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Preparing to Monitor for Sustainable Use of the Planet

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Abstract : Monitoring humankind's activities is common, for example, intensive care patients in hospitals, pharmaceuticals, food supplies, industrial processes, and economic health. Basically, monitoring is used to confirm that previously established quality control conditions are being met. If they are not, remedial measures are taken promptly. Monitoring for sustainable use of the planet will be orders of magnitude more complex than the systems just mentioned, but the principle remains the same - a feedback loop providing information about the system of concern is essential to verify that the system is functioning within acceptable limits. The absence of a sound monitoring system significantly increases the probability of unpleasant surprises. Since humankind must live sustainably for at least several generations to increase confidence that its practices are sustainable, the development time for the monitoring system will be extensive. Choosing the attributes to be monitored will be challenging, and the synthesis and integration of such diverse information will require much skill, especially in communication. However, the computer age makes coping with vast amounts of diverse information possible for the first time in human history. Paying attention to seemingly inconsequential components of sustainability, such as individual commitment, has merit.

Key words : Sustainability monitoring, Resource wars, Environmental quality control, Information feedback loops, Biospheric life support system.

Nothing puzzles me more than time and space; and yet nothing troubles me less, as I never think about them. **Charles Lamb**

A small leak will sink a ship.

Benjamin Franklin

Limitations of the Human Brain

Homo sapiens has been, for most of its time on the planet, a small-group species with a low population and a period of comparatively slow change. Pursuit of self interest has been beneficial to both the individual and the species. Szent-Gyorgi (1962) has commented that the human brain is an organ of survival: humans searched for food, mates, shelter, and favorable habitats to gain advantage. They could only influence and be affected by events of relatively small scale. At present, humans live in gigantic groups in an environment quite different from the one in which they evolved. To further complicate decision making, the perception of risk is not proportionate to the probability of damage. For example, the United States has been obsessed with terrorism since the tragic events of 9/11, but is relatively unconcerned with global climate change that has been accelerated by greenhouse gases produced by human society. Yet, the terrorists on that tragic day only killed thousands of individuals, whereas major climate change might well kill billions by adversely affecting such things as agricultural productivity, sea level rise, and so on. Worse yet, humankind is not equipped by evolution to personally detect

radioactive materials, persistent pollutants, and greenhouse gases.

Persons now alive are the first in human history to experience a doubling of the number of humans on Earth within a single life time. Many natural systems that individuals played in as children have been replaced by human artifacts (*e.g.*, housing developments, shopping malls). Even with these losses, exponential rates of change are now considered "normal." Ehrlich (1968, p. 18) has described a hypothetical situation that would exist if the human population doubled every 37 years for 900 years - a finite planet would have to house 60,000,000,000,000,000 humans, or 100 individuals for every square yard of land and ocean surface. Ironically, persons who favor perpetual exponential growth on a finite planet consider themselves conservatives. Scientists, such as Ehrlich, who use simple arithmetic to estimate what the continuation of present practices might produce, are labeled "prophets of gloom and doom" by "conservatives." Of course, Earth's carrying capacity for humans is well below 60×10^{15}, so unpleasant events such as famine, disease, resource wars, and so on will ensure that the population levels decline at some point. The question is: what should be monitored to provide information that human senses do not detect so that humankind can live sustainably? Science and technology will not be useful unless humankind develops a new set of ethical guidelines and uses them to make a mid-course correction in the economic, social, and political practices of contemporary society.

Definition

Monitoring is surveillance undertaken to ensure that previously established conditions are being met. Although monitoring need not be continuous, it must be carried out in an orderly and systematic way for the appropriate time interval since sustainability implies use for an indefinite period of time. Even if the information shows variation within acceptable limits, monitoring must continue to ensure that no malfunction goes undetected. A signal that the system is not functioning within acceptable limits makes immediate remedial action essential. Such a signal usually is followed by increased data gathering to determine the cause of the malfunction.

All monitoring systems generate false positives and false negatives, especially in the early developmental stages. A false positive indicates something is wrong when nothing is wrong. A false negative indicates variation within acceptable limits when these limits have actually been exceeded. The impact of both false positives and false negatives can be reduced by information redundancy, which provides confirming evidence on the validity of the signal.

