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Linkages to Biodiversity, Ecosystems, and Society[1]

Earth Day 2000 is significant for two reasons. First, it is the 30th anniversary of an international grass-roots effort to increase awareness of Earth's limited natural resources and the need to clean up and protect our environment. Second, it is the first Earth Day observance this century.

Also, last year, 1999, marked the 200th anniversary of a famous, controversial, and much debated prediction that bears directly on our recognition of the limited carrying capacity of Earth's biosphere, the relatively thin surface of our globe which supports life. More on Thomas Malthus, who proposed this theory, later.

Our topic today is *Linkages of Biodiversity, Ecosystems, and Society*. The first task is to define our terms so we can establish some common understanding of the concepts we are dealing with. They are by no means simple. The term *biodiversity* is defined as the variety of living things and the ecological complexes in which they occur. Considerable concern has arisen during the past 30 years or more about the status of biodiversity nationally and internationally. During the heyday of the environmental movement of the late 60's and the early 70's, concern about rapidly decreasing biodiversity resulted in enactment of the Endangered Species Act. We now consider it a global crisis.

Many of us immediately grasp the concept of species and the regional concerns and controversies that have erupted in recent years over the protection of endangered species. We are familiar with such species as the bald eagle, grizzly bear, spotted owl, snail darters, whooping cranes, condors, and various whales. There are now over 1200 species listed as threatened or endangered in the United States. But biodiversity is about more than species. It really is about the entire hierarchy of life and its organization – from genes to species to communities to landscapes.

An *Ecosystem* is a dynamic complex of plant, animal, fungal, and microorganism communities (or biodiversity) and their associated abiotic (nonliving) environment acting as an ecological unit. Geographically, it is a bit of a loose concept in that one could define an ecosystem at various scales ranging from a small pond to a large complex landscape. It depends upon one's purpose in delineating a particular ecological system – whether for scientific study or directed management. However, the geography is less important than the focus on ecological processes, functions, and values.

The English word *ecology* is derived from the Greek word *oikos* which means *house* and is interpreted as the immediate environment of man. In essence, the term ecosystem may be interpreted as the system of natural processes that functions to support the house of man. Whereas biodiversity encompasses the biotic components of the environment, the ecosystem concept is clearly focused on processes and rates therein. These include hydrologic flux and storage, biogeochemical cycling,

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[1] Presentation given at Earth Day 2000, Alcorn State University, Lorman, Mississippi, 26 April 2000.

productivity, and decomposition. In some sense, maintenance of biodiversity can be considered one of those processes and functions and, thus, we have our first linkage.

To really make the linkages between biodiversity, ecosystems, and society clear, though, we need to introduce the concept of *ecological integrity*. Some refer to it as ecological health. In any case, it is defined by Drs. Paul Angermeier and Jim Karr as system wholeness including all appropriate elements and occurrence of all processes at appropriate rates – that is, elements of biodiversity and rates of ecological processes (Angermeier and Karr 1994). Angermeier and Karr provide a good summary statement:

> …[ecological] integrity encompasses element composition (measured as numbers of items) and process performance (measured as rates) over multiple levels of [ecological] organization; it is assessed in comparison with naturally evolved conditions within a given region, [e.g., the Mississippi Delta region] …[it is] a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes.

This is a scientific way of saying that biodiversity is part and parcel of ecological process – biotic integrity depends on process integrity and vice versa. And, present and future generations of humans and the integrity of our social systems depend, in the long run, on the maintenance and integrity of our biota and the ecological processes of which they are a part. Note also that biodiversity is more directly quantifiable than process rates and therefore frequently serves as an indicator of ecological integrity.

As a species, *Homo sapiens* can endure famines, plagues, wars, and economic crises. We have proved this many times through the ages. Certainly, these events are harsh. They take tremendous tolls in terms of human agony, misery, and mortality. But, even though the losses in terms of individuals are great, our species has survived and gone on to prosper and expand. Recovery occurred because there was enough resource base with enough biodiversity to sustain human life. On the other hand, a loss of the natural resource base to a level that is not capable of sustaining life leaves no room for survival.

