. g., McNeill, 2000), and robust evidence indicates that present societal practices are unsustainable (e. g., Ehrlich, 1997). The concepts of natural capitalism (e. g., Hawken et al., 1999) and the natural step (e. g., Nattrass and Altomare, 1999) are similar alternatives to the present, unsustainable, infinite growth paradigm. Alternative paradigms exist for transportation (e. g., National Research Council, 1997) and company management (e. g., Anderson, 1998). Even with these alternatives, the increased risk of severe damage to the ecological life support system seems the likely choice over a change in personal and societal behavior.

Inherent Worth and Dignity of Each Individual During and After the End of Material Affluence

Nature has numerous ways of controlling numbers of individuals of a population of any species that exceeds the carrying capacity of its resource base. The most common controlling measures for animals are famine and disease. For humans, war can be added. At least half the planet's human population is living under conditions the other half would consider unacceptable. The ecological life support system is global and protecting its integrity requires an ethos (a set of guiding values) commonly shared. The demand for increased automotive mobility has both fragmented and destroyed natural systems, and highway construction still continues. To support increasing populations and per capita affluence, notable alterations have been made to protective vegetation, which has increased erosion and exacerbated flooding. The growth of towns and cities has also degraded natural systems. Just living as humans now do damages the planet's ecological life support system, but it also affects the resources available for others, the quality of life of future generations, and the survival of other species and the integrity of the planet's ecological life support system. Without adequate resources, the probability of any human, present or future, realizing a portion of the inherent potential and achieving some degree of dignity is small.

However, protecting the ecological life support system requires either voluntary individual restraint in use of resources on a large scale or some form of mutually agreed upon governmental coercion. Neither seems likely at present, at least in those societies with the larger per capita ecological footprints. However, present practices (e. g., favoring exponential growth on a finite planet) are almost certainly unsustainable and, thus, likely to produce environmental, economic, and political surprises. Two simultaneous surprises could interact synergistically and make the effects more devastating than simply adding the two together. Individual inherent worth and dignity are not likely to remain at present levels under these circumstances. The potential may well remain unchanged, but manifestation of worth and dignity probably will not.

The Planetary Human Feed Lot

In the United States, some domesticated mammals, such as cattle and pigs, are kept in high density in enclosures called "feed lots." Food and water are supplied and sometimes minimal shelter. Their environment or habitat differs dramatically from the habitat of their undomesticated counterparts. Wild pigs, particularly, presently inhabit an astonishingly diverse range of habitats and are exceedingly resistant to attempts of humans to eradicate them in areas where they are considered pests. Unlike many other organisms, they are not driven to extinction by a predator with a remarkable technological prowess. Surely, a charitable observer would credit wild pigs with more inherent worth and dignity than their domesticated counterparts in feed lots.

Why then are humans doing the same thing to their own species? Overpopulation due to the tyranny of a multitude of individually insignificant "small decisions" has resulted in ever increasing numbers of humans living in cities – some no more than marginally better for many individuals than the conditions in animal feed lots. Shelter may be better, but inoculation against disease is worse. The quality and quantity of food and water is less dependable, and starvation is more common than in feed lots.

Surely, the realization of inherent potential worth and dignity is a function of habitat and resource quality and quantity for all species. If so, then the inherent worth and dignity of humans should be discussed in a biospheric context so that there is transgenerational equity for the human species and equity and fairness for other species that collectively constitute the planet's ecological life support system.

Are Humans the Measure of All Things?

The first picture of Earth taken from outer space caused many people to feel insignificant. Yet, this idea was not new knowledge. Being part of a universe consisting of an estimated 50 billion galaxies is certainly ego-inflating, but, after all, it was human science and technology that enabled humans to have this new perspective. The more recent Hubble telescope, which recorded stars that were one billionth the intensity that humans can see with the naked eye, did not change the universe, but rather the temporal and spatial scales of the perspective. In many fields, such as astronomy and ecology, such information is increasing exponentially. This knowledge should increase awe and wonder, but should not deflate egos unless it appears to undermine human values and practices. Science documents the attributes of the natural world and attempts to achieve some degree of consilience with the multidimensional evidence generated. In the realm of human values and practices, i.e., religion and ethics, science may both illuminate and validate. However, scientific evidence may also indicate that it would benefit from modification and occasionally a major paradigm shift. Sustainability requires self-discipline, and self-discipline is well worth cultivating as the tyranny of small decisions demonstrates.

The Tyranny and Serendipity of Aggregate, Small Decisions

Economist Kahn (1966) and ecologist Odum (1982) have persuasively argued that seemingly insignificant, small decisions can both tyrannize lives and damage the environment if large numbers of people make similar, small decisions. Anyone who has been caught in a traffic jam understands this concept. However, aggregate decisions need not tyrannize. Aggregate, individual, small decisions can also benefit both human society and the environment (Cairns, in press), e.g., individuals donating to charities and using less fossil fuel. There is a major difference between the two situations. If the aggregate, individual, small decisions damage the integrity of the interdependent web of life (the ecological life support system), individual human worth and dignity will become a meaningless abstraction. If, on the other hand, the aggregate, individual, small decisions improve the integrity of the planet's ecological life support system, individual potential for both the human and other species is more likely to be realized.

If one acknowledges human society's dependence upon the ecological life support system and/or an ethical obligation to preserve its integrity, then one must accept the concomitant responsibility of judging the worth and dignity of each individual in the system context of the interdependent web of life. Society cannot ignore crimes against the biosphere by hiding behind an assertion of respect for the "worth and dignity" of each individual. Nor can society tolerate aggregate acts that damage the interdependent web of life by defending the rights and freedom of the individual. Nature exacts severe penalties upon societies that severely damage the ecological life support system (e.g., Diamond, 1994, 1997).

Small decisions are in a sense "invisible" because, in isolation from other similar, small decisions, they seem unimportant. However, unless each individual can "see" his/her personal contributions to the cumulative impact, society cannot achieve the "impossible dream" of sustainable use of the planet.

Anyone living in urban or suburban areas is so accustomed to having their lives tyrannized by aggregate, small, seemingly unimportant decisions that they rarely analyze them carefully. For example, traffic jams or slowdowns are solved by attempting to build more roads or enlarge existing roads rather than considering how these decisions increase human artifacts. At the end of the year 2000 and the beginning of 2001, California furnished an excellent example of this tyranny. Unusually cold weather, the holiday season, and escalating energy prices infuriated people who were accustomed to cheap energy on demand. Individual decisions to use appreciably less energy and to use energy more efficiently during an energy crisis, if sufficiently widespread, might well eliminate the “crisis” or, at the very least, lessen the possibility of brownouts and other inconveniences. For the poor, any significant increase in energy prices almost certainly affects the quality of their lives and their personal comfort.

The tyranny of small decisions affects species other than just humans, often leading to their extinction. The Associated Press (2000a) reports that the 2000 Red List of Threatened Species is the most comprehensive analysis of global conservation ever undertaken; even so, many species remain unidentified and many of these may become extinct before they are even given taxonomic names. As the Associated Press (2000b) notes, even though Rwanda is home to about half of the world’s 620 remaining mountain gorillas, Rwandans say that people come first and gorillas second. Demographic pressures resulting from millions of individual decisions will most likely cause the mountain gorilla’s extinction in that country, probably without appreciably helping humans in the long run if their present behavior persists. One can sympathize with the people in an impoverished country wishing for a more proportionate share of the world’s resources, but living sustainably is both a global and a regional problem. In the United States, Knight Ridder/Tribune (2000) reports that cell-phone road rules are not likely despite the fact that they appear to be a greater highway hazard than the unsafe tires that have recently received so much publicity. The article notes that some research implicates cell-phones in 450 highway deaths a year or more and the number of lesser accidents is considerably higher. Although not stated explicitly, a number of human deaths, injuries, and property damage is more acceptable than limiting individual freedom to use a cell phone under any circumstances while driving. If humans are reluctant to modify their behavior to protect other individuals of their own species, it seems unlikely that they will do so for other species.

Romo (2000) notes that the population of the border region with Mexico is projected to grow about 40% in the next two decades under a low estimate and more than double under the highest estimate. Ciudad Juárez, Mexico, with a population of about 1.4 million, relies entirely on ground water from the Hueco Bolson aquifer. However, hydrological studies have estimated the city’s wells could begin running out of fresh water in 5 years. This is another representative example of the tyranny of aggregate, seemingly insignificant small decisions. Regrettably, water resource misuse (as well as the misuse of other natural resources) is exacerbated by government subsidies. Fortunately, there are solutions to water resource problems, even in water-scarce areas (e.g., Committee on Sustainable Water Supplies for the Middle East, 1999). Naturally, these solutions require substantive changes in both individual and societal behavior since the quantity of water on the planet is finite and the percentage represented by fresh water exceedingly small.

Water quantity is only part of the problem, the other being water quality. For example, Soussan (2000) notes that samples taken from the San Juan River and Rio Grande waste water show traces of painkillers and estrogen. Other drug residues have been reported as well. Arguably, the more unsettling documentation of contaminants in water has been furnished by Colborn and Clement

(1992). Although particular industries are the source of many of these contaminants that disrupt human endocrine systems, they are being produced because of a number of individual decisions to use particular products.

In the absence of a societal ethos (e.g., Cairns, 2001) or set of guiding values mutually agreed upon, government coercion (i.e., legislation) seems to be the only way to avoid the tyranny of aggregate, small, individual decisions. Although this is unpalatable to anyone who values individual freedom, it is the planet's ecological life support system as well as human health that is being endangered. If societal literacy and ethics are not sufficiently robust to develop an ethos in time, undoubtedly laws and regulations will proliferate, as happened in World War II when resource use by individuals was severely restricted when the nation's survival was threatened.

The Ultimate Test of Human Intelligence

Human intelligence, which is responsible for both creativity and ingenuity, has had survival value for most of *Homo sapiens* existence on the planet. Evidence is persuasive that intelligence, coupled with compassion, literacy, and reason, has been enormously beneficial to individuals, the individual kin of the individuals, tribal units, and even sizable societies on occasion. On the other hand, intelligence during such events as World War II has been used to develop technologies enormously destructive to both humans and the environment.

If the planet's ecological life support system on which humans are dependent is severely damaged or placed in severe disequilibrium, which results in changes unfavorable to *Homo sapiens,* then intelligence will have failed the ultimate test of ensuring the survival of the human species. Sustainable use of the planet and natural capitalism both require the preservation and protection of natural capital (i.e., the ecological life support system and the services it delivers). Unless this preservation is accomplished, the concept of inherent worth and dignity of every person will have little or no meaning. Certainly it would have no meaning if the human species does not survive – an unpleasant but possible scenario if it continues to destroy its ecological life support system. Even if vital resources, such as quality water supply, are severely reduced in per capita terms, many inherent human qualities are unlikely to be fully expressed.

So the ultimate test of human intelligence is the ability to develop a harmonious relationship between each human and the interdependent web of life. Failure to see human society as a part of nature, rather than increasingly viewing humans as apart from nature, is surely failure to use intelligence as a long-term survival mechanism. Individual rights of humans are much discussed these days, but acknowledgment of a dependence on the interdependent web of life or a responsibility for maintaining its integrity is not. For some people, this is undoubtedly due to low ecological/environmental literacy (an uncharitable person might use the word *ignorance*) or, in some cases, it may be due to denial of the information despite substantial exposure to the evidence.

Although science can use evidence to develop probabilistic determinations of risks, etc., the value judgments must be based on ethical, moral, and religious considerations. It is important that religions explore in a much more substantive way the relationship between the inherent worth and dignity of every person in the context of the planet's life support system (the interdependent web of life of which humans are a part).

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Article 29

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Monitoring the Restoration of Natural Capital: Water and Land Ecosystems

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ABSTRACT

In the twentieth century, human society reached unprecedented heights of material development. Human-made capital abounds, although the disparity in per capita affluence is the greatest in human history. However, the natural capital that is the basis of this economic prosperity is rapidly declining. Natural capital includes all resources humans have used throughout time: water, soil, forests, breathable air, fisheries, and all other resources that, collectively, provide the ecosystem services upon which humankind depends. Human society "inherited" a 3.8-billion-year-old store of natural capital. However, if the capital is destroyed, the "interest" (ecosystem services) will be lost. Fortunately, natural capital can be increased by the methods and techniques of ecological restoration. Although this field is still in early developmental stages, a sufficient number of case histories from a wide range of ecoregions justify confidence in the restoration process. Unfortunately, current protocols for monitoring this process are simply inadequate. Monitoring is defined, in this context, as determining whether **previously established quality control conditions** are being met. Protocols for monitoring the risk or hazard of chemicals in the environment developed rapidly once the need for monitoring was perceived, so there is reason to believe that protocols will develop for monitoring ecological restoration as well. The validity of early protocols for assessing hazardous materials could be determined by using case histories where response thresholds had been inadvertently crossed. Case histories should serve as well for developing restoration protocols. Because of space constraints, some points of this discussion are more thoroughly addressed in the water section and others in the terrestrial section. Very commonly, the conceptual portions of the problems are quite similar for land and water (e.g., coping with exotic species); therefore, the emphasis deliberately differs. This organization does not mean that a problem given heavy emphasis in the water section is not as important in the land section and vice versa.

