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Ecological Overshoot and Ecological Restoration

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Abstract: Persuasive evidence indicates that humankind inhabits a planet with an ecological overshoot, *i.e.*, humankind is using ecological resources faster than they can be restored. In addition, human society is releasing pollutants and wastes more rapidly than natural systems can assimilate them. Ideally, the pollutants and wastes should be assimilated and transformed to a degree that they benefit other species. If overshoot persists, it could well result in a global environmental collapse that, in turn, would result in an economic collapse. To prevent such a disaster, human society must replace unsustainable practices with sustainable practices. This article focuses on ecological restoration, which increases natural capital (*i.e.*, natural resources) and the ecosystem services it provides. Societal change with ecological restoration should reduce the overshoot and make sustainable use of the planet possible.

Key words: Ecological overshoot, Ecological restoration, Natural capital, Ecosystem services, Restoration checklist, Sustainability.

Any nation concerned about the quality of life, now and forever, must be concerned about conservation. It will not be enough to merely halt the damage we've done. Our natural heritage must be recovered and restored . . . It's time to renew the environmental ethic in America—and to renew U.S. leadership on environmental issues around the world. Renewal is the way of nature, and it must now become the way of man. **Former US Vice President George Bush, 1988**

Humankind is not preserving natural capital for posterity, and persuasive evidence indicates a serious overshoot at the present time. Wackernagel *et al*. (2002) rely on the well-known ecological footprint as evidence of this overshoot. Meadows *et al*. (2004) used the 30-year update of the Club of Rome Report to demonstrate that humankind is depleting natural capital (and the services it provides) faster than it can be regenerated. Moreover, human society is discharging wastes in both quantities and qualities that the biospheric life support system cannot assimilate.

Sustainable use of the planet requires temporal and spatial spans much greater than those now commonly in use. However, the path to success is straight forward :

(1) stabilize the population,

(2) replace unsustainable practices with sustainable ones, and

(3) repair damage to the biospheric life support system. The last point is the focus of this commentary.

The United Nations, Worldwatch Institute, The Earth Policy Institute, and a wide variety of publications from organizations reporting on the state of the environment provide huge amounts of information on damage to both natural capital and the ecosystem services it provides, usually based on scientific studies. Sustainable use means that an entity can exist indefinitely. Clearly, humankind is far from this state at present. For example, Larsen (2005) document the loss of lakes and the decreasing size of seas. West Africa's Lake Chad is now only 5% of its former size. The Aral Sea in Central Asia is gradually turning into desert.

The National Research Council (NRC, 1992) provides a substantial number of case histories of successful ecological restoration in a variety of aquatic ecosystems. A major conclusion of the Council was that each of these entities functioned in a larger ecological landscape that was greatly influenced by other components of the hydrologic cycle, including adjacent terrestrial ecosystems. All too often, many restoration decisions had been made in a fragmented fashion unlikely to produce a self-maintaining aquatic ecosystem integrated into the larger ecological landscape, which is essential to sustainable use of the planet.

In view of the significant ecological overshoot, the restoration recommendations of the NRC were prophetic, since ecological overshoot was not well documented in 1992. Recommendations for restoration in the United States were proposed in the NRC volume (NRC, 1992); (1) for lakes—a net gain over the next 20 years (from 1992) of 2 million acres of restored lakes, out of the 4.3 million acres of lakes that had been degraded by 1992, (2) for rivers and streams—a restoration target of 400,000 miles of river-riparian ecosystems within a 20-year period; in 1992, this goal represented approximately 12% of a total of 3.2 million miles of US rivers and streams most affected to a significant degree by human activities; (3) for island and coastal wetlands—restoration at a rate that offsets any further loss of wetlands and contributes to an overall gain of 10 million wetland acres by 2010. None of these recommendations have been fully implemented. The ray of hope is that this situation may change soon. Although the words *economics* and *ecology* have the same Greek root word – *oikos*, the approach of these two fields to environmental problems has been drastically different. However, ecological restoration with the Panama Canal has been regarded as a good business deal by some (Science and Technology, 2005), but the restoration is structured in a way that also provides both social and environmental benefits. The beneficiaries of this project are an easily identifiable group. As a consequence, the group was willing to pay the costs involved in the restoration. When common areas (*e.g.*, oceans) are restored, the benefits are widely shared and restoration funds benefit large numbers of people; consequently, a consensus on sharing restoration costs may not easily be reached.

Of course, everyone would like to return a damaged ecosystem to a working model. However, this goal is unlikely to be successful for a number of reasons, each of which can be made less troublesome by the experimental sciences.