Humans are the only species with the intelligence and ability to bring about changes to ecological structure and functions sufficient to significantly alter biodiversity on a large scale. No other species has had the environmental impact that mankind has had. The good news is that we also have the intelligence to recognize the results of our actions and take corrective measures.

Webster's New World Dictionary defines *Society* as: "A group of persons united for the promotion of a common aim,…; an association of individuals, as a nation, organized for mutual profit and protection; persons…. Viewed in regard to manners, customs, or standards of living…" The important question here is: how do human societies connect with biodiversity? Or, in other words, what is the value of biodiversity to humans?

Several authors have attached different sorts of value to biodiversity. These generally include the following:

- Economic Value: This includes food, medicines, and ecotourism. For example, who can deny the utilitarian values of bison to the Indian Nations of the Great Plains?

- Ethical/Moral Value: Some have argued that we are the stewards of God's handiwork and have a moral responsibility to shepherd those resources appropriately.

- Aesthetic Value: Who can deny the beauty of nature, whether one is talking about a soaring eagle, or a mountain vista.

- Ecological Value: This could be interpreted as utilitarian from a human perspective – that is, in terms of ecosystem support services.

Ecological value is put forth under the hypothesis that biodiversity is indeed essential to healthy ecosystem functioning. It begs the question, however, "how much biodiversity is enough?" Clearly, considerable biodiversity has been lost in the face of generations of human exploitation, and we still seem to be getting on well enough. So what's the problem – how many species are enough?

Here we must temper our thoughts geographically. Certain regions are naturally more diverse than others. For example, contrast a tropical rainforest ecosystem with one in the tundra of the Northern Hemisphere. Each has a measure of biodiversity, but the systems are obviously quite different.

Many ecologists agree on utilitarian grounds that most natural systems can afford to lose some species without faltering, at least in their production of plant material. Several studies performed during the past decade support this concept (Baskin 1994). Researchers at the University of Minnesota, for example, have demonstrated in laboratory and field studies that plant productivity increases as plant species richness increases, and that systems with greater species richness are more resistant to stress, such as drought. Similarly, researchers at the United Nations Tropical Soil Biology and Fertility Program in Nairobi, Kenya, demonstrated that the best way to raise productivity in a maize field is by adding a diversity of crops to the system. Trends toward monoculture clearly invite the potential for disaster via host-specific diseases, insects, or other limiting factors.

While there is a threshold in the amount of productivity gained as species numbers increase, there is mounting evidence that redundancy in ecological systems is essential to long-term sustainability. And, of course, productivity is not the only ecosystem service provided – there are other issues including water quality, water retention, and nutrient cycling. The best analogy we have heard is the rivet-popper hypothesis. In essence, how many rivets can you pop off an airplane's wing before the wing fails to function? Clearly, there is redundant engineering involved here, perhaps not unlike the species redundancy in natural systems.

Of course, biodiversity is not just about birds, bees, butterflies, bears, and such – or what some refer to as the charismatic megafauna. For example, 70 to 80 percent of soil microorganisms are unknown. Yet this represents the "eye of the needle" through which all nutrients and organic matter must pass (Baskin 1994). Implications for agronomic sustainability are immense.

Human Populations and Biodiversity

Well let's get ourselves back to Mr. Malthus. Thomas Malthus, a British economist, declared in 1799 that the human population would continue to increase geometrically (or exponentially; 2-4-8-16-32-64-….); while resources to support our species would increase arithmetically (2-4-6-8-0-12-….), the implication being that eventually humanity would run out of resources – not be able to continue to grow *ad infinitum.* Malthusean theory has been widely and enthusiastically debated, mostly by economists. The counter-argument is centered on the idea that technological advancement will save the day and provide for unlimited human development and growth. So how are we doing?