1. INTRODUCTION

Human societies worldwide are curiously reluctant to admit human dependence upon Earth's natural cycles and systems. Economic growth and development are embraced with a fervor that virtually denies that human existence is based on an inheritance of a 3.8-billion-year-old accumulation of natural capital, very little of which will be left by the year 2100 if present rates of ecological destruction continue. Hawken, Lovins, and Lovins (1999) have advocated a new paradigm called **natural capitalism** that recognizes the crucial interdependence between the production and use of human-made capital and the maintenance and supply of natural capital. **Capital** is conventionally defined as accumulated wealth in the form of investments, factories, and equipment. However, Hawken, Lovins, and Lovins (1999) propose that economies need four types of capital to function properly:

1. human capital, in the form of labor and intelligence, culture, and organization
2. financial capital, consisting of cash, investments, and monetary instruments
3. manufactured capital, including infrastructure, machines, tools, and factories
4. natural capital, made up of resources, living organisms, and ecosystem services

It is unlikely that humans could destroy all life on Earth without destroying themselves in the process. Although the fragility of natural systems is often discussed, and they are often fragile, it seems highly probable that, of the estimated 30 million or more species on the planet, hundreds or thousands or even millions of these species are more likely to tolerate a polluted and degraded environment than is *Homo sapiens*. Human societies are embedded in ancient natural cycles: climatic, atmospheric, hydrologic, and elemental (such as carbon and nitrogen). Vulnerability of human societies to changes in hydrologic cycles is currently evident, such as droughts in India and floods in Mozambique. Mainstream scientists accept that anthropogenic alterations of other major cycles is possible.

Over the years, many attempts have been made to place a monetary value on natural capital. One of the most notable, in terms of attention received, is that of Costanza et al. (1997) in which the biological services benefitting human society were estimated to be worth at least US 35 trillion annually. However, this assessment does not appear to have resulted in a paradigm shift in attitudes toward natural capital. As many economists have noted, estimating the value of natural capital is a difficult and imprecise exercise. These services have been free for most of human history; why should this change? More persuasive than these considerations is the realization that many of the services humans receive from the natural world have no known substitutes at any price. In short, technological systems simply cannot replace the biospheric life-support system. This inadequacy is illustrated by the failings of the Biosphere 2 project in Arizona, U.S., that was unable to provide breathable air for the eight people living there. Biosphere 2 cost US 200 million to build with annual costs per person of about US 9 million (Avise 1994).

Natural capital is being both displaced by human artifacts and degraded by present economic systems, arguably because exploitation has a higher priority than stewardship. If sustainable use of the planet is to be achieved, natural capital must be replaced and cherished. The process of rebuilding natural capital is called ecological restoration. The National Research Council (1992) report, *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*, urges readers to take a broad landscape perspective because the two ecosystems (land and water) are inextricably linked. This linkage is commonly recognized. Many books and case histories discuss ecological restoration, but little information exists about monitoring the process. The chapter that follows focuses on the components of a restoration management protocol.

2. MONITORING

Monitoring is surveillance undertaken to ensure that **previously established quality control conditions** are being met. Regrettably, the term **monitoring** is often used to designate a study (gathering of data) or surveillance (a systematic and orderly gathering of information through time), neither of which require either a precise statement of acceptable conditions nor remedial action should quality control conditions not be met. Monitoring in a restoration context is similar to the workings of an intensive care unit in a hospital; deviation from established norms sets off alarms and brings emergency staff to take immediate corrective action. Similar monitoring systems are used in many industries, such as nuclear power production, pharmaceutical production, and production of components for electronic devices.

Equally regrettably, the term **ecological restoration** has been defined in literally hundreds of different ways; sometimes more than one definition is used within a single governmental agency. In fact, the National Research Council's (1992) report recognizes this dilemma and calls for a single definition of ecological restoration to be used throughout the federal government. Today this dilemma persists still, though soon a decade will have passed since the report was published. Combining such loosely defined terms as **monitoring** and **ecological restoration** might either lead to more confusion or more precision. In this discussion, the National Research Council's (1992, p. 18, box 1.1) definition of **ecological restoration** is adopted: "the return of an ecosystem to a close approximation of its condition prior to disturbance. In restoration, ecological damage to the resource is repaired. Both the structure and the functions of the ecosystem are re-created. Merely re-creating the form without the functions, or the functions in an artificial configuration bearing little resemblance to a natural resource, does not constitute restoration. The goal is to emulate a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs. Often, natural resource restoration requires one or more of the following processes: reconstruction of antecedent physical, hydrologic, and morphologic conditions; chemical cleanup or adjustment of the environment; and biological manipulation, including revegetation and the reintroduction of absent or currently nonviable native species."

Self-maintenance is an extremely important attribute because it is direct evidence that ecological integrity has been restored. However, integrity of an ecosystem is exceedingly difficult to measure, especially when one considers that all ecosystems are dynamic; they are subject to seasonal cycles, long-term trends, and episodic alterations due to floods, fire, drought, invasion of exotic species, and the like. Furthermore, at the landscape level, a mosaic of different habitat types exist that are interactive, but in which changes are not synchronized.

3. ECOSYSTEM HEALTH

Clearly, monitoring ecological restoration to increase natural capital would benefit from a goal simply stated and generally understood. The most likely choice at present is the goal of **ecosystem health**. A healthy ecosystem is likely to be self-maintaining and likely to deliver ecosystem services reliably. Regarding human health, physicians have shifted their goals from attaining absence of disease and malfunction in their patients to attaining presence of indicators of "fitness" or "good condition." Even critics of ecosystem health (Calow 2000) think that "we should remain skeptical about the ecosystem health concept, except insofar as it is clearly intended pragmatically to refer to the extent ecosystems can deliver services to humanity." It is worth noting that the concept of "health," whether at the individual, population, or ecosystem level, necessarily involves value judgments (Rapport et al. 2000). Therefore Nielsen (1999) asserts that "in the final analysis, what is considered healthy must be reasonable from biological, physical, ethical, and aesthetic points of view as determined by people. Therefore health is not a science *per se*. It is then a social construct and its defining characteristics will evolve with time and circumstance." Clearly, many scientists, particularly ecologists, are uncomfortable with the prospect of introducing human goals and values into the evaluation of ecosystems. However, both ecological restoration and increasing natural capital will require public support over considerable geographic areas and spans of time. As the

National Research Council (1992) notes, restoration inevitably involves a matrix of ecological and human values. Cairns (1994) speculates that human society and natural systems are co-evolving, a process that could be very beneficial if the relationship is a good one but disastrous if not. Throughout this discussion, ecosystem condition or health is considered the ultimate goal in monitoring ecological restoration. From this concept will derive the attributes to be monitored, including both scientific and human values that form basic components of the monitoring protocol. At this early developmental stage, producing a well-defined protocol is neither appropriate nor does the information exist to permit it. However, guidelines for further development seem fairly clear, and some illustrative examples that could produce the kinds of attributes and components of a restoration monitoring protocol will be given.

4. EARLY WARNING SYSTEMS

Over three decades ago, it was clear that early warning monitoring systems required rapid generation of information (Cairns et al. 1970). Also needed was automation of the time-consuming task of gathering data, such as identifying species (Cairns et al. 1972). To be effective, this biotic information had to find use in a landscape context (Cairns 1975). Finally, such information had to be transmitted from remote sites that were particularly suitable for monitoring effects of airborne contaminants. Satellites are particularly useful for remote transmissions. Some of the computer-interfaced biological early warning systems developed by Morgan (1986, 1991) used biological sensors that can, through the use of telemetry, send early warning signals to nearby, more powerful transmitters. The information can be transmitted by satellite to a receiving station quite distant from an early warning site. With automation, a biological response can initiate collection of water samples for water chemistry analyses and even the visitation by a sampling team to a site. Such expenditures of resources may appear excessive. However, remote lakes have not only intrinsic ecological value but are also valuable as reference sites, particularly because evidence gathered there helps to distinguish between two conditions that affect all monitoring sites: (1) To what extent do airborne contaminants from sources well outside the bioregion provoke early warning monitoring signals? and (2) To what extent do natural, episodic events initiate early warning signals? A carefully designed system for monitoring chemical, physical, and biological attributes should facilitate distinguishing one type of early warning signal from the other. It is hoped that such information is of sufficient value in protecting and restoring ecological integrity that such organizations as the US National Science Foundation, the German Deutsche Forschungsgemeinschaft, and their counterparts in other countries will support efforts that should be valuable in ecological assessment throughout the globe. Remote bioregions are threatened by airborne contaminants and their isolation is increasingly diminished, especially given the greatly heightened interest in ecotourism. Money supporting scientific inquiry is well spent when it serves both basic science and aids in restoring natural capital, for which the basic ecological science is still in its early developing stages. Remote bioregions may be better suited to detecting effects of airborne contaminants than local regions.

5. LANDSCAPE PERSPECTIVE AND INTEGRATED MANAGEMENT

Effective monitoring of natural capital restoration requires a landscape or ecosystem perspective. Land uses in an entire catchment basin are important considerations in managing the hydrologic system, including connecting streams and wetlands. Although the tendency toward a holistic education has become more strongly supported, the narrowly targeted funding of government agencies, and particularly their mission statements, frequently dictate a fragmented approach to both land and water monitoring and restoration. Professionals with a landscape approach are often frustrated by bureaucratic complexities because, in the United States as in many other countries, no single government agency is responsible for ensuring an integrated landscape approach to ecological problems, especially in monitoring, management, and restoration of natural capital. At the very least, all governments need an interagency program to coordinate the selection, planning, and evaluation of restoration and monitoring projects.

Should substantive monitoring of natural capital restoration projects soon become mandatory, there would be a paucity of qualified people to implement monitoring programs. Skilled professionals capable of monitoring at a landscape or ecoregion level are badly needed in the education system to encourage development of essential professional skills. Training programs must necessarily cross traditional disciplinary boundaries, especially those between basic and applied ecology, while maintaining a level of expertise about which the disciplines can be justifiably proud.

6. ECOLOGICAL RESTORATION

As Hynes (1970; as quoted on p. 165 in National Research Council 1992) notes:

> Human activities have profoundly affected rivers and streams in all parts of the world, to such an extent that it is now extremely difficult to find any stream which has not been in some way altered, and probably quite impossible to find any such river. The effects range from pollution to changes in the pattern of flow, and they have become increasingly marked during the past two or three centuries.

Human activities that alter hydrologic systems are the norm rather than the exception, and streams and rivers are the focus of many of these efforts. Water has been diverted from its natural flow to dry areas that are densely populated, and irrigation has reduced the flow of water in many areas so that it is far from the hydrologic norm. Even temporary withdrawal, for cooling water in steam-generated electric power plants and similar industrial uses, alters both the temperature and some chemical characteristics when chlorination is introduced to reduce fouling of the cooling equipment. These disturbances to hydrologic systems create some enormous difficulties. Whenever the structure and function, including resident species and functional attributes, can be known in considerable detail, the choice of ecological restoration is fairly straightforward. Assuming that suitable species for recolonization can be obtained without placing a donor system into ecological disequilibrium, the predisturbance condition should be restored. Of course, adequate funding and political will should be sufficiently strong to assure that ecological integrity, once restored, is not again damaged.

In cases where a detailed structural and functional inventory is not available or adequate sources of species representative of predisturbance conditions are not available, much professional judgment is required to set ecological goals, criteria for success, and explicit descriptions of the quality control criteria. If these criteria are not met, immediate corrective action is essential. Failure to meet quality control conditions should also trigger a reevaluation of the project design, possibly with a mid-course correction to another design. Damaged and recovering ecosystems are particularly vulnerable to invasion by exotic species, and the probability of invasion is vastly increased if the area being restored is surrounded by other damaged or disturbed ecosystems already colonized by exotic species.

7. INFORMING THE PUBLIC

It is strongly advisable to communicate as much information as possible to the general public. An informed and deeply involved public can be an enormous asset, and appreciation of such a group for the restoration work is particularly gratifying. Frequently, some people who have an especially deep interest are guardians of sampling devices and study areas. In one instance, bystanders' queries to graduate students who were studying a heavily used beach recreation area led to citizen participation in informal reporting sessions. Some citizens observed daily sampling procedures and enjoyed listening to daily briefings. A danger exists when engaging citizens in this sort of activity since raw data can be misleading and a few days of normal variation in one direction can be mistaken for a trend. On the other hand, appearing secretive can be very counterproductive, especially when the scientific process is not well understood.

However, even if informal communication works well, public meetings with a formal agenda and a question-and-answer session should be scheduled regularly. Ideally, these meetings could be broadcast by local public information television and radio stations and captured on videotape, or at the very least, on audiotape. In addition to having a record of full disclosure, these recordings are particularly valuable for answering questions that were addressed thoroughly in previous meetings. A skilled recording secretary with a good cross-reference system can tactfully inform questioners of questions previously answered in detail, directing them to the exact location of the recorded information they seek.

In some cases, citizens choose a single person to represent their particular interests. This approach can work particularly well if the choice is well made. However, a solitary zealous person with a personal agenda differing markedly from the public agenda can be extremely disruptive and expensive. This situation is particularly trying when such a person informs the press of charges that are unfounded, particularly if the press thinks that any controversy is newsworthy. The individual may also believe that every team member on the restoration project owes him unlimited time and access to data and information whenever his demand is made. These requests, if honored, can result in the loss of perishable samples and, at best, the entire project may suffer delays. Individuals having personal agendas are often much less disruptive in public meetings where their behavior is quickly and usually correctly assessed by other participants. Even when a single person is chosen to represent a group, public meetings should still be conducted so that citizens can observe and judge for themselves. Any appearance of controversy quickly increases attendance. More participation almost always works in favor of those with a reasoned, evidence-based approach and a willingness to admit that all restoration activities are somewhat experimental, all monitoring activities require seasoned professional evaluation, and preliminary raw data can be misleading if not subjected to the validating and confirming procedures of the scientific method.