The Primary Goal of Sustainability Monitoring

Sustainable use of the planet requires a healthy biospheric life support system that consists of natural capital and the ecosystem services it provides. Holl and Cairns (2002) have provided an overview of monitoring and appraisal with particular focus on restoring damaged ecosystems. Cairns (2002a) discusses monitoring the restoration of natural capital for both land and water ecosystems. Since most of Earth's ecosystems have suffered some anthropogenic damage, this topic is important because repairing ecological damage will increase natural capital and the dependability of ecosystem services. In addition, various endpoints or attributes can be used in monitoring both

healthy natural systems and those being restored. More detailed descriptions of methods and procedures are given by Cairns and colleagues (1977, 1982). An early discussion of rapid biological information systems is also available (Cairns *et al.*, 1970, 1977). These early publications are mentioned because not much attention has been given to automated, rapid biological information systems, which should be useful in achieving sustainable use of the planet.

Information Balancing

The plethora of information from monitoring the world's economy (*e.g.*, criteria such as consumer confidence, inflation rate, monetary exchange rates, stock and bond prices, unemployment rate, housing starts, trade balances, *etc*.) is given daily attention by the news media and a number of sources that focus primarily on the health and condition of the economic system. Discovery of any unfavorable trends usually produces immediate remedial action, particularly at the national level of developed countries and institutions such as the World Bank. Second- and third-world countries have less sophisticated systems, and remedial actions are often blocked by powerful political forces. However, most of these countries use the methods and procedures of developed countries as models for improving their capabilities.

The health of the economic system is an obsession for most of the world's leaders, while the health of Earth's biospheric life support system receives comparatively little attention. This imbalance does not seem rational since a persuasive case has been made for natural capital as the basis for all other forms of capital (Hawken *et al.*, 1999).

Motivation

Monitoring is widely practiced in developed countries and is expanding in third-world countries. The need for monitoring in a hospital intensive care facility is abundantly clear - the patient is in critical condition. Quality control monitoring of food, pharmaceuticals, and airplanes is also taken for granted because the general public and its leaders have witnessed the consequences of inadequate quality control. Similarly, quality control monitoring in industry, especially of electronic components, is intense and continual.

Why then is quality control monitoring of Earth's biospheric life support system met with apathy? Most likely, it is not viewed as a system but rather as its component parts (*e.g.*, trees, animals, etc.). In cities and highly urbanized areas, personal contact with natural systems is rare and, even then, often for recreational activities and not as a critical life support system essential to human survival. Natural capital and the ecosystem services it provides are essential to sustainable use of the planet (*e.g.*, Daily and Ellison, 2002). Although environmental change on Earth has been the norm for approximately 4 billion years, it was due to natural causes over which humans had little control. Even though hominids have altered the environment for about 4 million years, the most radical anthropogenic changes (in rate, scale, and intensity of change), were most dramatic in the 20th century (*e.g.*, McNeill, 2000) and have continued into the 21st century. This unique situation makes monitoring both more difficult and more necessary. An essential exercise is to determine which trends are unsustainable (*e.g.*, exponential population growth) and which are sustainable (*e.g.*, development of alternative energy sources to

replace fossil fuels). Metrics such as exponential population increase, global heating, ozone hole size, damage to coral reefs, loss of tropical rainforest, topsoil depletion, and the like already have robust scientific data upon which to make a decision. What is lacking is the will to make decisions. Waste emissions into the air from industry and automobiles exceed emissions from all the planet's volcanoes. Ecological disequilibrium resulting from human activities will result in a variety of changes, including synergistic interactions, that make Earth less habitable for humans and many other species.

Connecting the Diverse Webs

Since humankind does not yet realize it is a part of natural systems and dependent upon them, communications about environmental problems should be based on the special groups that perceive themselves as independent from or weakly linked to the planet's biospheric life support system. The biggest threat to humankind is not terrorists and weapons of mass destruction, but the rapid impairment and destruction of the biospheric life support system. The quest for sustainable use of the planet adds another ethical responsibility - to leave a habitable planet for posterity.

In this discussion, the word *web* is used to emphasize that major, special-interest groups have a variety of agendas, many of which have important shared components. Multi-national corporations may compete in advertising campaigns, but often share an interest in cheap labor. Individual citizens also have special interests, but share quite predictable, strongly held "needs" and demands. The demand for low taxes is very important in the United States - the first US President Bush made a widely quoted statement: "Read my lips - no more taxes." Citizens often have unreasonable expectations of politicians, such as better schools and roads, with no increase in taxes.