(1) Precise evidence on either the structure or the function of the ecosystem before it was damaged is usually not available. Often, detailed lists of species have never been compiled. However, this scenario does not mean that all restoration efforts will be wasted.

(2) The predisturbance aquatic function and related chemical, physical, and biological conditions of a naturalistic system is difficult to establish (Magnuson *et al*., 1980; Cairns, 1988; Lewis, 1989). Ecological restoration is a holistic process that cannot be achieved by manipulation of a few species and/or particular chemical/physical processes.

(3) Natural ecosystems are self-maintaining and have been for billions of years. Consequently, they have sufficient resilience to respond to natural changes in the environment. Self-regulation in nature is not a conscious undertaking, but rather, the result of resource partitioning in which finite or limited resources are acquired by a substantial array of species. Natural ecosystems adjust to environmental change by means of

continuous colonization/decolonization processes. MacArthur and Wilson (1967) developed this concept. Although, many publications now exist on this subject, opportunities still exist in this area for the experimental sciences. For example, much information is still needed on the relationship between species succession and the ecological recovery process, despite the fact that McIntosh (1980) provided an overview of this important topic approximately 25 years ago.

(4) Many activities described as ecological restoration would more accurately be described as rehabilitation. In rehabilitation, the intent is not to restore the entire dynamic system, but rather, to repair or improve selected attributes, such as commercial or recreational fisheries, of particular value to humans. Rehabilitation has some merit in an era of major climate change, persistent pollutants, and reduced air quality, which may well impair reestablishing the conditions that existed before the ecosystem was damaged.

(5) A key factor in both ecosystem restoration and rehabilitation is species available for colonization from sources outside the system being repaired. Succession of species is a natural and necessary part of ecosystem dynamics. However, the continual colonization process to compensate for decolonization due to natural cycles or anthropogenic ecosystem damage impair this process. Establishing a network of protected areas (*e.g.*, Avasthi, 2005) may well enhance the flow of species, which may have been diminished due to ecosystem fragmentation.

(6) Ethical issues exist even in such a commendable activity as ecological restoration (Cairns, 2003).

(a) Human management, if skillful, can remediate ecological damage (but, management can also be the problem). One example is the problem caused with fragmentation by roads, which illustrates the conflict inherent in simultaneously pursuing the two goals of expanding a road system that has many economic benefits and trying to preserve natural ecosystems by reducing the threats to them.

(b) When an ecosystem is damaged by human development, such as a wetland, an attempt is often made to replace the lost ecosystem elsewhere. This attempt may not be successful and may damage a different, existing ecosystem that is in reasonably good condition.

(c) Natural systems are often treated as a means of supplying a human want instead of being regarded as ecological life support systems.

(d) Uncertainty is a normal feature of science, stock market predictions, and life in general. Uncertainty accompanies almost every prediction (Lemons, 1996), so it should not impede ecosystem restoration or reduce ecological overshoot.

(e) Often, restoring a damaged ecosystem may involve the species best able to tolerate anthropogenic stress. Also, if no restoration is carried out, human-dominated ecosystems could become the norm.

(f) If the species lost due to ecosystem damage is replaced with a species from an undamaged ecosystem, the reduction of the population size in the donating system may damage it.

(7) Damaged and restored ecosystems are part of a landscape mosaic, even though they are often considered separate systems. Natural species succession occurs in diverse landscapes with heterogeneous niches for wildlife. Some species exist as subpopulations on patches of habitat scattered across a landscape. Natural variation makes sites more or less favorable as part of natural variability. Species move to the most favorable sites as conditions become less favorable in the habitat they occupy. Since, these patches of exploitable habitat change seasonably or on longer cycles, a mosaic enables species that exploit them to find favorable sites when the site they occupy temporarily becomes less suitable. In short, each site may at some time provide a refuge for a species during a period of stress.

(8) Reparation generally refers to making amends for some wrong/injury by restoring or repairing, by which the individual or other entity (*e.g.*, ecosystem) is recompensed for real or imagined damage by the individual or organization perceived as causing the damage. Often, the individual or organization no longer exists and, therefore, ecological restoration must be provided with money and resources from society. People who believe that human society is dependent on the planet's biospheric life support system would support restoration as an act of enlightened self interest. For them, the carrying capacity of the planet is a function of the biospheric life support system. An ecological overshoot can be reduced by restoring damaged ecosystems in a landscape context. Healthy, resilient ecosystems provide a greater carrying capacity than damaged ecosystems.

(9) Ecosystem services are essential to maintain the planet's carrying capacity for all living life forms. Human damage to ecosystems has impaired their ability to provide ecosystem services upon which humankind depends. Ecosystem services should be a major component of ecological restoration. Biophysical and socioeconomic features of ecosystems strongly determine human-ecosystem interactions and the ecosystem services delivered (Maass *et al.*, 2005).