8. EARLY SOCIETAL ASSOCIATION WITH RIVERS

Very early in human society, rivers were associated with a variety of human uses, particularly as transportation routes. The Romans and many other cultures found them useful in transporting wastes away from human populations, a use that became quite common following the Industrial Revolution. Gameson and Wheeler (1977) give a superb historic account of the use and abuse of the Thames River in England. Their account of the British Parliament's reaction to pollution is particularly telling, since the Houses of Parliament are located alongside the Thames and the stench from it invaded the building. Parliament's solution was to hang cloth sheets soaked in vinegar to counteract the stench. Regrettably, much attention is still given to symptoms and often little attention to basic causes, even in today's supposedly enlightened times when political attempts may try to aim monitoring programs at symptoms rather than underlying ecological causes. Regulatory agencies are driven by funding from legislative bodies, and sound science may often take a back seat in the quest for funding.

The National Research Council (1992) volume lists seven changes that have stressed flowing water systems and impaired their value for human use and environmental services: (1) water quantity or flow mistiming, (2) morphological modifications of the channel and riparian zone, (3) excessive erosion and sedimentation, (4) deterioration of substrate quality, (5) deterioration of water quality, (6) decline of native species, and (7) introduction of alien or exotic species. Because rivers and streams may suffer from impairments in their catchment basins or watersheds, riparian or flood plain zones, and channels and pools, monitoring programs must be designed with both the source of a problem and the locus of the problem in mind. Therefore, monitoring programs must be characterized by a high degree of site specificity.

Arguably, the most extreme form of ecological stress to rivers and streams is the appropriation of large volumes of water flowing on the surface, either by direct withdrawal for irrigation and other purposes or by pumping from aquifers associated with the riparian zone. Dams are often associated with water appropriation projects since availability can be better controlled. In some cases, appropriation may be so great that the water reaching the mouth of the river or its estuary may bear little chemical, physical, or biological resemblance to its natural state prior to appropriation or impoundment. Persuasive evidence in Postel's (1999) book suggests that these stresses are likely to worsen appreciably for the foreseeable future. Unless considerably more attention is given to in-stream ecological needs, restoration of natural capital to a naturalistic assemblage of organisms and functions will not be feasible. In such cases, the term **river restoration** is grossly misapplied. The Willamette River in northwest Oregon, U.S., is a badly perturbed ecosystem that has been altered greatly from its original condition. Despite these great alterations, it has been described by some as a river restoration success story (Starbird 1972; State of Oregon, Department of Environmental Quality 1989). The Willamette River restoration has been directed primarily toward water quality restoration, protecting beneficial uses of the river water, and managing particular species of game fish. Much of the Willamette water quality improvement has been accomplished by augmenting summer water flows with impounded water to dilute pollutants. A parody of this approach is "the solution to pollution is dilution." No holistic effort was made to re-create the river's natural, antecedent biological or ecological conditions (National Research Council 1992). This case illustrates that, until some standard meaning and definition of the term **river restoration** can be agreed upon, one must be careful to determine and define precisely what is being restored. If monitoring has been indicated, one must ascertain whether the term **monitoring** is used in conjunction with the explicit designation of ecological quality control criteria which, if outside expected boundaries, produce immediate corrective responses, or whether the term is used, as occurs so often to indicate merely a gathering of data having no predetermined ecological quality control criteria in mind. The latter meaning attempts to avoid responsibility for corrective action or for identifying conditions mandating corrective action.

9. INFLUENCE OF IMPOUNDMENT

River impoundment is a major means of altering natural capital. Despite problems with past alterations, major impoundment projects are still underway, such as Three Gorges Dam Project in China. Fortunately, the influence of impoundment on ecological parameters of a river system can be conceptualized. For example, Ward and Stanford (1983) have provided a theoretical framework for conceptualizing the influence of impoundments on ecological parameters in a river ecosystem. Discontinuity distance (DD) is the downstream (positive) or upstream (negative) shift of a parameter for a given distance (x) due to stream regulation. Parameter intensity (PI) is a measure of the difference in the parameter intensity attributed to stream regulation. Using this theoretical framework, one can approximate both how far a river has departed hydrologically from its natural flow and the likelihood of reestablishing ecological parameters of its predisturbance community. Most likely, a naturalistic assemblage of organisms in both structure and function best suited to the altered environmental conditions is the only one acceptable to human societies because of the major social adjustments that would otherwise be required to regain predisturbance conditions. Thus, a monitoring plan should be based on the altered hydrologic dynamics rather than naturally occurring ones. Additionally, endpoints should include some societal values that, ideally, are compatible with the protecting and accumulating natural capital.

The effect of dam removal on natural capital is almost certain to be a major issue in the twenty-first century. For example, in the United States between 1991 and 1993 alone, more than 200 electric power generating projects (representing perhaps more than twice this number of dams) were considered for license renewal (Echaverria, Barrow, and Roos-Collins, 1989). Restoration of a formerly impounded reach of the Milwaukee River in West Bend, Wisconsin, U.S. followed removal of the Woolen Mills Dam. The Wisconsin Department of Natural Resources ordered West Bend to rebuild or remove the dam for public safety reasons (Nelson and Pajak, 1990). Cairns and Palmer (1993) discuss the problem of aging reservoirs and the opportunity for ecological restoration; numerous opportunities will arise for enhancing natural capital in rejuvenating reservoirs or eliminating dams in the twenty-first century.

10. RESTORING SINUOSITY

Although hydrologists are often not involved in planning stream and river restoration projects, several examples illustrate how efficacious this approach can be, such as restoration of the Rio Blanco in southwestern Colorado. Hydrologist D. L. Rosgen (Berger 1992) reduced the river's bank-full width from a 400-foot-wide braided channel to a stable, 65-foot-wide channel (National Research Council 1992) with a high pool-to-riffle ratio. In this example, "soft engineering" techniques and natural materials were used to combat stream and river degradation and bank erosion. Soft engineering techniques restabilized river channels and banks without straightening them and without confining water flows in channels lined with concrete or riprap. This approach required a study of the river's natural hydrological and hydraulic tendencies and used earth-moving equipment to return the fluvial system to a stable, naturalistic configuration. In the early 1990s, the braided channel remained upstream from the demonstration area and downstream as well. If these conditions were to persist, monitoring during the natural capital restoration period would be most informative if the divergence from the disturbed leveed areas were contrasted with the changes toward a more naturalistic system in the project area. In the post-restoration period, the degree to which failure to regain integrity was influenced by surrounding ecosystems, particularly upstream reaches, should be documented. It is interesting to note that, despite the focus on hydrologic dynamics, the Rio Blanco's biota rebounded rather well, particularly the fishery. Almost certainly, tributary streams, and perhaps a few remaining pools, furnished the organisms that recolonized the entire restored reach. In the absence of such natural recolonization, assisted recolonization would have been necessary if evidence existed that it would enhance the recovery. In both natural recolonization and assisted recolonization, monitoring should include not only chemical and physical changes and attributes but changes in both biological structure and function as well. Because the fishery in this area was relatively limited in diversity, it proved much easier to document accumulation of natural capital than would have been the case in a much more complex fishery. Regardless of whether recolonization is assisted or natural, such attributes as recruitment rates, growth rates, food supply, and changes in carrying capacity are among the most obvious attributes requiring measurement in any monitoring program designed to assess the condition of natural capital.

Despite vast differences from the Rio Blanco in project size, ecoregion, and temporal and spatial scales, the Kissimmee River demonstration restoration project in Florida, U.S., exhibits an interesting correspondence with the restoration of the Rio Blanco given that both had sinuosity restored. The Kissimmee River is part of the larger Florida Everglades ecological landscape. The US Army Corps of Engineers (COE) proposed the excavation of a canal from Lake Kissimmee to Lake Okeechobee to replace the original Kissimmee River (U.S. Department of the Interior 1958). Their primary purposes were to improve and use more intensely the grazing lands within the basin, control floods, and increase the amount of developed land. The channelization of the Kissimmee River cut the length of the original reach approximately in half. Because the hydrology, particularly the flooding of adjacent wetlands, is a unique characteristic of the Kissimmee-Okeechobee-Everglades ecosystem, this dramatic hydrologic change resulted in several ecological problems: destruction of much of the associated wetlands and floodplains, the disruption of excavating for the canal, the construction of associated east-west roads, and changes in natural river flow timing. Loftin, Toth, and Obeysekera (1990) and Toth (1990) noted that the channelization of the Kissimmee River alone drained 34,000 acres of Kissimmee floodplain wetlands, killing an estimated 5 billion small fish and 6 billion shrimp. Additionally, 13,000 acres of natural Kissimmee wetlands were converted to "impounded wetlands," resulting in a significant loss of ecological values (Loftin, Toth, and Obeysekera 1990). Another 7,000 acres of wetlands were obliterated along with about 35 miles of the original river channel when the COE's new C-38 canal left the excavated spoil piled along the canal banks to form levees (Loftin, Toth, and Obeysekera 1990). Six indigenous species of fish were extirpated from the river as a result of these activities (Toth 1990). Although the Kissimmee channelization project had been opposed from the start by various conservation groups, numerous politically strong groups overrode these objections and the canal was built. However, the ecological degradation was so massive and so swift that it could hardly be missed by even the most casual observer. As a result, the Governor's Conference on Water Management in South Florida, the Central and South Florida Flood Control District, began calling in 1971 for reflooding the Kissimmee wetlands, even before the COE had finished its initial work (Dreher 1986). General public awareness of the ecological consequences of constructing the canal was sufficiently strong and the time period was short enough that many of the propagules in the original wetlands had not entirely disappeared, nor had the sinuous original channel. These two features were indeed beneficial because restoring some water to the original channels and reflooding the wetlands produced dramatic ecological improvements and showed that the ecosystem had retained much of its ecological resiliency. In this case, developing a natural capital restoration monitoring program, although not without complexities and problems, was fairly straightforward since the condition of the system prior to disturbance had been amply, albeit not exhaustively, documented. However, extensive human artifacts appeared in areas that had previously been wetlands or part of the floodplain, etc. It is unlikely that these human artifacts can be removed in large numbers, nor is it likely that the C-38 canal can be filled in, although sedimentation will almost certainly be permitted and eventually reduce the size of the canal. As a consequence, natural capital has not been fully restored.

These two case histories have been presented here because they illustrate contrasting situations with regards to restoration monitoring. In both cases, the natural capital restoration involved restoring some of the predisturbance attributes. In addition, a source of recolonizing organisms was available, either from tributary streams (Rio Blanco) or because some of the wetland species propagules had sufficient resiliency to survive a multi-year, abnormal hydrologic regime. If propagules had not been available to the extent that they were, assisted recolonization would have been necessary and, therefore would have significantly altered the natural capital restoration monitoring program. The restored reach of the Rio Blanco ran through land belonging to a single individual and the restoration expense was borne by that individual, though alterations to the river's hydrology had been carried out by a government agency. Even so, governmental agencies had to approve the restoration plan, and accordingly some compliance restoration monitoring was necessary. If some compliance monitoring was mandated in this case where private funds and private property were involved, it is difficult to imagine a case in which no compliance restoration monitoring would be required; if such exceptional cases exist, they are exceedingly rare. It is also worth noting that, in both cases, the government organization causing the ecological disruption was requested by local citizens to intervene.

The Kissimmee restoration project differed from the Rio Blanco in two important ways. First, the government agency that caused the ecological disruption by building the C-38 canal (at the request of local citizens and their representatives) was also asked by the same groups to restore the lost natural capital. The restoration request came only after the loss of natural capital became abundantly clear with precipitous drops in populations of many valuable species of game fish, birds, and the like. Second, the Kissimmee project, partly due to its size, was involved with many special-interest groups that often had conflicting opinions on the best remedial action. Some groups speculated that the restoration of natural capital would endanger other forms of capital; natural capital that would benefit the general public was placed well below their tightly focused financial interests. The pressure of informed citizens supported partial ecological restoration, which was not perceived to threaten financial interests that benefitted from flood control.

As a consequence of the need to balance ecological and economic interests, natural capital restoration must be directed to a new array of conditions with the possibility that only some may closely approach the attributes and characteristics of an undisturbed ecosystem. A naturalistic community will be a new one, not one resembling the predisturbance community in all respects. Both pre-restoration and post-restoration monitoring designs should be heavily influenced by the determination of the degree to which a restored ecosystem is self-maintaining. The important point is that natural capital occurs in many forms, and much professional judgment is required to evaluate it.

11. RESTORING FLOOD REGIMES TO GENERATE NATURAL CAPITAL

The unusual floods of 1993 on the Mississippi River in the U.S. illustrate that floods of sufficient magnitude to overcome restraining structures built by the COE can reestablish lost habitat and result in the reappearance of species thought to be lost (e.g., R. E. Sparks, personal communication). Not surprisingly, some aquatic species are as dependent on floods or other episodic events as many terrestrial species are dependent on episodic events such as fires. Recently, simulated floods or controlled releases have proven efficacious in reestablishing certain species, although the precise amplitude, duration, and frequency of flooding needed to maintain viable populations of these particular species is not yet known with precision (R. E. Sparks, personal communication). Arguably, most riverine systems have flood-dependent species, and in many systems they are threatened or endangered. In some systems, these species have been extirpated, but viable populations exist elsewhere. In all riverine natural capital restoration projects, pre- and post-restoration monitoring should include both direct measurements of the viability of populations of these species and monitoring of the chemical and physical conditions and habitat reestablishment necessary for their survival. In such cases, in-stream ecological integrity requires simulated floods at particular seasons and of particular amplitudes, frequencies, and durations. In a very real sense, reestablishing a naturalistic community of plants and animals requires an approximation of certain naturalistic hydrologic events.

12. WATER QUALITY RESTORATION TO INCREASE NATURAL CAPITAL

Two notable success stories illustrate water quality restoration to increase natural capital. One is the restoration of water quality in the Ohio River in the U.S. by the Ohio River Valley Water Sanitation Commission (ORSANCO), and the other is the restoration of water quality in the Thames River in the United Kingdom (U.K.) by the Thames Water Authority (TWA).