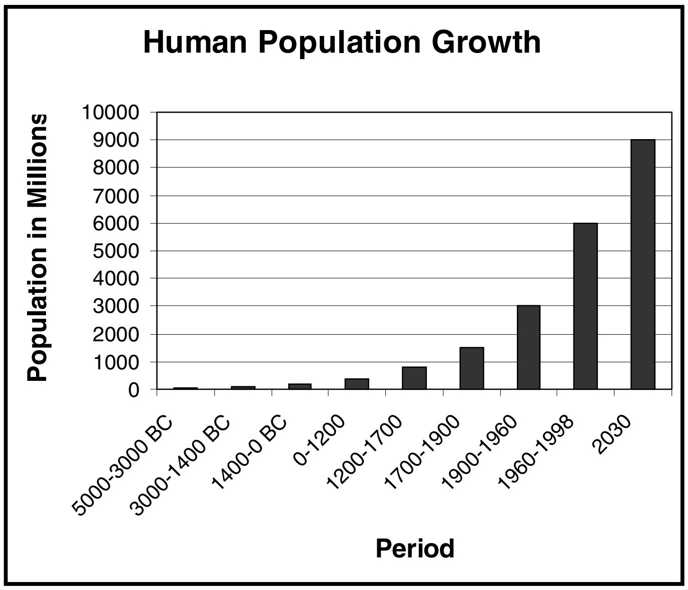

Figure 1. Human popuilation growth

Population increases do appear to be following Malthus's predictions as can be seen in Figure 1. Our doubling time has decreased two orders of magnitude since a time 5,000 years BC. And we are now expected to peak population-wise around the year 2050. We still seem to have adequate resources, due in large measure to dramatic improvements in agricultural technology and the Green Revolution that has given us high-yield crop varieties.

Yet if we look to biodiversity as an indicator of ecological health, signs of change are with us as well. We are causing major landscape modifications across the globe. Ecosystems that once supported complex assemblages of many plants and animals now support only a few. For example, the Great Plains of North America's mid-section were originally comprised of native prairie grasses that provided the infrastructure for complex communities including bison, coyotes, prairie dogs, and others. The westward settlement of the United States resulted in:

- Replacement of Native Americans with European settlers.
- Replacement of native grasses with cereal crops such as wheat, barley, and rye.
- Replacement of bison with cattle and sheep.

The tall grass prairie that dominated the eastern one-third of this region is now reduced to 4 percent of its original range (Steinauer and Collins 1996). And the Longleaf Pine communities of the southeast have been reduced to a mere 3 percent of their original range (Ware, Frost, and Doerr 1993).

The Mississippi Delta was one of the largest and most important bottomland hardwood ecosystems in the world less than a century ago. Panthers (*Felis concolor*) and black bears (*Ursus americanus*) resided there in abundance. It was not uncommon for a single bear hunter to bag over 100 bears in a single year. The original ecosystem has been replaced by cotton, soybeans, and catfish farms. The 60,000-acre Delta National Forest is the largest remaining remnant of original bottomland hardwood forest. Panthers are extinct there, while only 300 black bears remain in all of Mississippi, Louisiana, and East Texas.

Globally, rates of species extinction are thought to now have increased dramatically over natural baseline rates as can be seen in Figure 2. According to E. O. Wilson, a noted Harvard biologist, we can anticipate a 10- to 20-percent loss of all existing species over a 30-year period (Wilson 1992). Tropical rain forests alone, which represent 6 percent of Earth's land surface and harbor an estimated 50 percent of all species, may be experiencing extinction rates 1,000 to 10,000 times higher than normal.

