PART I

Sustainability and Regeneration

Chapter 1

Introduction to Sustainability

Sustainable development: *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*
—Brundtland Commission (U.N. Commission on
Environment and Development), 1987

We have lived by the assumption that what was good for us would be good for the world. We have been wrong. We must change our lives, so that it will be possible to live by the contrary assumption that what is good for the world will be good for us. And that requires that we make the effort to know the world and to learn what is good for it. We must learn to cooperate in its processes, and to yield to its limits.
—Wendell Berry, *Recollected Essays,* 1981

Basic human needs have changed very little over time. We have always needed food, energy, air, and water. The processes that meet these needs have also remained essentially unchanged. We are dependent on photosynthesis and a variety of cyclical phenomena for the continued functioning of these processes, but this has always been the case. Why, then, are we now talking so much about "sustainability"?

The answer to this question lies in the increased population of humans on earth (Figure 1-1). This book is not about overpopulation or population control. The earth's actual carrying capacity for humans is debatable. What is no longer debatable is whether humans have the capacity to significantly degrade processes on which we depend for our well-being and, indeed, our survival. There is ample evidence that we are able to temporarily or permanently disrupt these processes. In the following sections, we will consider some of the systems and processes that we need for survival, ways in which we can disrupt them, and how we may avoid such disruptions.

CYCLES AND REGENERATIVE SYSTEMS

Chemical cycles form the basis for our continued survival on earth. Photosynthesis is a process in which plants and certain bacteria trap solar energy. The energy is stored in

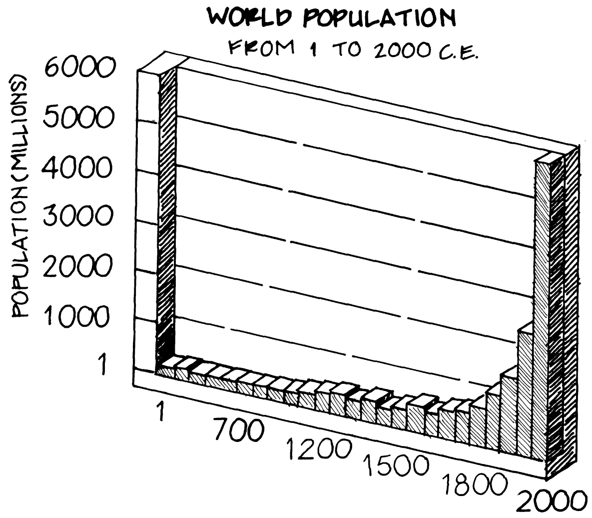

Figure 1-1 World population increase from 1 to 2000 C.E.

chemical bonds that join carbon dioxide (CO_2) to water in order to produce carbohydrate (CH_2O, a basic organic molecule) and oxygen (O_2):

$$CO_2 + H_2O \xrightarrow{\text{sunlight}} CH_2O + O_2$$

(carbon dioxide + water yields carbohydrate + oxygen)

Once bound in the carbohydrate, the trapped solar energy becomes available to other organisms that depend on it for their own metabolic functioning.

For this process to continue, there must be solar energy, adequate CO_2 (a gas, derived from the atmosphere), and water (in liquid form). Because plants and photosynthetic bacteria are living organisms, their immediate environment must be free of toxic materials and at a temperature that falls within the upper and lower limits that the plants and bacteria can tolerate.

There is not an infinite store of CO_2 in the atmosphere (air is 79% nitrogen, 20% oxygen, and less than 1% carbon dioxide). Carbon dioxide is continually replenished from a number of sources. For example, in the aerobic digestion of carbohydrates (which liberates energy stored in carbohydrate bonds):

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

(carbohydrate + oxygen yields carbon dioxide + water)

Similarly, in terrestrial environments, there is not an infinite store of water. Water must be continually replenished, usually through precipitation. Such precipitation becomes available as a result of evaporation from surface waters and condensation in the atmosphere.