The improvement in water quality in the Ohio River is notable in several respects. First, the catchment or drainage basin is enormous, covering (with tributaries) 17 states. Second, the organization primarily responsible for this effort – carried out, of course, in conjunction with many state, regional, and other authorities – had no regulatory power, only the power of persuasion. Third, no strong multidimensional ecological goals were stated, although the primary goals were to improve certain aspects of water quality, such as dissolved oxygen concentration, and to reduce toxicity. Nevertheless, improving water quality, not to standards characteristic of a freely free flowing river but to markedly higher standards than existed in its worst condition, resulted in substantial ecological benefits and increased natural capital. Measurable dissolved oxygen concentrations were missing from some reaches of the river for certain periods of time, some rather lengthy. Restoring even a very few parts per million (i.e., three parts per million) dissolved oxygen concentration conferred substantive benefits to accumulation of natural capital. Notable economic benefits resulted as well, such as reduced treatment costs for municipal and industrial water.

The ORSANCO story illustrates several important points. Possibly the most important is that water quality improvements can be made over a vast area with numerous political jurisdictions and an extraordinary diversity of special interests. Also illustrated is that continuous quality control monitoring is essential if clearly stated goals and objectives are to be achieved and, once achieved, maintained. Water quality cannot be taken for granted, as it so often has been in the past. Clearly, societies must invest resources to achieve and maintain quality control objectives. An ideal situation is one in which the detail of assessment is high, the time scale is long, and the spatial scale is large; however, the usual assessment case is one in which the detail of assessment is low, the time scale is short, and the spatial scale is small. In view of the ORSANCO's stated goals (particularly with dissolved oxygen concentration), the level of assessment was comprehensive, although from an ecological standpoint it was not. In terms of both time scale and spatial scale, the situation was close to the ideal. The ORSANCO case history illustrates that restoration projects contain a mixture of ecological values and human values, and the ratio will not always be the same for each project. Presumably, in an ecologically literate society acknowledging that the earth's ecological life-support system is essential to human survival, the two types of values will coincide. However, it is essential to test the validity of this assumption because it would be remarkable if it always proved correct. The ORSANCO goals and objectives would never have been achieved had a substantial effort not been made to educate people about the benefits of improved water quality. The project also illustrates, as does the Thames River case history discussed below, that even waste treatment plant operators, both industrial and municipal, can meet future regulatory standards and criteria for waste water quality with equipment that is definitely not state-of-the-art and, in some cases, is decades old. For 19 years, I taught an advanced course at the University of Michigan Biological Station near Pellston, Michigan, U.S., that included field trips to a variety of waste treatment plants. One visit was to an industrial plant in Cheboygan, Michigan that produced disposable diapers from partially processed pulp obtained from elsewhere. The waste treatment system at that time (1970s and early 1980s) was not the latest available, but the person in charge was highly motivated, extremely knowledgeable, and was meeting future regulatory standards of waste water quality using equipment that was well over a decade old. If their motivation is strong, skilled professional waste treatment plant operators and personnel can do splendid things without state-of-the-art equipment.

A second example of successful restoration of water quality is illustrated by the Thames River in the U.K. The Potomac River in the U.S. was experiencing low flows in 1966 (Blackburn 1979), and a group of professionals from the U.S. investigated how water shortages due to low flow in the Thames River (Thames Water Authority, 1978) were managed in terms of water supply. To American professionals, the most striking difference between American and British management was the absence of attorneys-at-law when purely scientific and engineering decisions were being made by the British. At its best, the American legal system is an admirable way to express and enforce mutually agreed upon social contracts. It is, however, very poorly suited to the scientific process. The preponderance of evidence accepted by mainstream scientists influenced the U.K. decisions almost entirely. In the U.S., even the most extreme scientific views garner a disproportionate share of court time. As a caveat, it is worth noting that mainstream scientists and engineers were not particularly effective in correcting gross environmental abuse in the U.S. when it received widespread public attention about 50 years ago. Arguably, every important environmental case of that period in the U.S. was settled in courts of law rather than in “courts” of science. However, courts of law, wherever they may be, are not well suited to implementing the precautionary principle. The essence of this principle is that precautionary action should be taken even in the face of substantive uncertainty when the consequences of not doing so may be particularly severe. Except for compliance monitoring, all monitoring is based on the precautionary principle because it is intended to provide an early warning signal that certain established quality control conditions are not being met. In order to take full advantage of any early warning signal, prompt corrective action must be initiated as soon as a signal appears that previously established quality control conditions are not being met. This principle is as important in environmental monitoring, particularly in monitoring natural capital protection and restoration where ecological recovery is taking place, as it is in the intensive care section of a hospital.

As Calow (1995) notes, ecosystems are not organized in the same way as persons, and therefore the definition of their health, integrity, or condition must be approached differently. Odum (1989, 1996) notes that most organisms, in particular humans, are imbued with a series of physical feedback loops collectively grouped under the term **homeostasis**. Homeostasis maintains such functions as temperature, respiration, blood pressure, and the like, within certain relatively narrow ranges. Odum uses the term **homeorhesis** (or, varying within limits) for the condition of ecosystems; when a threshold is crossed, a new equilibrium condition may be reached. Most ecological monitoring, and in particular monitoring the restoration of natural capital, is undertaken to ensure that both the established goals and conditions of the project are met and that no anthropogenic effects are placing the system into ecological disequilibrium. Ecosystems are capable of self-maintenance and, thus, preservation of their natural capital. Disequilibrium should be avoided. Odum (1989) recognized years ago that new properties emerge in each successively higher level of biological hierarchical organization from cellular components to cells, tissues, individuals, populations, communities, ecosystems, and landscapes; moreover, observations of lower levels give no basis for predicting the properties that emerge at higher levels. However, ecological hierarchy differs from human social hierarchy (Golley 1998). In a human social hierarchy, such as an army, higher units control lower units, whereas ecological hierarchies do not exhibit this kind of control structure. The concept of "health," whether at the individual, population, or ecosystem level, necessarily involves value judgments (e.g., Rapport et al. 2000). In the final analysis, what is considered healthy must be from biological, physical, ethical, and aesthetic points of view as determined by people (Nielsen 1999). Rapport et al. (2000) conclude that the determination of health is not a science *per se*. It is a social construct, and its defining characteristics change with time and circumstance. As a consequence, particularly in developing monitoring protocols, the uneasy relationship between science and law must continue. However, courts of law must improve the ways in which the scientific process can be communicated within the courts, and scientists must recognize that communication outside of their area of specialization must necessarily be different from that within their area of specialization. In the absence of such a multidimensional approach, monitoring natural capital restoration will never function as it should. Some organisms can live in water of aberrant quality, as recent evidence gathered from ocean floor thermal vents shows. The quest for sustainable use of the planet, which appears to be the most likely means of developing a new relationship between human society and natural ecosystems, requires maintenance of natural capital to meet perceived human needs as well as meeting the ecological requirements of the planet's biospheric life support system. Although representing only preliminary steps in the direction of a more felicitous relationship between human society and natural systems, the ORSANCO and Thames case histories do provide grounds for cautious optimism about increasing natural capital.

13. MONITORING RESTORATION OF NATURAL CAPITAL THAT IS CENTERED ON A SINGLE SPECIES

Monitoring of any restoration centered on one species is fairly straightforward in terms of the types of evidence to be gathered but can, nevertheless, be quite laborious. Well known measurements such as recruitment rates, growth rates, demographic relationships, and the like are well established for many organisms, although not for as many threatened or endangered species as desired. This disparity is especially true where the effective gene pool may be smaller than originally estimated due to fragmentation of species populations by barriers not initially apparent to humans. For example, some fragmentary evidence indicates that even large mammals such as whales may not be as well studied as originally thought. The danger in centering natural capital restoration upon a single species is that the criteria used to promote the well being of a chosen species does not necessarily mean that all species in the associated community of organisms are equally well protected or, in some cases, that the ecological requirements of all associated species are being met equally or even at all. In an extreme case, such narrowly centered natural capital restoration could result in a community resembling an agricultural monoculture crop that is characterized by low natural capital. An example is restoring a trout fishery where the primary objective is to increase the carrying capacity for trout with no attention paid to the larger community of organisms or to the ecosystem except insofar as trout are concerned. However, in nature, a species is imbedded in a particular habitat characterized by the presence of certain other species, collectively called a community, and a particular set of ecological attributes, collectively called an ecosystem. Although the species occupies an ecological niche, the boundary conditions of this niche are determined by the biological, chemical, and physical attributes of the system. It is unlikely that natural capital restoration centered upon a single species with the narrow perspective just described can be self-maintaining. It will require a variety of subsidies, including habitat maintenance, to suit its particular needs or perhaps even a hatchery to increase the recruitment rate well beyond that achieved by natural spawning conditions. In short, a single species-centered natural capital restoration viewed too narrowly requires continual ongoing management and, most likely, considerable subsidies in terms of energy, investment of human time, and investment of particular resources (e.g., hatcheries and the like). In short, much other capital is expended to maintain the natural capital and is not a desirable remedy.

Monitoring for even the most narrowly viewed natural capital restoration centered on one species would nevertheless benefit from the monitoring of conditions necessary for maintaining a naturalistic community characteristic of that particular ecoregion and habitat conditions. For at least the first half of the twenty-first century, Earth's human population is expected to increase substantially, perhaps doubling from present levels by the year 2050. Additionally, some segments of this population are experiencing increased levels of unprecedented affluence. Finally, ecosystems are being degraded, and even replaced with human artifacts, at a far higher rate than they are being restored on a finite planet. This means that multiple use is the most probable outcome, except in very unusual circumstances. The basis for enlightened multiple use is the maintenance of a variety of ecosystem services; these are most likely to be delivered reliably and in the highest quality and quantity from healthy ecosystems representing abundant natural capital. As a consequence, even when the intent of natural capital restoration is focused on a single species (which is to be applauded if a commercially or recreationally important species is threatened or endangered), the monitoring should be carried out at all levels of biological organization to ensure that all are characterized by integrity and health. This requirement is definitely a prerequisite for sustainable use even when the primary focus is on one species, because that species is imbedded in a complex interacting system and because human society must ensure that a large variety of ecosystem services, well beyond the capabilities of one species, are delivered by all ecosystems. Developing monitoring protocols to determine the health and condition of both a single species and higher levels of biological organization will not pose the greatest problems. What will cause considerable trouble is the judgment required when conditions for the maintenance of ecosystem integrity and the well being of the single species being restored appears to, or actually does, diverge. If this situation occurs, a protracted legal battle may endanger both the ecosystem and the species; a judgment on corrective action to protect the ecosystem, and if possible the species, must be made quickly. If monitoring is occurring at different levels of biological organization, it seems prudent to protect the integrity of the entire system, even if a particular species may suffer or even be lost. This decision is, of course, a value judgment, and science makes recommendations, but not value judgments. It does uncover probable consequences of a particular course of action. If it is accepted that human health and ecosystem health are inextricably linked, then the judgment must nearly always favor the ecosystem and the protection and accumulation of natural capital.

14. MONITORING RIVERINE NATURAL CAPITAL RESTORATION IN DRY REGIONS

The National Research Council (1999) report shows that, for some dry countries in the Middle East, a consensus can be reached when goals for sharing limited water resources are based on a reasoned approach. However, Postel's (1999) book shows that a worldwide crisis is looming as a consequence of mismanaging water resources. Affluent countries can switch to more efficient use of agricultural water, such as drip irrigation or crops that require less water. However, the relatively sophisticated delivery systems for drip irrigation and other water-saving devices are well beyond the financial reach of less affluent countries. Switching to more drought-tolerant crops is less burdensome financially, but the skills to manage these new crops effectively require more education and a willingness to abandon methods that are no longer suitable. Although evidence of the need to change irrigation and other agricultural practices in dry regions is substantial (arguably, overwhelming), politicians and other decision makers seem reluctant to advocate such sweeping changes that might arouse the ire of citizens. At the end of the twentieth century, both the British Broadcasting Corporation and National Public Radio in American reported instances of civil disobedience; road blocks occurred in Guatemala when the government tried to privatize the agricultural water delivery system and farmers understandably decided the change would increase their operating costs. The National Research Council (1999) and Postel (1999) abundantly document problems of water scarcity in arid regions and provide many useful references. But one conclusion appears inescapable; with ever increasing demands on freshwater supplies in arid regions, the impending loss of substantial aquifer sources, and loss of agricultural land resulting from accumulated mineral salts due to evaporation of irrigation water, it will be difficult to maintain stream flows of surface waters and, consequently, the biological integrity of these aquatic ecosystems. Thus, the prospects of increasing natural capital in water ecosystems do not appear to be encouraging. Nevertheless, increases in natural capital of rivers and streams has been accomplished despite formidable obstacles.

Transfers of water from comparatively water-rich areas will exacerbate aquatic ecosystem problems in the donor areas and, at worst, will subsidize and encourage the continuation of poor water management in water-poor areas that engendered the problems. Water subsidies in the form of grain (using the assumption that one thousand tons of water are required to produce one ton of wheat) are unlikely to meet the existing deficit, let alone the projected deficits. The shift to sustainable use of finite ecological resources on a finite planet will be traumatic for human society and, undoubtedly, will result in much human suffering if the transition period is not managed skillfully. However, the trauma to aquatic ecosystems with some remaining degree of ecological integrity will probably range from severe to appalling.