(10) Since, each ecosystem has unique attributes, all restoration must be carefully planned before any actual work begins. At the beginning, the project mission, goals, and objectives must be explicitly stated. A restoration checklist (pp. 57-58) from the National Research Council Report (NRC, 1992) provides guidance in planning a restoration project.

Restoration Checklist

Project Planning and Design

1. Has the problem requiring treatment been clearly understood and defined?

2. Is there a consensus on the restoration program's mission?
3. Have the goals and objectives been identified?
4. Has the restoration been planned with adequate scope and expertise?
5. Does the restoration management design have an annual or midcourse correction point in line with adaptive management procedures?
6. Are the performance indicators—the measurable biological, physical, and chemical attributes—directly and appropriately linked to the objectives?
7. Have adequate monitoring, surveillance, management, and maintenance programs been developed along with the project, so that monitoring costs and operational details are anticipated and monitoring results will be available to serve as input in improving restoration techniques used as the project matures?
8. Has an appropriate reference system (or systems) been selected from which to extract target values of performance indicators for comparison in conducting the project evaluation?
9. Have sufficient baseline data been collected over a suitable period of time on the project ecosystem to facilitate before-and-after treatment comparisons?
10. Have critical project procedures been tested on a small experimental scale in part of the project area to minimize the risks of failure?
11. Has the project been designed to make the restored ecosystem as self-sustaining as possible to minimize maintenance requirements?
12. Has thought been given to how long monitoring will have to be continued before the project can be declared effective?
13. Have risk and uncertainty been adequately considered in project planning?

During Restoration

1. Based on the monitoring results, are the anticipated intermediate objectives being achieved? If not, are appropriate steps being taken to correct the problem(s)?
2. Do the objectives or performance indicators need to be modified? If so, what changes may be required in the monitoring program?
3. Is the monitoring program adequate?

Post-Restoration

1. To what extent were project goals and objectives achieved?
2. How similar in structure and function is the restored ecosystem to the target ecosystem?
3. To what extent is the restored ecosystem self-sustaining, and what are the maintenance requirements?
4. If all natural ecosystem functions were not restored, have critical ecosystem functions been restored?
5. If all natural components of the ecosystem were not restored, have critical components been restored?
6. How long did the project take?
7. What lessons have been learned from this effort?
8. Have those lessons been shared with interested parties to maximize the potential for technology transfer?
9. What was the final cost, in net present value terms, of the restoration project?
10. What were the ecological, economic, and social benefits realized by the project?
11. How cost-effective was the project?
12. Would another approach to restoration have produced desirable results at lower cost?

Restoration projects fail for a number of general reasons: (1) lack of a specific goal and defining goals in vague generalities (such as "optimize ecosystem integrity), (2) use of the restoration project to justify ecological destruction of another ecosystem, (3) institution of restoration course corrections on site without discussion and/or consultation with experts, (4) failure to follow up and verify that project goals are being met, (5) denial of access to government agencies or representatives of local citizens to the restoration project, and (6) absence of peer review by qualified professionals.

Unfortunately, a number of alternative substitutes have been offered for true ecological restoration. None of these protect and restore natural capital and the ecosystem services it provides. Often, developers will agree to establish a system that ensures that two acres of vernal pool habitat will be purchased for conservation purposes for every one developed (Environmental News Service, 2005). Two major problems exist in such agreements: (1) no new acreage is added and one third of existing acreage is lost, and (2) no substantive statement is made of what is meant by *conserve*. In the same vein, Wal-Mart has announced that it would purchase an amount of land for conservation equal to all the land its stores, parking lots, and distribution centers use for the next 10 years (Associated Press, 2005). No details were given about the ecological differences between the habitat lost and the replacement habitat, nor were any details given about how the purchased habitat would be protected.

The expectation is that US wildlife refuges would have exemplary protection, but the continuing debate on oil drilling in the US Artic National Wildlife Refuge has caused much concern over this issue, since the March 2005 US Senate voted to open the Artic Refuge to drilling (Fischman, 2005). The US National Wildlife Refuge system is larger than the aggregate of US national parks and has a more important biota, including 1.7 million acres of protected wetlands and 250 imperiled species. This system was established over the time span of a century, and, during President Clinton's administration, the US Congress emphasized the crucial role of the refuge system in scientific nature protection, especially as a source of species to recolonize damaged ecosystems. In the US state of Wyoming, a prominent sportsman who was a previous president of the Wildlife Management Institute and now for the Theodore Roosevelt Conservation Partnership is challenging US President George Bush because, among other factors, the antelope herd follows a pathway that is at least 7,000 years old (Wilkinson, 2005). The proliferation of natural gas wellheads may disrupt such ancient wildlife cycles.