The political web is another complex system. While the corporate web shares a quest for wealth, politicians focus on power. Seidel (1998) presents a superb, detailed analysis of these issues with a very useful set of references.

The fourth web is the interdependent web of life - natural systems and the ecosystem services they provide. This one is the most important because humankind cannot survive without it. Ironically, this web is the one receiving the least attention, with serious threats to its integrity.

Sustainable use of the planet requires a mutualistic interaction between and among the four webs, but serious obstacles exist to this interaction.

(1) As Seidel (1998) points out, most of humankind's serious problems are not receiving attention because politicians would be required to take actions that would almost certainly weaken the support of special-interest groups and weaken their alliances with them.

(2) Corporate executives are focused on profits, competition, production problems, emergencies, and the like. Events in the United Sates at the beginning of the 21st century suggest that some executives have not given their organizations the integrity expected of leaders. Simon (1976) remarks that executives are aware that they are dealing with greatly simplified models of the "real world" and are not disturbed by this realization because they perceive that most of this information has no substantive

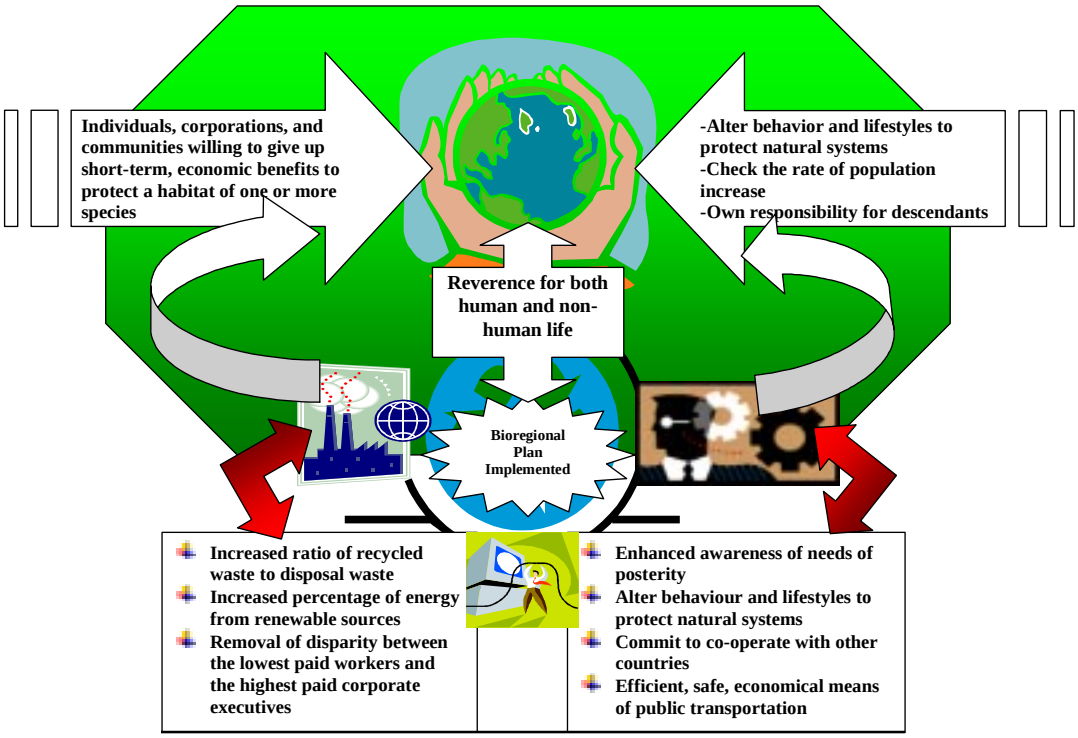

Fig 1: Mapping the Information Flow for Ecological Restoration

relevance to the problems that they face. Many issues require expedient solutions, but others, such as sustainable use of the planet, require reflection and a high degree of literacy about complex, long-term problems confronting humankind. US Senator Gore (1992) observed that the most one can expect from the political process falls short of minimal requirements for effective action.

Waiting for the Four Webs to Communicate Effectively

If Boulding (1981) is correct, the skills that enable individuals to acquire the power of leadership make them unfit to exercise it. In the 2004 US Democratic primaries, one individual expressed his preference for a candidate as a guy he would feel comfortable drinking a beer with - in short, voters elect people they can understand rather than vote on the basis of leadership qualities. When the future of posterity becomes an important issue in an election, perhaps a paradigm shift will be underway.