As Hawken, Lovins, and Lovins (1999) note, protecting existing natural capital and increasing natural capital are essential to sustainable use of the planet, the long-term well being of human society, and even to a profitable industrial complex. However, they caution that the necessary paradigm shift is unlikely to occur sufficiently quickly or uniformly over the entire planet to permit a substantial number of restoration programs, or even to protect all remaining ecosystems with some degree of ecological integrity. The Associated Press (2000) reported that the Ethiopian government has appealed for 922,000 tons of food aid to assist some 7.7 million people threatened with starvation. In the article, Nigel Roberts, the World Bank's director in Ethiopia, stated that it was important to understand that Ethiopia experiences persistent food crises. The proposed solution was to transform a basically agrarian economy by promoting development in urban areas and increasing the purchasing power of those living in drought-affected areas. There was no indication of where food was to be produced to meet the demands created by this transformation. It is instructive that in all the press coverage of the droughts, except in coverage by environmental organizations, little mention was made of the effects of drought on aquatic ecosystems.

The aquatic ecosystems in arid regions of the planet have unique biotas. Because they are, in effect, ecological islands surrounded by large areas inhospitable to aquatic organisms, their biotas are likely to be so highly specialized that replacement would be virtually impossible. Natural capital restoration monitoring in these areas should be focused on retaining sufficient sources of recolonizing organisms so that, if meaningful natural capital restoration is ever undertaken during this century, suitable species will be available, as well as some understanding of both the structure and function of aquatic communities and ecosystems in arid regions. Because societies in severe disequilibrium such as Ethiopia are unlikely to be interested in such problems, with 7.7 million people approaching starvation, help must come from outside the region. However, some immediate efforts to restore the natural capital of aquatic ecosystems in arid regions should be undertaken, even during the present emergency, to develop case histories that will determine techniques that are efficacious and those that are not. All of the unique problems associated with natural capital restoration in arid regions must be studied more thoroughly. Because the ecological attributes are likely to be unique, research of these systems undertaken to explore natural capital monitoring in arid regions is essential. It is also essential to educate and train personnel in natural capital restoration and monitoring techniques and methods so that adequate numbers of qualified persons will be available when needed.

15. THE ROLE OF SPECIES REFUGIA IN NATURAL CAPITAL RESTORATION

Human society must neither impair nor destroy the refugia from which recolonizing individuals of species could emerge. In some seas, such as the Mediterranean or the Baltic, refugia for at least some of the smallest species might easily be established. For the largest species, especially those (such as whales) that use impressive migratory routes, a viable breeding population must be protected and maintained even though special refugia may not be feasible. Species are the irreplaceable currency of natural capital. New species are not likely to appear in large numbers in time frames of interest to human society.

However, while having species available is critically important, they are not in themselves adequate to ensure restoration of natural capital. Organisms are unlikely to recolonize an area, even if propagules exist, if the antecedent, predisturbance, chemical, and physical conditions remain unrestored to a degree acceptable by these organisms. Reestablishing antecedent chemical and physical conditions in vast marine ecosystems will be a formidable, arguably impossible, undertaking. In such ecosystems, loss of substantial amounts of natural capital may not be amenable to remediation.

In no endeavor is the absence of an ecosystem approach more evident than in attempts to monitor, restore, and protect natural capital. The pivotal feature of the ecosystem approach is the integration of multidimensional information. It is clearly irrational to focus only on fragmented quality control objectives such as “concentrations not to exceed x parts per million (milligrams per liter)” or to require that pH, dissolved oxygen concentration, and other attributes be considered in isolation from a variety of other attributes; organisms respond to aggregate conditions, not to each attribute in isolation from others. As has been the case in determinations of human health, absence of symptoms of deleterious effects is in itself not an indication of health, robust condition, or ecological integrity. This observation is not intended as a denigration of symptoms of poor condition, because they always deserve attention. Rather, it is an attempt to reach beyond these severely limited criteria to positive affirmations of health. Ultimately, the paradigm must shift from an ecosystem perspective to a biospheric perspective; indications already exist of an awareness of the need for such a perspective to grasp the ramifications of such planet-wide phenomena as global climate change (including global warming), biotic impoverishment, and the like.

It is important to recognize that, at the global, national, regional, or even finer levels, no single organization has an exemplary record of the multidimensional approach needed to restore and protect natural capital. No single organization is implementing an ecosystem approach effectively, although some come closer to this enviable goal than others. Two interrelated reasons explain this lack of implementation: (1) most organizations have very explicit mission statements; if the charge is to protect ecosystem integrity, the financial support for doing so is inadequate and the regulatory authority to enforce quality control criteria and goals is inadequate, and (2) the ecosystem approach requires orchestration of information from a wide variety of sources, and the importance of particular information from particular sources changes with each problem to be resolved. Special interest groups, including nations, vigorously oppose coordination when the stated goals, although ecologically persuasive, run counter to their perceived short-term national interests. The essential foundational assumption of natural capital restoration monitoring is that sufficiently comprehensive multidimensional information feedback loops are adequate to determine the degree of ecosystem health and integrity and that restorative practices are enabling an ecosystem to achieve a healthy condition. Present human demands on ecosystem resources, including space, indicate that new equilibrium conditions are virtually inevitable for some ecosystems (such as the Mediterranean Sea and the Baltic Sea) and that new states or new equilibria do not necessarily imply an inability to achieve self maintenance. This situation, in turn, means less dependable delivery of ecosystem services. Natural capital restoration is in its early developmental stages, and, as is typical for such endeavors, much uncertainty exists. Additionally, as is the case for most complex multivariate situations, uncertainty can never be eliminated. Nevertheless, there is abundant persuasive evidence that, despite uncertainties, present methods and techniques available for natural capital restoration always produce conditions superior to the damaged conditions.

However, reducing uncertainty requires that baseline information about the health and integrity of a variety of Earth's ecosystems be obtained as quickly as possible because rapid changes are occurring globally, arguably in every ecosystem on Earth. A concomitant problem is the global increase in biotic impoverishment, or the loss of biodiversity, since effective natural capital restoration of a complex, highly interactive web of life is facilitated if critical components have not been lost. Regrettably, knowledge of all species that constitute critical components across varieties of ecosystems is faulty. Unfortunately, humankind only notices critical thresholds after they have been crossed, not in an experimental laboratory, but in ecosystems that may have reached their present status over hundreds, thousands, or even millions of years. Without adequate background information on both structural and functional attributes, it will be difficult to distinguish among a new ecological equilibrium condition in response to anthropogenic stress, or a new state of ecological integrity resulting from natural successional changes, or a combination of the two. In the absence of background information on structural and functional characteristics of ecosystems, it will be difficult to determine the degree to which exotic invaders have compromised ecological integrity and ecosystem health. Therefore, it will be difficult to develop comprehensive quality control monitoring systems leading to and maintaining stated goals for natural capital. An important early warning signal for monitoring ecological attributes in any ecosystem is to determine when they have remained beyond normal ranges of stability for a significant period of time or whether the costs of the ecological adjustment processes required to keep them stable and self-maintaining have been significantly increased.

Some considerable semantic problems exist in all discussions such as this one. The term **ecosystem management** really suggests that humans are managing ecosystems to reach desired goals when, in fact, ecosystems have been "managing" themselves; they have evolved in their own way without human intervention for millions of years. What really warrants discussion is how to develop a relationship of human society with ecosystems that does not threaten their integrity and health. The term **ecosystem approach** is also misleading when what is really meant is that human society should have an ecosystem perspective and that ecosystems should be approached with enlightened self-interest, not short-term exploitative interest. It is essential to recognize that one can use an ecosystem approach, as defined by Caldwell (1988), which indicates that a comprehensive ecosystem approach should include all types of interactions present without including all of the interactions. Put more bluntly, it is not possible to appease every research investigator by including that person's favorite methods; nor are standard methods necessarily the best choices, whatever their origin, though they routinely fare better in courts of law. Monitoring of natural capital restoration requires the use of specific questions and goals. However, when the term's specificity is poorly interpreted as a narrow disciplinary focus, it can destroy the harmony of a transdisciplinary team approach required for ecological restoration and appear to the public as wrangling among "pointy headed intellectuals."

16. MONITORING THE RESTORATION OF NATURAL CAPITAL IN LAND ECOSYSTEMS

The basic conceptual problems are quite similar for monitoring natural capital restoration in both terrestrial and water ecosystems. For terrestrial ecosystems, one can select suitable endpoints from those suggested by Clarke (1986), Noss (1990), Spellerberg (1991), and Likens and Bormann (1995). Arguably, because they are familiar to most biologists and easy to use, plant composition and cover are commonly used. Illustrative sources for terrestrial plant sampling methods are Müller-Dombois and Ellenberg (1974), Grieg-Smith (1983), Sutter (1996), Masters (1987), and Sauer (1998). Guidelines for developing restoration monitoring and appraisal programs for both land and water ecosystems are discussed in Holl and Cairns (*in press*).

17. COPING WITH TERRESTRIAL EXOTIC SPECIES

Exotic species often achieve a level of ecological dominance that threatens or displaces the natural capital base of indigenous species. In addition to a host of scientific problems, exotics pose an interesting ethical and moral dilemma. After all, humans originated in Africa and are "exotic" invaders of the remaining planet. Additionally, humans brought with them plants and animals that were not indigenous to the geographic areas they now inhabit (e.g., Diamond 1997). No species comes close to destroying or commandering natural capital as thoroughly as *Homo sapiens*, but humans are more concerned with the impact of other species on natural capital than with their own.

It is difficult to estimate the degree to which an exotic might be regarded as natural capital in the U.S. Kudzu has economic value in Japan as livestock feed and it has some herbal use. The Asian clam is consumed in some areas of the world but not in the U.S. These troublesome exotics have already demonstrated their potential to multiply, spread, and disrupt (e.g., Cairns and Bidwell 1996). Since total eradication seems rather improbable in most cases, it might be well to develop their exploitable resource potential in ways that diminish their numbers. Monitoring the effects and abundance of exotic species appears essential, and both should result in insights into the problem. As Moody and Mack (1988) have demonstrated, such efforts tend to focus on the largest populations, but reducing the overall spread of invasive species may be most effective by controlling "satellite" populations. Hobbs and Humphries (1995) recommend surveillance beyond the focal populations of invasive species to detect new satellite populations. Not surprisingly, efforts to eradicate exotics may have unintended effects upon indigenous species. For example, Glausiusz (1996) describes such a case involving the exotic salt cedar (*Tamarix ramosissima*) that has lowered the water table and altered flooding regimes along many streams in southwestern U.S. It provides nesting habitat for the southwestern willow flycatcher (*Empidonax traillii extimus*) and, thus, removal affects a desirable indigenous species.

18. MONITORING SOIL AS NATURAL CAPITAL

Microbial communities in soils have critical nutrient cycling processes upon which plant communities depend (e.g., Allen et al. 1999). Soil nitrogen levels may be substantively elevated by nitrogen fixing plants and, thus, facilitate invasions (Maron and Connors 1996). Illustrative examples of methods suitable for quality control monitoring in this context are given in Smith and Mullins (1991), Weaver (1994), and Sparks (1996). Parameters most frequently measured include total microbial biomass, certain enzyme levels, and other microbial processes such as respiration, N_2 fixation, and N mineralization (Ross et al. 1992; Brookes 1995).

19. CONCLUDING STATEMENT

Restoring natural capital will require a major paradigm shift of global human society, although much can be accomplished locally, regionally, and nationally. Some issues, such as global climate change, must be addressed at this level, whereas other issues, such as restoration of soils and other forms of natural capital, are quite amenable to local efforts. These changes will require a new view of human society's relationship with natural systems (e.g., Cairns 1994) and will foster monitoring to ensure that previously established quality control conditions for the restoration of natural capital are being maintained. It is abundantly clear that the restoration of natural capital dramatically transcends the capabilities of any particular discipline, and monitoring of this process must be multidimensional. The crucial question is whether reason guided by intelligence will cause the paradigm shift or whether it will be caused by severe consequences resulting from human society's failure to make the shift in the relationship soon enough. In short, the key issue to implementing the precautionary principle of taking action when probable consequences of not doing so are severe, even though considerable uncertainty exists about the probability of occurrence. There is reason for cautious optimism about what can be done, but comparable justification for pessimism about what will be done. Basically, the paradigm shift will require a change in human society's value system, but the science and engineering methods and procedures should be prepared to meet this new challenge if or when the shift occurs.

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Article 30

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Sustainability and Sacred Values

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ABSTRACT: Successful implementation of the quest for sustainable use of the planet requires that human society both reexamine and expand present views of what is sacred and what is not. The most important aspect will be going beyond a homocentric focus to a biocentric emphasis. A unifying theme would be the desire to leave a habitable planet for human descendants and those of other species. It is unlikely that society can be confident of achieving sustainability until persuasive evidence supporting this belief has existed for several generations. In order for sustainable use of the planet to persist indefinitely, the conditions essential to this state must be morally preserved on sacred grounds. Viewing natural systems as sacred requires not only preventing damage to them but, wherever possible, repairing damage to them caused by humankind.

Each stage of human civilization is defined by our mental structures; the concepts we create and then project upon the universe

Edwin H. Land (at the groundbreaking, House of the American Academy of Arts and Sciences, 2 April 1979)

Introduction

A new relationship between humankind and Earth based on a belief that the planet's biospheric life support system is sacred is needed for humanity to create planetary sustainability. A spiritually based biophilia that is attentive to scientific evidence is a central solution to the large-scale environmental problems that beset humanity. This discussion largely, but not entirely, stays within this theme. It is essential that humankind be guided by nature-based cultures that understand the symbiotic relationship between humankind and nature. Starting with the cave painters of Chauvet, Lascaux, and Altamira, humankind depicts, through art, a special relationship with nature that venerates humankind's co-existence and interdependence with the environment, an environment in which subject and object and predator and prey are intrinsically linked as one. Today, in cultures that maintain some vestiges of this relationship with Earth, humankind can, though only distantly, discern a sense of co-evolutionary unity with the surrounding environment.