Conclusions :

With an ecological overshoot already in place and no precise knowledge of how close humankind is to the tipping point where ecosystem services will probably be either unfavorable of even unsuitable for the human species, strong action is needed at once. Since, ecosystem restoration is a slow process, which is essential for sustainable use of the planet, it should begin at once in those areas where a recovery is highly probable. Short-term replacement of unsustainable practices with sustainable ones will almost certainly reduce the ecological overshoot more quickly than ecological restoration. Finally, human demand on ecosystems must not exceed their resilience, and natural capital must not be used so rapidly that it is depleted.

Maintaining the biospheric life support system in a close approximation of its present function and structure or improving integrity are essential because its ecosystem services are so favorable to *Homo sapiens*. At some point, massive damage to the biospheric life support system must cease. Since persuasive evidence of an ecological overshoot already exists, the time to halt further damage and repair existing damage is now. Recovery from an overshoot should be possible unless the planet's ecosystems lose their resiliency. Make no mistake—ecological restoration will greatly benefit humankind and may even be necessary for its survival. Evolutionary processes will continue, even if over 90% of the species now alive become extinct. What is the probability that *Homo sapiens* will survive the loss of a large portion of the 30+ million species? Ecological restoration and sustainable use of the planet are acts of enlightened self interest.

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References :

Associated Press (2005) : Wal-Mart pledges $35 million for wildlife.

Avasthi A. (2005) : California tries to connect its scattered marine reserves., *Science*, **308,** 487-488.

Cairns J. Jr. (1988) : Increasing diversity by restoring damaged ecosystems. In Biodiversity. (Ed) E. O. Wilson (Washington, DC: National Academy Press) Pp 333-343.

Cairns J. Jr. (2003) : Ethical issues in ecological restoration. Ethics in Science and Environmental Politics.

Environmental News Service (2005) : Enviros, developers agree to conserve California vernal pools.

Fischman RL (2005) : No refuge is an island. Grist Magazine.

Larsen J. (2005) : Disappearing lakes, shrinking seas. *Eco-Economy* Update 2005-3, 7 April (Washington, DC: Earth Policy News)

Lemons J. (Ed) (1996) : Scientific Uncertainty. (Cambridge, MA: Blackwell Science)

Lewis R. R. III (1989) : Wetland Restoration, Creation, and Enhancement Technology: Suggestions for Standardization. Wetland Creation and Restoration: *The Status of Science*. Vol. II, EPA600/3/89/038B. (Washington, DC: USEPA).

Maass J. M., Balvanera P., Castillo A., Daily G. C., Mooney H. A., Ehrlich P., Quesada M., Miranda A., Jaramillo V. J., Garcia-Oliva F., Martinez-Yrizar A., Cotler H., Lopez-Blanco J., Perez-Jimenez A., Burquez A., Tinoco C., Ceballos G., Barraza L., Ayala R., Sarukhan J. (2005) : Ecosystem services of tropical dry forests: insights into long-term ecological and social research on the Pacific Coast of Mexico., *Ecology and Society*, **10(1)**, 17-26

MacArthur R. H., Wilson E. O. (1967) : The theory of island biogeography. (Princeton, NJ: Princeton University Press).

Magnuson J. J., Regier H. A., Christie W. J., Sonzogni W. C. (1980) : To rehabilitate and restore Great Lakes ecosystems. In: The Recovery Process in Damaged Ecosystems. (Ed) J. Cairns Jr. (Ann Arbor, MI: Ann Arbor Science Publishers, Inc.) Pp. 95-112.

McIntosh R. P. (1980) : The relationship between succession and the recovery process. In: The Recovery Process in Damaged Ecosystems. (Ed) J. Cairns Jr. (Ann Arbor, MI: Ann Arbor Science Publishers Inc.) Pp. 11-62.

Meadows D., Randers J., Meadows D. (2004) : The Limits to Growth: The 30 Year Update. (White River Junction, VT: Chelsea Green Publishing Co.).

National Research Council (1992) : Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. (Washington, DC: National Academy Press).

Science and Technology (2005) : Are you being served? The Economist 21 April http://www.economist.com/printededition/PrinterFriendly.cfm?story_ID+3886849.

Wackernagel M., Schulz N. B., Deumling D., Linares A. C., and seven others (2002) : Tracking the ecological overshoot of the human economy., *Proc Nat Acad Sci.*, **99(14)**, 9266-9271

Wilkinson T. (2005) : Drilling where antelope play. Christian Sci Monitor 13 April http://www.csmonitor.com/2005/0413/p01s02-usec.html.