Although (or even perhaps because of) the United States is the nation-state contributing approximately 24% of the planet's anthropogenic greenhouse gases, the findings of mainstream science have had little or no impact on political, corporate, or personal decisions until the last few years when global heating (*warming* sounds too cozy) has received much attention. Human activities, especially use of fossil fuels, cause a significant increase in greenhouse gases.

Most global heating over the last half century is most probably due to the increase in greenhouse gases. After accounting for uncertainties, global average surface temperatures are projected to increase by 1.4 to 5.8° C (2.7 to 10.4° F) between 1990 and 2100. These conclusions were reached by the Intergovernmental Panel on Climate Change (2001) and confirmed by the US National Research Council (the operating arm of the US National Academies of Science and Engineering) (2001). More recent reports from the Intergovernmental Panel on Climate Change in 2007 are getting much more attention than earlier reports. Despite the prestige of both scientists and organizations involved in these reports, their credibility has been questioned by US politicians. The results were quite different in Europe, but the important factor is the lack of political leadership to address the problem. Under these conditions, neither corporations nor the majority of private citizens are likely to consider global climate change a major problem. Until the situation improves, scientific information will not markedly affect political decisions.

Interim Sustainability Monitoring

The most effective way to achieve sustainability is to eliminate or reduce unsustainable practices such as exponential growth in population and resource use, destruction of natural systems and the services they provide, reduction in the size of both national and personal ecological footprints, development of alternative energy sources, and the like. Since interest in an issue is inversely related to the temporal and/or spatial distance involved, working on local sustainability goals should be worthwhile. Two illustrative measurements that can be gathered locally or regionally are: (1) a bird census - Bird watchers are everywhere! The Audubon Annual Bird Count, or something similar, has both short- and long-term advantages. Local or regional bird clubs are also useful; (2) ecological footprint size - Most individuals are unaware of critical measurement. A number of websites offer measurements for ecological footprint size: *http://www.earthday.net/footprint; http://www.lead.org/leadnet/footprint/results.CFM; http://www.mec.ca/Apps.ecoCalc/ecoCalcHousing.jsp*. Obviously, monitoring changes in ecological footprint size, both + and -, are important to achieving sustainable use of the planet.

Some other illustrative practices of human society worth monitoring follow.

(1) Does human society have an ethos (*i.e.*, a set of guiding beliefs) regarding its relationship with natural systems?

(2) What is the rate of population increase (*i.e.*, natural births + immigration [both legal and illegal])?

(3) Is there an efficient, safe, economical means of public transportation that is used on a regular basis by a majority of citizens?

(4) What is the ratio of environmental repair (*i.e.*, ecological restoration) to environmental damage?

(5) Has a bioregional plan been developed and implemented?

(6) What percentage of energy use is based on renewable sources (*i.e.*, wind, solar, tidal, etc.) and are plans being developed for reducing use of fossil fuels?

(7) What is the ratio of recycled waste (cans, newspapers, etc.) to total waste generated per household and per bioregion?