The mission of this discussion is to persuade people to alter their behaviors and come to an environmental awaking of a co-evolutionary relationship with nature so that species, ecosystems, and humanity can be sustained. How do we make credible the threats we perceive? How do we hold attention? Have we overloaded the reader with anxiety and guilt? What do they know, want, fear, and care about? Is the tempo of injury to the planet a symptom of some deep-seated psychopathology? How do we treat humanity's addiction to technology? How do we establish a balance between people and nature? Why does society persist in destroying its habitat? Movements that fail to consider carefully some of these factors may fail to persuade. To be upbeat, when it comes to raising the collective consciousness about liabilities of industrialization and population growth, many scientists and citizens have done a remarkable job at articulating impending risks. The health of the planet is now a major political issue in every industrial society.

'Is it ethical for *Homo sapiens* to modify the planet so that one species can inhabit it indefinitely when other species are unlikely to have a comparable opportunity?' (Cairns 2002a). In order to achieve sustainable use of the planet, some globally shared ethical values are essential. Although some species have existed for impressive temporal spans, most do not. Successional processes are characteristic of virtually all dynamic, biotic communities (the biota of oceanic thermal vents and other remarkable habitats may have a much lower successional rate due to their uniqueness and harsh conditions). If a single species (*Homo sapiens*) can expect to exist indefinitely on the planet, it is essential that the goals and conditions for sustainability be widely accepted and implemented. If these goals and conditions are successfully met, sustainability requires that they be secured against violation, infringement, etc. This condition meets one of the dictionary definitions of sacred — sacred things are held in reverence. Another dictionary definition of sacred is 'properly immune from violence, interference, etc.' A sacrilege is the violation or profanation of anything sacred or held sacred. If one accepts these definitions of sacred, then the goals and conditions for a sustainable world become sacred.

The biospheric life support system

Homo sapiens has been dependent for its entire existence upon the biospheric (ecological) life support system for both natural capital and ecosystem services (Hawken et al. 1999). Yet the 20th century saw damage to natural systems that was unprecedented in human history (McNeill 2000). It is abundantly clear that the practices that caused this damage are not sustainable. The primary cause of this damage is society's addiction to exponential economic growth, which is revered and fits one of the definitions of sacred (i.e. secured against violation or infringement), although most people would be reluctant to use the word *sacred* in this context.

It has often been said that humans protect what they love and love what they understand. However, ecosystems have no easily identified boundaries and are also complex, multivariate systems that are difficult to understand, even for professional ecologists. Of course, charismatic species are loved by many humans who often protect the habitat of that particular species. However, even in such instances, society has been only marginally successful in even preserving these species.

Arguably, the most persuasive assumption that explains human society's failure to revere nature and to make its integrity sacred is the belief that nature, as Sinsheimer (1978) noted, does not set traps for unwanted species. One of the principal supports for this assumption is the belief of some economists that human society can function without natural resources (e.g. Simon 1981). If humans do not need nature, why view it as inviolate (e.g. sacred)? Further support for failure to revere nature is the belief that humans should dominate nature (White 1967).

Sacred beliefs

Arguably, the present is an age of sacred beliefs rather than sacred places or symbols, although these still play a role. These sacred beliefs often have little to do with organized religion, although they are, on a long-term basis, more matters of faith than robust evidence— we believe what we do not see. Four of the most prominent sacred beliefs follow. (1) Perpetual economic growth is possible on a finite planet and will solve all societal problems as a rising tide lifts all ships. (2) For every societal problem, there is a technological/economic solution, that is, every problem created by technology will be solved by a new technology for which funds will become available when the marketplace indicates the need for a solution. (3) Humans everywhere should be numerous, wealthy, and in control of the forces of nature (e.g. Kahn et al. 1976). (4) Humans are identified primarily by their material possessions (e.g. Goffman 1961).

The first attribute mentioned to an ‘outsider’ is growth. Even churches and academic institutions are concerned with growth, as are municipalities, industries, and the like. Up to a point, growth in numbers of individuals does frequently result in economies of size, but eventually diseconomies appear (e.g. Brown 2001). However, society has become accustomed to the momentum of growth and is reluctant to change. In addition, many individuals continue to reap profits since tax burdens, loss of amenities, reduced quality of life, etc. are spread over the entire population, while the major financial benefits continue for a small portion of the population. Hardin’s (1968) classic essay on the tragedy of the commons illustrates how the system continues to reward those who ignore the cost to others (and even eventually to themselves). Teune (1988) goes even further by stating that individually based secular morality cannot accept a world without growth. Cairns (2002b) discusses the relationship between individual worth and dignity and the integrity of the interdependent web of life. In the absence of an ecological life support system, the individual cannot survive. Alternatively, reduction in quantity and quality of ecosystems will affect both quality of life and the expression of individual worth and dignity. As the situation worsens in each bioregion, the numbers of environmental refugees will increase adversely , affecting or even destabilizing other areas (e.g. Cairns, in press). Exceeding the carrying capacity of natural systems may have severe consequences, essentially ignored by those who favor exponential growth, especially economic growth. Numerous publications discuss the rapid growth of the human population in the last century. Astonishingly, most people consider the present rate of growth to be normal and past rates abnormal. However, the 20th century was, in many ecological respects, an aberration.

The present boom in population growth is the most spectacular in human history and almost certainly neither likely to continue nor to occur again. One of the characteristics of exponential growth is that catastrophe arrives so suddenly that the slowly changing social system cannot adjust. The last few centuries have been remarkably benign climatically for humans. However, severe ecological disequilibrium could easily have consequences that would dwarf those of terrorism, with which some countries have been preoccupied recently. This comparison is not intended to denigrate antiterrorist activities that, if effective, should reduce human suffering. However, the funds devoted to sustainable use of the planet and protection of the biospheric life support system are not proportional to the comparative risks involved.

Lauber (1978) states that the primary motivation for growth is not the pursuit of material gratification by the masses, but the pursuit of power by elites. The still unfolding ENRON stock scandal in the United States appears to support, at least partly, this assumption. If wealth is associated with power, then the fact that, in the United States, 1% of the population controls 34.3% of the wealth supports this conclusion (e.g. DeMarco and Hightower 1988). Durant and Durant (1968, p. 20) state: ‘Inequality is not only natural and inborn, it grows with the complexity of civilization.’ However, they also conclude (p. 57) that, although the concentration of wealth is natural and inevitable, it is periodically alleviated by violent or partial redistribution. They espouse the view that all economic history is the slow heartbeat of the social organism, a vast systole and diastole of concentrating wealth and compulsive redistribution. This view is a stark contrast to the perpetual exponential growth paradigm that is now the dominant belief globally. Clearly, perpetual economic growth on a finite planet is a social trap (e.g. Costanza 1987) that places both individuals and societies in patterns of behavior with the lure of short-term benefits. These promises may mask long-term costs, which often override the short-term benefits. Sustainability seeks to avoid practices that undermine societal well being and rewards behaviors that produce long-term benefits to both human society and natural systems. Holding such practices inviolate (i.e. sacred) should be one of the pillars of a sustainable society.

Coevolution

The ecological life support system (the biosphere) consists of an extraordinary web of interrelationships, energy and nutrient flows, and a variety of cyclic events. Although competition receives much attention, mutualistic interactions are critically important to the web's structure and function. Lovelock (1988) hypothesizes that primary evolution occurs at the global level, and individual species evolve within this matrix. Cairns (1994) believes that the coevolution between human society and natural systems can be either hostile (e.g. pests and pesticides) or benign (e.g. ecosystem services benefiting humans). Sagan & Margulis (1993) speculate that biospheric relations are undergoing a major reorganization because of the distress humans, who are sentient beings, feel because of dysfunctional anthropogenic changes. In contrast, Gadgil (1993) confesses to being a confirmed biophilic, but notes that this trait is not widely shared by kinfolk.

Transition to a sustainable world

The most desirable transition to a sustainable world is facilitated by a vastly increased ecological literacy. In his superb book, Orr (1992) remarks that 'Natural evolution at the ecosystem level leads toward increasing diversity, ecological complexity, stability, and balance. Left to itself, nature evolves in ways that tend to create systems that are stable over long periods of time within relatively narrow limits.' In contrast, he notes that 'Modern societies seem to have adopted the purpose of growing to their maximum extent. Evolution has equipped humans with no instinct that tells us when enough is enough.' Wilson (2002) makes a statement that is appropriate in this context: 'At the end of the day, in a more democratic world, it will be ethics and desires of the people, not their leaders, who give power to government and the NGOs or take it away. They will decide if there are to be more or fewer (nature) reserves, and choose whether particular species live or die.' I share Wilson's conviction that adequate resources exist to save life on Earth but have trouble deciding what will be the primary impetus for a shift in ethical values. One hopes it will be enlightenment, but it may well be a major ecological catastrophe adversely affecting humankind. This major point merits amplification, that is, we may need a 9/11 or ENRON environmental catastrophe to reshape our institutions and refocus our consciousness toward a sustainable ethos. It is amazing how institutional change can rapidly occur under a 9/11 emergency. The question is whether the environmental insults will be contained to allow mid-course correction.

Paradigm shift

Anyone well acquainted with the ecological destruction in the world all too often verges on uncontrolled panic, and Leopold was correct in stating that, to be an ecologist, is to live in a world of wounds. It does not require a trained eye to see the wounds, but it takes a moderate level of ecological literacy to appreciate their full gravity. However, only an individual with little or no common sense can entirely avoid the implications for human society, even when oblivious to the fate of other species. Except for the truly masochistic, a few illustrative examples should make the point. Fischetti (2001) describes in persuasive detail not only what will probably happen to New Orleans, a Gulf of Mexico city that lies below sea level, but what has already happened: e.g. the state of Louisiana (USA) in which New Orleans is located loses 1 acre of land every 24 minutes. Emergency management personnel have already stored 10 000 new 'body bags' for the dead if a disaster occurs. The tiny village of Chesire, West Virginia (population 221), may disappear from the map because, among other factors, the U.S. Center for Disease Control confirmed that the levels of sulfur dioxide and sulfuric acid could be hazardous to human health (Kipling 2002). As a consequence, residents may be forced to vacate their homes. The 11 000 inhabitants of the tiny island of Tuvalu must leave because of rising sea levels. The Earth Summit (Rogers 1993) provides an excellent analysis of biodiversity and other problems. Probably the most useful and concise summary of the global environmental condition is Brown's annual *State of the World Report* (Brown 2002).

The continual statements that there is insufficient evidence of environmental damage are specious. In the first place, the primary burden of proof of damage or lack thereof should be the responsibility of those few who will benefit financially from the proposed action rather than the large number who will pay for any damages resulting from ignorance or deliberate avoidance of responsibility. In the United States, the ENRON scandal is a good illustration of this in the financial world. Many people lost their life savings as well as their retirement benefits while the corporate executives 'retired' with stupendous benefits. ENRON and 9/11 are also timely examples of how we all were enveloped in a false sense of security. Imagine proposing the 9/11 scenario on 9/10 or before. Even Hollywood would have rejected the script as too far fetched. Likewise, if the best Wall Street financiers had been informed that many of blue chip companies were seated in sand before the ENRON debacle, no one would have taken the information seriously. Life is non-linear.

However, there is an even more important point. It is impossible to prove that any situation is 'safe,' like global climate change, especially if it is unprecedented in spatial and temporal scales. This uncertainty requires that all environmental decisions be based primarily on ethical values — a sense of the sacred. I have been a scientist for over half a century and have the highest respect for sound science. However, no amount of sound science can replace ethical value judgments, although the latter should be guided by sound science.

In contrast, from civic leaders of small towns to those with international influence, economic growth is the mantra given with no hesitation or apology. In fact, espousing non-economic values, such as ethics and the sacred, could easily be fatal to a public career since all leaders depend on financial support from a variety of sources that benefit from unrestrained economic growth. Some industries are even environmentally damaging and are still the recipients of substantial government subsidies (e.g. Roodman 1996).

Optimism about sustainable use of the planet

The geological/paleontological record shows that most species have a fatal flaw that ends their time on the ecological stage in the evolutionary theater. Materialism and failure to cherish other life forms may be the fatal flaw of humans that limits the duration of their time on the planet. Learning to live sustainably will extend the time, perhaps for a long period. It will also expand the sense of community with others of the human species and with millions of other species with which humans share the planet. The hope that this vision will be widely shared makes me optimistic about the future.

Berry (2002) expressed his concern about spending his life on 2 losing sides — the causes of agrarianism and conservation, 'despite local victories have suffered an accumulation of losses, some of them probably irreparable — while the third side, that of land-exploiting corporations, has appeared to grow ever richer.' Berry uses the word *appeared* because he feels that the wealth of corporations is illusory because their wealth is based not on the resources of nature, which corporations are recklessly destroying, but on fantasy. Berry feels that the dualism of domestic and wild has obscured the absolute dependence of human domesticity upon the wildness that supports it.

He feels that domesticity and wildness are intimately connected and what is alien to both is corporate industrialism. Although Berry does not use the words *ethics* and *sacred*, it is abundantly clear that both are essential to a mutualistic relationship between humans and wild systems.

Suzuki (1998) uses the word *sacred* in the title of his book and begins with two critical sentences in the introduction (p. 7): 'These fundamental requirements (for humans — insert mine) are rooted in the Earth and its life-support systems. They are worthy of reverence and respect, that is, they are sacred.' Ehrlich (2000) identifies a crucial relationship between reverence and science — he is convinced that a quasi-religious movement, one concerned with the need to change the values that now govern much of human activity, is essential to the persistence of human civilization. These warnings will be heard once serious environmental non-linear impacts are encountered and accepted. He feels that science, even the science of ecology, cannot answer all questions and that there are 'other ways of knowing' — this concept does not diminish the absolutely critical role that good science must play in saving civilization.