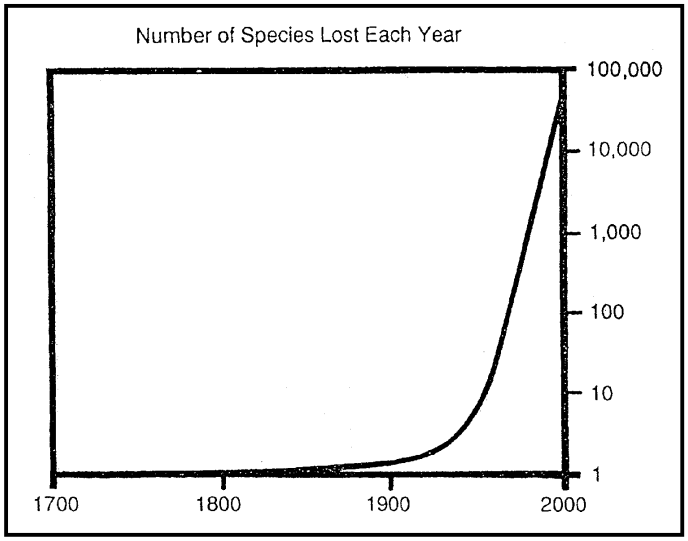

Figure 2. Estimated loss of living species from 1700 to 1992. Normal or "background" rate of extinction remained essentially unchanged for the last 65 million years — from the disappearance of the dinosaurs along with countless other species at the end of the Cretaceous era until the present century

Wilson has called what is happening a "biodiversity crisis." He says (Wilson 1989):

> The human species came into being at a time of greatest biological diversity in the history of the earth. Today as human populations expand and alter the natural environment, they are reducing biological diversity to its lowest level since the end of the Mesozoic era, sixty-five million years ago. The ultimate consequences of this biological collision are beyond calculation and certain to be harmful. That, in essence, is the biodiversity crisis.

The relationship is clear: with increasing human populations, biological diversity is rapidly falling victim to land clearing for agriculture and development, invasions of exotic species, pollution, and human-caused changes in atmosphere and climate. What does all this mean for society today?

Our prime challenge is being able to sustain and advance our quality of life globally while maintaining ecological integrity, (i.e., the ecological systems and biotic diversity upon which all life, including the house of man, depends). Some have put forward the proposition that technological advances can and will continue to mitigate loss and degradation of natural resources. So far we have been successful. How long can we sustain it?

Nonrenewable resources, such as coal and minerals, exist in finite quantities. Renewable resources, such as water, trees, and grass, are recycled and replaced naturally as long as the ecological functions and processes remain healthy. We are beginning to see the limits of nonrenewable resources, although their ultimate depletion is still several decades distant. We are beginning to see changes in ecological functions that might negatively affect replenishment of renewable resources. While some maintain that technological advancement will continue forever, others are beginning to realize that there might well be limits to development. How many rivets can we pop before our systems become dysfunctional?

We are faced with economic and ecological reality. This reality was addressed by Garrett Hardin over 30 years ago in his now famous treatise "The Tragedy of the Commons" (Hardin 1968). Biodiversity and ecosystems are common property resources. In the absence of external control, the classic free market system based on individual choice does not result in wise use and allocation of these resources. Profit maximizing behavior results naturally in eventual overuse and ruin. External management to overcome such market failure is key, and leads to our final points.

Ecosystem Management has been put forward in recent years as the means to address the problems we have identified here today. We distinguish this specifically from more traditional single resource management approaches that focus on the principle of maximum sustained yield. In a nutshell, its major components include:

- Participatory Ecological Understanding: There has to be a shared scientific and public (or stakeholder) understanding of the systems to be managed whether a municipality, county, state, region, or even a nation. Ecosystem management cannot rely strictly on science and we must recognize that science is not just for scientists. Public participation is essential.

- Collaborative Planning Systems: Desired future conditions for the managed system are based on an integration of ecological, economic, and social equity goals. Scientific values become only one part of the equation. Community participation is essential.

- Adaptive Management: Ecosystem management also recognizes our relatively poor understanding of ecological processes and functions, which are highly interactive and nonlinear. This necessitates incorporation of ecological monitoring systems and a planning system that allows for periodic review and management adjustments.

Implementation of such an approach requires a great deal of interdisciplinary thinking and acting. It requires integrated teams of biologists, ecologists, political scientists, economists, social scientists, and others to make it work. It places a great deal of responsibility on colleges and universities to train students in such collaborative modes of operation – somewhat out of tradition.

In closing, let us celebrate this 30^{th} Earth Day with a renewed vigor toward conservation of these God-given irreplaceable natural resources upon which we depend for human advancement and our very survival. Major changes often result from relatively minor local actions – and we must be wise enough to recognize these cumulative impacts before they occur and plan our sustainable development accordingly.

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