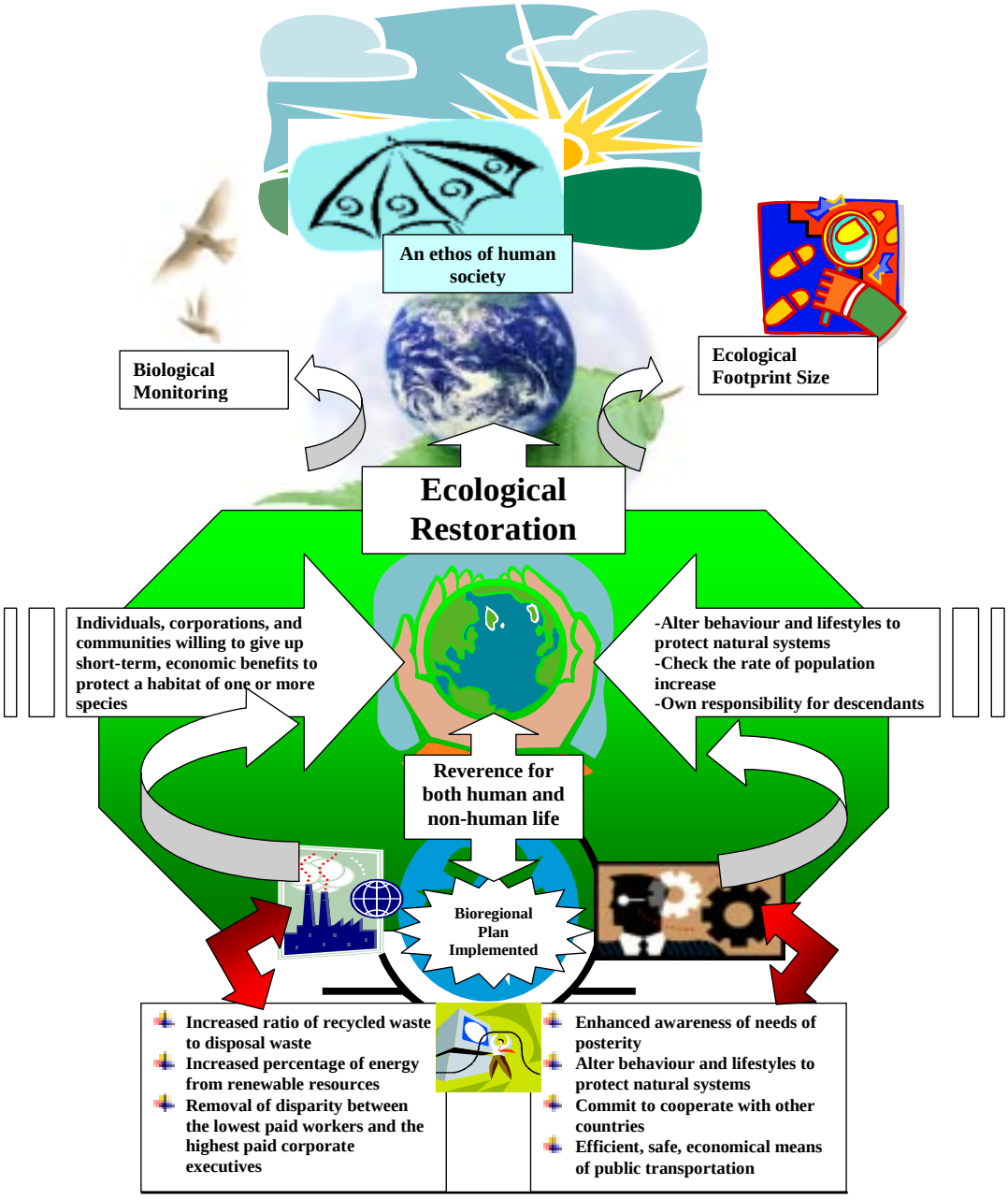

Fig 2: Additional ComponentsNecessary for Ecological Restoration

(8) To what degree are the needs of posterity considered?

(9) Is human society willing to alter behavior and lifestyles to protect natural systems?

(10) Are individuals, corporations, and communities willing to give up short-term, economic benefits to protect a habitat that, if lost, might result in the loss of one or more species?

(11) Is there a commitment to co-operate with other countries to avoid global heating and other global environmental problems?

(12) Is there a reverence for both human and non-human life?

(13) To what degree do citizens accept responsibility for their own descendants?

(14) Is there a massive disparity between the lowest paid workers and the highest paid corporate executives?

A loss of integrity and ethos will inevitably result in dysfunctional ecosystems. Natural system integrity probably will not survive in the absence of a mutualistic relationship with human society. Humans cannot extinguish life on Earth without serious, perhaps fatal, effects on human society. Boulding (1977) remarks: "It may be, therefore, that evolutionary sustainability is a different matter from the sustainability of any particular system *(and one might add species)* within the process, for though all particular systems may become extinct, the evolutionary process may go on." This hypothesis seems plausible, and, if one accepts it, presents a compelling reason for cherishing and preserving the system so favorable to *Homo sapiens* for as long as possible.

What Humans Perceive

Ornstein and Ehrlich (1989) remark that a frog sitting in a pot of water that is heated slowly will stay there until heat kills it, unlike a frog thrown into boiling water that will attempt to escape. The lesson is that, if change is too gradual or too small, it will not register. Humans do not appear to differ dramatically from frogs since, despite having larger brains, they have not developed a deep global concern about global heating. The connection between combustion of fossil fuels and global temperature increase has been noted since 1986 (Arrhenius), but, despite a massive increase in data supporting this hypothesis (Intergovernmental Panel on Climate Change, 2007), some world leaders essentially disregard the information. Humankind could vastly expand its perception of the planet's natural systems if scientific information were better understood and acted upon.