Suzuki and Ehrlich, both scientists, do not reject science but rather view science as a source of information, which will probably make a reverence for Earth's ecological life support system more meaningful. In this context, it is important to remember that information is not knowledge and knowledge is not wisdom. Knowledge is a synthesis of information as Wilson (1998) espouses in *Consilience: The Unity of Knowledge*. He recounts how the vision that reached its apogee in the Age of Enlightenment was gradually lost due to the increased fragmentation (reductionist science) and specialization of knowledge in the last 2 centuries. Wilson clearly believes in a new age of synthesis, which includes biology and the physical sciences, religion, philosophy, anthropology, and the arts. An enlightened synthesis would almost certainly include all the 'tribal units' now known as the disciplines. The synthesis may likely be instrumental at also understanding environmental problems holistically, problems that involve wide time and space scales and disciplinary integration. At the moment, we have a paucity of synthesis across disciplines on most subjects, environmental and otherwise. The idea of consilience does not denigrate the disciplines, but rather shows how integrating them will provide a new vision of the world and the relationship of humans with other life forms.

Hawken (1993) and Hawken et al. (1999) provide numerous persuasive examples of the ways in which capitalism can flourish and natural capital remain intact. Most important, Hawken et al. (1999, p. 309) point out, in the often acrimonious debate between ecologists and economists, that both sides may be right. Ecologists have robust evidence that the worldwide trend of indicators of ecological health has been downward. Economists also have persuasive evidence of increased human life expectancy, decreased child mortality, improved nutritional intake, and improved standards of living, despite global exponential population increase. The apparently contradictory trends and the heated arguments that ensue are the delight of the news media. However, contradictions can be explained by the concept of overshoot: the ability to exceed Earth's carrying capacity temporarily and put natural systems into decline. Hawken et al. (1999) have a superb metaphor for this situation — the ability to accelerate an automobile that is low on gasoline does not prove that the tank is full. To achieve status or even acceptance in a profession, trade, or any occupation, one must adopt a particular mind set. To achieve sustainable use of the planet, both individuals and societies must transcend a host of mind sets and become eclectic without abandoning any original skills. Becoming eclectic is essential to the vision — the skills are essential to the implementation. This goal seems truly formidable, arguably impossible. If, as Lévi-Strauss (1968) speculated, human ancestors living 2 or 3 hundred thousand years ago had some minds of the caliber of Plato or Einstein as a group, they were also probably as capable as humans are today. The aggregate skills may now be applied to shopping on the internet or to the patience of acquiring food or to enduring commuter traffic delays, but they can be redirected, especially if rampant consumerism is reduced (e.g. Durning 1992, Levering & Urbanska 1992).

The sacred earth

For me, a major shock followed the release of 'World Scientists' Warning to Humanity' by the Union of Concerned Scientists (1992). More than 1600 scientists from 71 countries signed the document. All were senior scientists, and the total included over half of all the living recipients of the Nobel Prize. The document began by stating that human beings and the natural world are on a collision course, then noted the harsh and often irreversible damage to the environment and critical resources caused by human activities. The document concluded that a vast change is needed in humankind's stewardship of Earth and all life on it if vast human misery is to be avoided and the planet is to be saved from irretrievable mutilation. As one of the scientists who signed the document, I eagerly awaited the media response and was prepared to answer questions from the local news media and colleagues. Nothing happened; I was stunned. Meanwhile, the ecologically destructive course continued unchanged. It is noteworthy that, after 9/11, journalists researched those authors and analysts that forewarned of impending risks from homeland terrorism. Airport security vulnerability reports have resurfaced and authors are receiving spotlight attention. Viewing humankind as part of a larger living system should expand the range of compassion for all life forms, both temporally and spatially. The Union of Concerned Scientists expressed it well:

As scientists, many of us have had profound experiences of awe and reverence before the universe. We understand that what is regarded as sacred is more likely to be treated with care and respect. Our planetary home should be so regarded. Efforts to safeguard and cherish the environment need to be infused with a vision of the sacred.

All humankind, not just scientists, should embrace this view.

Action or inaction?

Cairns (1994) describes 2 relationships between human society and natural systems. The accepted practice in the 20th century was to dominate nature (i.e. developing pesticides, clear cutting forests, damming rivers, etc.). At the same time, nature evades human domination by such techniques as evolving pesticide and drug resistant organisms; invading human settlements with cockroaches, rats, and whitetail deer; and proliferating exotic species. The activities of humankind should be subjected to ethical analysis (i.e. eco-ethics) to determine what values (including the sacred) are damaged or strengthened by particular policies and practices. Both ecosystems and human social systems are dynamic and so must be the relationship between them. Katz (2000) believes in a dualism of human artifacts and natural entities and argues (Katz 1997) that ecological restoration of damaged ecosystems (and to a certain extent, policies of natural resource management) do not actually restore or manage natural systems. Katz believes that, once a system has been created, designed, or managed by human technology and science, it is no longer a natural system, but rather an artifact resulting from human intervention and design. The National Research Council (1992) recognized the difficulty of replicating nature as follows: 'In this report, restoration is defined as the return of an ecosystem to a close approximation of its condition prior to disturbance. In restoration, ecological damage to the resource is repaired.'

Ecological restoration has been introduced at this point because restoration is the best way humankind can make reparations for the enormous ecological damage it has caused. If the result is a self-maintaining ecosystem, ecological dynamics will ensure that the restored ecosystem will develop its own integrity, structure, and function. It will then eventually be 'natural' — even if human intervention is essential to reactivate natural processes. Five major, global extinctions have occurred, and humans have regarded what emerged as natural. After each extinction, dramatic changes occurred in types of species, but the ecosystem dynamics were probably rather similar, even though the ecosystems did not look alike. Natural systems can survive without humans — after all, they did so for most of the time that life has been on Earth! However, far less evidence supports the idea that humans can continue to exist without a mutualistic relationship with nature. Who doubts that, if humankind were to commit ecological suicide, the remaining species would evolve new and different life forms over evolutionary time (e.g. Gould 1998)? What is the probability that some of the 30+ million species on Earth will survive an extinction driven by activities of humankind? Most ecotoxicologists would affirm that, even if humans drive many more species to extinction, enough would remain to tolerate the changed conditions to rediversify over evolutionary time. As Wilson (1992) remarks, although nature is violent, life is resilient. Therefore, a spirit of stewardship that enhances (rather than diminishes) biodiversity, has reverence for life, and holds Earth sacred is not 'faking nature,' even if the restored systems do not initially duplicate self-maintaining natural systems. Evolutionary dynamics will recreate natural systems whatever humankind does, however distasteful it may be, over the 21st century or beyond. Assisting nature rather than damaging it is an expression of reverence rather than an attempt to delude humankind. Therefore, I find Katz's (2000) views and the somewhat similar views of Elliot (1982, 1997) non-persuasive. Katz (2000) does believe that humanity and nature exist in an interdependent relationship. If one accepts his assertion, the major question is: which actions of humankind are ethical and which components are unethical in this relationship? Enlightened ecological restoration to improve biodiversity and restore ecosystem dynamics is ethical (pertaining to right and wrong in conduct) and biotic impoverishment is unethical. If the relationship (a connection, association, or involvement) is guided by eco-ethics, it seems perfectly acceptable.

Important ethical questions

The most common questions people ask about the environment concern how long a resource will last, how many humans the planet can hold, etc. Even for questions thus phrased, no simple, direct, persuasive answer surfaces. However, phrasing the questions so that the ethical values become more evident ensures that the response will not only be more complex but also more realistic. Some illustrative examples follow.

(1) *How many humans should be on the planet if one wishes them to have a quality life, including a mutualistic relationship with natural systems?* It took approximately 2 million years for the planet's human population to reach 1 billion. The 5th billion was added in 12 years. Clearly, this rate of increase is neither sustainable nor likely to result in a quality life. Malthus raised the question of human population size over 200 years ago and has been denounced for 2 centuries. More recently, Cohen (1995) addressed the very complex question of how many people Earth can support but not the eco-ethical question of how many people should Earth support. His book, though excellent, does not address either the 'how' or the 'should' question. Post reviews confirm this oversight, and he himself admitted this major shortcoming to a richly researched piece of work.

(2) *How long can the human population be sustained if humankind chooses to lead an eco-ethical life style?* In the United States just after the middle of the 20th century, there was a fad among college students of seeing how many of them could be crammed into a pay telephone booth (these

were small enclosures, now nearly extinct, to protect telephone customers from inclement weather and to provide a small degree of privacy). The numbers were startling and received much attention from the news media. The practice was sustainable for only minutes at the most, and the 'quality of life' was not a long-term consideration. Later, the telephone booth was replaced with the Volkswagen 'Beetle' with similar results. Of course, neither had much effect upon ecosystems. However, from an eco-ethical perspective, what can be done with human population density is clearly not what should be done!

(3) *How much space should be set aside for the primary use of the over 30 million fellow species with which humans share the planet?* This important eco-ethical question involves ethos, compassion, equity, and fairness. Should humankind act as if it were the only important species on the planet? If not, how much of Earth, land, and water should be left for the more than 30 million other life forms? Also, should quality be a factor? Wildlands (and water) should not be areas that are unattractive to humans, but areas fitting the needs of other species. Since some species require large areas in order to have self-maintaining populations with a viable gene pool, the areas will have to be selected accordingly. How will human access to wild areas be controlled? What will the buffer zones between wild areas and human occupied areas look like? And, of course, the ultimate eco-ethical question: what percentage of Earth should be devoted to other life forms — 10, 20, 30%, or even as much as 50%? The latter Fig. seems large but, at 10% for other species and 90% for humans, Earth would be quite similar to animal 'feed lots' where the density is so great that living conditions are barely adequate. In order for these areas set aside for other species to function successfully in the long term, they would have to be regarded as inviolate, i.e. sacred. One does not drill for oil on sacred land or build a dam on it to satisfy short-term perceived human needs. For those who believe that humans are not resource limited (e.g. Simon 1981), this dedication of large parts of Earth to occupancy by other species should pose no problems. Human ingenuity will always find a substitute for scarce resources. For those who believe humans are resource limited, resolving these issues ethically will require much thought and discussion. Sustainable use of the planet requires not only discussion but also sound decisions and implementation of them.

(4) *Who should decide which areas are sacred and who should protect them?* Ideally, the people who live closest to the areas should make this decision. However, in many Third World countries, forested nature preserves are disappearing one tree at a time at the hands of people who need fuel. Often the exploiters are relatives of those persons employed to protect the forest. Some species are being driven to extinction by those hunters who sell 'bush meat' to poor people. Other species fall victim to poachers who invade nature preserves to harvest body parts of animals thought to increase virility or other attributes in humans. Finally, a large illegal market exists for exotic animals to be pets. Powerful taboos would be necessary to stop or greatly diminish these practices. For migratory species, local control is inadequate unless protection extends to all parts of the migratory system. Globalization has assisted the immigration to and colonization of areas previously inaccessible to many species. If these species are exotics, they are capable of causing major ecological disturbance, even disequilibrium in the areas they manage to colonize. Once established, they are difficult, arguably impossible, to eradicate, as noted in the examples of the rabbit in Australia and kudzu vine in the United States. There is abundant literature on this subject, but usually no inexpensive, effective means of control or elimination. Clearly, both local and global identification and protection of sacred areas are essential.

(5) *What is the role of each individual with respect to the interdependent web of life?* Cairns (2002b) asserts that, if humans acknowledge a dependence on Earth's biospheric life support sys-

tem (the interdependent web of life) or, at a minimum, a respect for the interdependent web of life, it seems reasonable to judge the inherent worth of an individual in the context of the individual's relationship with the interdependent web of life. Is it a destructive or constructive relationship? If destructive, one might acknowledge 'potential worth,' but there should be persuasive evidence supporting a characterization of 'actual worth.' Most individuals require good conditions to achieve inherent worth. Assessment of dignity is more elusive. But, if dignity is defined as 'bearing, conduct, or speech indicative of self-respect or appreciation of the formality or gravity of an occasion or situation,' it is difficult to visualize how a person lacking a strong sense of eco-ethics could qualify. It is equally difficult to visualize how sustainable use of the planet will be achieved without a strong sense of eco-ethics.

(6) *How can renewable natural resources remain inviolate (sacred) if they are depleted faster than the natural rates at which they renew themselves?* The answer to this question seems so obvious that it verges on the platitudinous but, since humankind has failed to follow the use of these resources at rates equal to or less than the natural rate of regeneration, it is worth restating.

(7) *Can either development or growth, as presently understood, continue indefinitely? If not, is it ethical to continue to use these words in conjunction with the word sustainable (as in sustainable development and sustainable growth or its variant 'smart growth')?* Development is usually defined as the process of developing growth. Since sustainable development and sustainable growth (or 'smart growth') are often used as if they were interchangeable, this definition is almost certainly what is intended. Growth usually means to get larger and is often used as the first descriptor of various organizations, from industry to churches. Economic growth is a major objective of most of the planet's economies. But, if something were viewed as sacred, would one want it to be developed? Brown (1978) calculated that, if the planet's human population continued to increase at the annual rate of 2%, then in 2000 years Earth would be a solid mass of people. Yet, many of the world's present leaders regard a 2% economic growth rate as unacceptable (too small) and most are unwilling to address stabilizing the human population. Nevertheless, a 2% growth rate means the human population will double in 35 years. Surely the only planet in the solar system that is capable of supporting human life and millions of other life forms should be considered sacred (inviolate). Most would agree that major areas should be 'humanized,' but surely eco-ethics requires that those areas allocated to 'wild systems' be larger than they now are and treated with more reverence.