Early in my professional career, I witnessed the hostile treatment given by Rachel Carson (1962) when she remarked that pesticides were having widespread adverse effects on a variety of species. *Silent Spring*, now a classic, represented a defining moment in the field of ecotoxicology, but, as a young research investigator in this field, I had serious doubts about my ability to endure the widespread attacks upon her credibility and integrity in the news media. Regrettably, Carson died of cancer in 1963, still being denounced as unscientific and a "scare monger." Carson is now revered and honored, but she should not have had to endure the ridicule and attacks on her scientific integrity that she did. No scientist should be required to endure personal attacks for merely reaching conclusions that pesticides are hazardous. If monitoring for sustainability is to become a way of expanding the perception

of the world, bearers of displeasing information cannot be humiliated.

Information Overload

In the first half of the 20th century, only a relatively few professionals in chemistry, sanitary engineering (now environmental engineering), and biology were interested in the response of natural systems to anthropogenic pollutants. Using a single species for toxicity testing was then considered "cutting edge." Toxicity tests on one species should not have been considered a reliable predictor of the response of millions of other species, yet the battle went on for many years (*e.g.*, Cairns, 1983). Humankind appears to be making comparable mistakes concerning the effects of anthropogenic practices upon ecosystem services at a global level. Both natural capital and the ecosystem services it provides are at serious risk, but little effort is being made to determine how close this ecological life support system is to collapsing or going into disequilibrium.

As Campbell (1989) remarks: "Our everyday reasoning is not governed primarily by the rules of logic or probability calculus, but depends to a surprisingly large extent on what we know, on the way knowledge is organized in memory and how such knowledge is evoked." When humans were in small groups and intimately associated with their resource base, their knowledge had to be appropriately organized or they would lack food, shelter, and warmth and either died and/or had few or no descendants. Even if they had appropriate knowledge about their resource base, they still had to avoid predation and/or disease. In short, human ancestors had an effective monitoring system that permitted long-term survival as a small-group species.

Now humans live in comparatively enormous groups without an intimate relationship with their resource base and often without an adequate knowledge of the diseases that threaten them (*e.g.*, AIDS). Logic was not a sine qua non for remote ancestors and is not humankind's forte now, or it would not be making such ineffective efforts to live sustainably. Humankind's previous knowledge was based on local or regional systems for which valid or invalid information elicited a significant, immediate response. At present, economic information, particularly economic growth, dominates human actions to a point where environmental information about such issues as global heating , the dangers of perpetual exponential growth, species extinction, and the planet's carrying capacity for humans are either ignored or derided. "Tunnel vision" (Piattelli-Palmarini, 1994) is the norm; holistic thinking is the exception. As Ornstein and Ehrlich (1989) remark: humankind's brain is both the source of the problem and its solution. Learning how to balance options effectively is a good starting point. Is terrorism as great a threat to security as global climate change, exponential population growth, pollution, and excessive demands on finite planetary resources? As always, funds, personnel, and technology are limited and should be directed to the monitoring of high risk situations instead of those emotional issues that are distasteful, even repugnant, but less of a threat to humankind's survival. Emotions cannot dominate monitoring if it is to be a successful quality control system.

Material Possessions and Sustainability

One of the biggest obstacles to achieving sustainability in wealthy countries is the status associated with abundant material possessions. Curiously, advertisements promote purchase of a mass-produced car as an expression of individuality when it is an attempt to conform. During the "flower child"/"hippy" era in the

United States, colleges labeled a professor in a suit and tie or dress as a conformist, when, in fact, the majority of students were wearing a uniform - blue jeans with holes in the knees and ragged trouser cuffs. The students differed from society as a whole, but conformed to a dress code of their own. Fromm (1941) remarked that what people perceive as individuality is in reality an attempt to conform. However, conformity might favor sustainable use of the planet if a paradigm based on material possessions shifted to a paradigm in which status and honor are based on dedication to sustainable practices. One thing is certain, humankind will not choose the most useful attributes to monitor until the obstacles to selecting the most appropriate ones are recognized. First, individuals must make choices based on a sense of kinship with other members of the human species and the other life forms with which they share the planet. Second, individuals must acknowledge that incremental changes, not easily perceived, may have major effects that should be a major concern and, thus, should be monitored. Third, humans must acknowledge that any exponential change can become dangerous very quickly. Fourth, when change occurs more rapidly than normal, feedback loops may not be effective. For example, Wilson (1996) estimates that the number of species on the planet is being reduced at a rate that is 100 to 1,000 times more rapid than in pre-human times. Evolution can cope with mass extinctions over huge spans of time, but *Homo sapiens* may not survive this challenge. Fifth, humankind must cease allowing governments to alter or ignore science in their policy decisions (*e.g.*, Union of Concerned Scientists, 2004). The US Pentagon Report (Townsend and Harris, 2004) warns that abrupt climate change could bring the planet to the edge of anarchy. Sixth, the crucial role of moral philosophy in education for sustainability must be given greater attention (*e.g.*, Nath, 2003). Seventh, the costs of conservation, including monitoring, should receive more attention, particularly natural capital (*e.g.*, Hawken *et al*., 1999) and ecosystem services (*e.g.*, Daily and Ellison, 2002). Eight, humankind needs to control emotional drives better. Wars begin easily, destroy natural capital, and make profligate use of resources (*e.g.*, Cairns, 2003). As the United States has found in the 21st century, the conventional wars in Afghanistan and Iraq were over quickly; however, sectarian violence continued and rehabilitation of the infrastructure and stabilizing the political systems appear likely to require at least an order of magnitude more time, many lives, and enormous sums of money. Wars are destructive, and sustainable practices are constructive. Money spent on wars would better be utilized to achieve sustainability. Ninth, biological evolution selects for competition, but the social evolution that is needed for sustainability must be directed toward mutualistic relationships. Tenth, sustainable use of the planet requires more expertise than a solitary individual can achieve. Political leaders often cannot avoid showing favoritism to contributors of huge amounts of money to campaign funds because the politician expounds a certain philosophy. Favoritism hampers consilience (literally, leaping together) of special interest groups, the general public, and the environment. Eleventh, humankind does not act consciously, although individuals may. Humankind's impact upon natural systems represents the cumulative impact of a huge number of individual and organizational actions based on self interests that are mostly uncoordinated. Stabilizing feedback monitoring loops and controls are lacking, although they are essential to staying within Earth's carrying capacity and living sustainably.

Purpose of Monitoring

Monitoring is used to either determine if desirable quality control conditions are being met or if new practices are moving the system toward desired goals (*e.g.*, Holl and Cairns, 2002). Both quality control conditions and goals are value judgments (*e.g.*, Cairns, 2002b), which must be discussed before selecting monitoring methods and procedures. Provision must be made for periodic course corrections after monitoring has begun, which are necessary because of new scientific information or altered value judgments. The major danger in this process is the attempt to suppress or alter scientific information for political and ideological reasons.

Attempts to politicize science are, arguably, as old as science itself. Scientists are typically accused of being politically motivated. Sad to say, some are. Others are lured to refute mainstream science by large consulting fees. Sustainability ethics must guide all decisions, especially monitoring, instead of the special interests of specific groups.

Resource Wars

As global resources are depleted, resource wars are likely, but not inevitable. Klare (2001, p. 27) notes that, in the 21st century, oil is most likely to provoke conflict. The probability of resource wars could be markedly diminished by an enlightened energy policy, reduced personal use of energy, and development of alternative energy sources. Industrialized societies that have not prepared for post-peak-oil-perceived threats to their oil supplies may, in extreme cases, provoke war. Klare (2007) predicts that conflicts over oil will constitute a significant feature of the global security environment in the decades to come. Monitoring resource availability and allocation is an important component of the quest for sustainable use of the planet. Climate change must be considered in matters of war and peace (Renner, 2002).

Concluding Statement

The 21st century will be a chaotic time of both environmental and social change. Humankind will be better prepared for these changes if a monitoring system is in place to provide an early warning of these changes. The four 2007 reports of the Intergovernmental Panel on Climate Change provide both a preliminary list of environmental attributes to be monitored and the names of a core group of scientists qualified to develop a comprehensive monitoring system. A companion system for monitoring social changes is essential. New, major costs will occur, but they will be minor compared to the cost of doing nothing.

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