Conclusions and speculations

Archeologists the world over have revealed unmistakable signs of the ecological collapse of ancient civilizations. One cannot help but speculate that these were societies where eco-ethics did not prevail. It also seems quite likely that evidence of unsustainable practices was evident to all but the most casual observers. The belief that humankind has always triumphed over adversity in the past and will continue to do so in the future is not supported by the historic record. The human species has survived, but the loss of human life and degree of suffering must have been as unthinkable to those then alive as an overshoot in carrying capacity is today. If this situation is the case, then the fate of humans is no different than that of any species that exceeds its carrying capacity. If so, then human intelligence, as defined at present, does not seem to provide as much survival value as one would expect. If reason prevails, some of the numerous warning signs will get more attention than they now do. The wise approach to sustainable use, without abuse, of the planet is almost certainly a combination of eco-ethics and all of the scientific, social, and economic information that will make implementation effective. The major determinant should be eco-ethics because sustainability is basically an interlocking, interactive series of value judgments. Arguably, only ethics will restrain human demands upon the planet's natural capital and ecological life support system. A common belief seems to be that, however severe the environmental crisis, it is possible to return to the pre-crisis condition. This return may well be possible if the overshoot in exceeding carrying capacity is modest, quickly discovered, and within the resilience of natural systems. If not, it is highly probable that there will be an extended period of ecological disequilibrium and, when conditions reach dynamic stability, they will be markedly different than the present equilibrium state. The new conditions will probably be less favorable to humankind than the conditions that favored the human species for a huge span of time.

As the first draft of this manuscript is being completed, it is possible to visualize that the worst possible situations could happen — a nuclear exchange between India and Pakistan, leading to a wider and even more devastating war. In contrast, it is possible that preliminary steps could be taken to increase the probability of achieving sustainable use of the planet. It has been said that exceptional political leadership can only emerge in a time of crisis. Perhaps in the sustainability crisis, ethical and spiritual leadership will emerge.

Addendum: useful literature, commentary, and recommendations

To paraphrase Cairns (1997), when cause and effect relationships are obscure and uncertain, we are less likely to be motivated to action. Operant learning is unlikely to change global behavior relevant to environmental issues.

The following books represent an interesting mixture of ethical values and science. All have a reverence for life and believe Earth is sacred (should not be violated). They are not listed in any order.

The Sacred Balance (Suzuki 1998) is a superb expression of an environmental ethic — finding peace with Earth. *Wisdom of the Elders* (Suzuki and Knudtson's 1992) provides a collection of readings that give the profound ecological wisdom of a variety of indigenous peoples through their sacred stories. They illustrate the world view in which parts and processes of the universe are holy and are in marked contrast to the economic development mantra so characteristic of the present. The spiritual dimension is, however, not disconnected from ordinary life.

Earth in Mind (Orr 1994) has the unifying theme that the environmental crisis originated from the inability to think about ecological patterns, systems of causation, and the long-term effects of human actions. Orr believes that educators must become students of the ecologically proficient mind and of the practices that must be developed to foster such minds. He bluntly states that this necessity will require the redesign of education itself. A telling point is that the people who have lived sustainably on the planet for any length of time did not have texts describing how to live sustainably — education is no guarantee of ecological decency, prudence, or wisdom. He concludes that what needs to be expressed is an affinity for life.

The Wooing of Earth (Dubos 1980) uses a word seldom seen these days. *Woo* means to court or to seek the favor, affection, or love of. This book is in sharp contrast to the publications of Katz and Elliot discussed earlier. Dubos believes that humans can improve on nature as well as correct environmental damage by deliberate social action. He further acknowledges that the 'humanization' of wilderness has been achieved at great ecological cost. Dubos concludes that ecological management can be effective only if it takes into consideration the visceral and spiritual values that link humans to Earth.

Man's Responsibility for Nature (Passmore 1974) examines Western traditions and ecological problems. Passmore asks what the West has to jettison and what it has to retain if it is to have any prospect of solving the problems that confront it.

One of the pioneering books in this area is *In Defense of Earth* (Caldwell 1972). It has taken 3 decades for most of the concepts in this book to become accepted by even a substantial minority, and many are still indifferent to the ideas in this book and many are violently opposed to them. Caldwell's dedication is as timely today as when the book was published: 'To the men and women in many countries and in many organizations who must succeed in their efforts to obtain a sustainable relationship between man and Earth if the human experiment is to continue.' Notice the warning that, unless the relationship changes for the better, humankind may not persist on the planet.

A Global Ethic for Global Politics and Economics (Küng 1998) translated into English from the German original discusses the lack of universal values and the replacement of ideas with specialized interests. This book emphasizes ethics and many topics relevant to the issues in this article.

Let the Mountains Talk, Let the Rivers Run: A Call to Those Who Would Save the Earth (Brower 1995) successfully communicates a reverence for nature to large numbers of individuals. Brower has been called the 'archdruid' of modern environmentalism. He does not hesitate to discuss his mistakes, but, more important, he never lost hope! In 1995, Brower sent me a copy of his book inscribed: 'Persevere!' A good message for all of us who believe in eco-ethics!

Wild Minds (Hauser 2000) is a 'good read' for those who would like to know what is happening in the minds of their fellow species. Some understanding is a must for the complex mental operations of the animal mind that enables it to adapt to the complex niches with which it is associated. This book couples sound science with humor.

The next 3 titles address the interfaces between many parts of society and natural systems:

Mid-course Correction (Anderson 1998) is particularly important because it was written by the CEO of one of the world's largest interior furnishings companies and, therefore, unlikely to be dismissed by other corporate executives. Anderson's quest is first to become sustainable and then to become restorative; he wants to sustain and protect Earth. The already cited book *Natural Capitalism* (Hawken et al. 1999) has similar goals (both were influenced by the Natural Step Program), but it is so different that both should be read. Although the word *sacred* is not used, both books clearly intend to maintain the integrity of natural systems and feel they should be inviolate (used but not abused). It is worth noting that Hawken was a founder of the Smith Public Broadcasting Services series *Growing a Business*.

Sustainable Development: Rules of the Game (Roy F. Weston 1995) is really a booklet, but an extremely important one. Roy F. Weston, Inc. is a prestigious international consulting firm specializing in environmental solutions for industry. It notes that, to achieve sustainability, corporations need to emulate the economics of nature as the straightest path to making sustainability work. Nature is described as the quintessential supply sider, with its resources not readily available on demand. Through systematic recycling and reuse, nature does not push its inventory of renewable and nonrenewable resources beyond critical limits for sustainability. In short, there is respect and reverence for the machinery of nature (as Ehrlich 1986 has described it).

The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation (Nattrass & Altomare 1999) is an outgrowth of the Natural Step Program pioneered by Dr. Karl-Henrik Robert, who sees humankind running into a funnel of declining life — sustaining resources and increasing demands upon them. Again, he espouses a reverence for natural systems and a desire to preserve their integrity.

The last 4 books illustrate the possibility of a mutualistic interface between humankind and the natural systems of which it is a part:

Striking a Balance: Improving Stewardship of Marine Areas (National Research Council 1997) had among its objectives some alternative models for the governance of marine areas. An important point in the context of this book is the listing of the characteristics of traditional bureaucracies and describing organizational alternatives that would better preserve and protect marine ecosystem integrity.

The New Economy of Nature: The Quest to Make Conservation Profitable (Daily & Ellison 2002) uses case histories and stories to illustrate the dynamic interplay of science, economics, business, and politics necessary for achieving a basis for sound conservation of natural resources.

Arguably, the most promising harbinger of change is *Human Natures* (Ehrlich 2000). It is a typical Ehrlich publication with a huge number of eclectic references. The critical issue (on p. 330) is: 'Our challenge is to learn to deal sensibly with both nature and our natures — for all of us to learn to be both environmentalists and "people people."' Ehrlich is fully aware of the basic problem (also on p. 330):

> So here we are, small-group animals trying to live, with increasingly rare exceptions, in gigantic groups — trying to maintain health, happiness, and a feeling of connectedness in an increasingly impersonal world in which individual natures are based on ever smaller fractions of society's culture.

Ehrlich has beautifully identified a very crucial issue — namely, how should human natures enhance connectiveness within the species and to the interdependent web of life of which they are a part? Ehrlich remains optimistic about what could be done but, with good reason, pessimistic about what will be done.

Finally, Cairns (2002c) examines *Goals and Conditions for a Sustainable World*, a collection of essays, mostly from peer-reviewed scientific journals, on the quest for sustainable use of the planet, which is just beginning and is immensely complicated. Humankind will not know that it 'got it right' until there is robust evidence of sustainability.

I frequently get asked why I do not write a simple, straightforward article about sustainability that could be quickly and easily understood. H. L. Mencken had a devastating response to such requests — 'for every complex problem there is a simple direct solution and it is invariably wrong.' Of course, the quest for broad generalities and unifying themes is essential, but it is impossible to resolve any complex problem without a substantial level of literacy. No simple, easy formula exists for improving the long-term situation, but there is an abundance of measures to eliminate clearly unsustainable practices. One could start by determining the size of the ecological footprint (e.g. Wackernagel & Rees 1996) for one's nation, one's region, or oneself. Or one could read about individual journeys into awareness for conserving Earth's natural resources (e.g. Rohe 2002). Or one could get a variety of views on the social and economic dimensions of sustainability. Although the titles of the individual essays rarely mention it, a definite undercurrent of reverence for natural systems persists in a significant number of essays.

Among the books I found helpful for a broad perspective, *Something New Under the Sun: An Environmental History of the Twentieth-Century World* (McNeill 2000) is worth reading and re-reading. It documents how humankind has crossed threshold after threshold all too often, resulting in a non-linear response that swiftly produced undesirable, unanticipated effects. For example, incremental increases in fishing efforts resulted in a collapse of some oceanic fisheries. Since humankind continues many unsustainable practices, and even subsidizes and extols them, there is a significant probability that more, and probably bigger, ecological problems will be encountered in the 21st century. A prudent society would prefer to take precautionary action. As McNeill notes, many of the ecological buffers (e.g. open land, 'unused' water, unpolluted areas) that aided humankind in difficult times in the past are now largely gone.

GeoDestinies (Youngquist 1997) beautifully illustrates the degree of control Earth's resources have over humankind, such as the degree to which oil has controlled and shaped human society. The exhaustion of natural resources will probably have an equally profound effect. Youngquist clearly does not believe that crucial resources will be as quickly replaced as some economists think. For example, economist Julian Simon (1981) states that even the total weight of Earth is not a theoretical limit to the supply of copper available to humankind; rather, the total weight of the universe would be the theoretical limit. Youngquist believes that the omnipotence of science and technology is a myth. Moreover, the United States and other industrial nations have paid to retain access to Persian Gulf oil, which is about half the world's supply. A notable section of Youngquists' book is devoted to the Gulf War, a response to Iraq's invasion of Kuwait. Ultimately, 660 000 military troops from 28 nations freed Kuwait and protected Saudi Arabia at a huge expenditure of manpower and material. The environmental terrorism of Saddam Hussein of Iraq was particularly notable in the Gulf War because he set Kuwait's oil wells on fire; however, the Iraqi retreat was so rapid that not all wells could be blown up or set afire. Enough were burned to turn the sky black, and an estimated 4.6 million barrels of oil were burning each day (Hobbs & Radke 1992, Hawley 1992), with much, far-reaching environmental damage (e.g., Camby 1991 Earle 1992, El-Bay 1992). These resource wars and environmental terrorism deserve careful attention because they may well be harbingers of the future. Clearly, Saddam Hussein, as well as the coalition led by the United States, did not believe that resources were infinitely substitutable. Worse yet, if Hussein could not have them, no one else was going to either — hence the fires. Most of the calculations of resource availability and how many people they will support do not include acts such as these.

Encompassing Nature (Torrance 1998) is a daunting book best read in small sections, each followed by a period of reflection. The underlying message is quite straightforward: (1) Cultures of the not too distant past had a far more intimate relationship with the world and commonly included rivers and mountains, clouds, rainbows, thunderbolts, sun, moon, and stars among the living things such as plants and animals. (2) Around the turn of the 19th century, nature writers were deeply troubled by humankind's separation from the natural world. This realization was often accompanied by an intense longing for a reconnection with the natural world. In short, the 'holistic' world of creatures, rocks, rivers, and stars had no existence in isolation from the human and divine. (3) A tendency appeared, in at least some civilizations, for cosmogenic myths to be accompanied by religious or metaphysical reflection on the world and humankind's place within it. (4) At present, there is a dichotomy of nature and culture. (5) No single literacy genre encompasses writing about nature throughout the ages, since such a genre could no more be isolated from the myths, hymns and songs, epics and dramas, religious scriptures, and philosophical or scientific treatises that make up the classics of literature than the experience of the extrahuman world can be isolated from our humanity. (6) No sane person will minimize the gravity of the threat, or the urgent need to combat it, by conservation, reduction of pollution, population control, and wiser use of resources.

The book also includes some sections in which the 'archaic' cosmology (in which the whole Earth was considered to be sacred) is given prominent attention. The introduction, from which the above points were obtained, is an essential guide to the organization of the components. The information is difficult to synthesize, but this itself is an important issue since it illustrates how difficult it will be to reach a global consensus on sustainable use of the planet. If Earth is not regarded as sacred and there is much uncertainty in the sciences, how will any unifying theme emerge? The probability is that one or more environmental catastrophes, with large spatial and temporal spans, will be required for the emergence of a new paradigm regarding the need for a mutualistic relationship between humankind and natural systems. This emergence is likely to be hindered by resource wars and the inability of the world's leaders to implement a long-term perspective on both the human and environmental condition.

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