None of these facts are startling. They do, however, illustrate two essential concepts. First, the processes that make solar energy, water, oxygen, and carbon dioxide available are linked. Disrupting one process can have an impact on the others. Second, the processes are "regenerative." The carbon, oxygen, and water (hydrologic) cycles can continue indefinitely because each end product (such as carbohydrate in photosynthesis) is a source for another process that occurs elsewhere in the cycle (such as carbohydrate in digestion).

DISRUPTION OF REGENERATIVE CYCLES

The linkages between natural cycles, and their regenerative nature, are both strengths and weaknesses. This finely tuned arrangement can, and has, continued essentially unchanged for vast periods of time. That is good for organisms, like us, that need stability to persist. The arrangement is apparently quite robust, having been disrupted and reestablished multiple times in the past (assuming the correctness of postulated collisions with meteors or comets that disrupted the cycles for a time). This is good for the biological history of our planet, though less good for the multitude of species made extinct by such events.

These are strengths of the linked and regenerative cycles. A weakness, however, is that the system was formed, shaped, and modified by events that occurred in earth's history. The regenerative cycles are robust with respect to most perturbations that would be expected to occur naturally (without the intervention of something unexpected), even to the point of minor cosmic collisions.

Yet this robustness probably does not extend to all possible perturbations. Very large cosmic events (such as our sun "going nova"—exploding at the end of its existence) would permanently disrupt all regenerative cycles on earth. Conceivably, the introduction of a powerful toxin or some other major change in our environment could produce the same result.

From our perspective (that of a single species), we need to be concerned about less dramatic disruptions as well. Events that do not permanently disrupt the linked cycles may, in fact, disrupt us. As a species, we depend on the stability of our environment for our continued well-being. Ironically, as our dependence on technology grows, so does our dependence on stability. Witness the recent speculation about the potential effects of a programming error that we collectively called "Y2K" and the outwardly rippling effects of the tragic events of September 11, 2001.

These issues may be valid, but they still do not explain the recent emergence of "sustainability" and "sustainable design" as areas of concern. The reason is the perception among many people that humans may be in the process of creating their own perturbations to the systems on which they depend.

HUMAN PERTURBATIONS TO THE LANDSCAPE

For much of our history, our ability to disrupt regenerative cycles was limited. Occasionally, as we congregated in towns and cities, our wastes would overwhelm the capacity of nearby waters to process the waste load (convert the organic molecules to water, carbon dioxide, and inorganic nutrients). When that happened, the waters became smelly, unsafe to use, and sometimes a source of contagious diseases. Our agricultural practices have often degraded the soil, but when that happened our ancestors would clear another site or move as a group to an unspoiled location.

As our technical proficiency increased (in agriculture, manufacturing, energy production, health care, etc.), both our population and our per capita ability to alter our environment increased. When our numbers were small and our technical proficiency limited, the worst we could do was fairly insignificant to the earth as a whole. There is a growing consensus that we are now in a position to disrupt, permanently or temporarily, some regenerative systems on a global scale. As our population and technical ability continue to expand, the likelihood of such problems occurring will increase. Like the giraffe growing up in a garage, we will eventually have to consider our limits.

Large-Scale Human Perturbations

There are a variety of ways that human activities can interrupt essential regenerative cycles. An extreme example is the potential of our weapons of destruction. Although as yet untested, the "nuclear winter" postulated to occur following a limited exchange of nuclear weapons is an example of how our activities could induce a global-scale breakdown of photosynthesis that would be similar to the posited effect of a collision with an asteroid. There are, however, other examples that are less unthinkable and more pertinent to the subject of this book.

Eutrophication (Nutrient Enrichment) of Water Bodies

As late as the 1960s, we (in the United States) regarded bodies of water as convenient receptacles of raw wastes. Much of our sewage and all of the waste that ran off our land with storm water ended up in receiving waters (streams, rivers, lakes, coastal waters). The effects of raw and nearly raw sewage on receiving waters (that is, the overwhelming of the water's ability to process such waste) was sufficiently obvious that we applied our technical ability to the treatment of sewage and avoided the problem of organic overloading at the point of discharge.

Unfortunately, implementing sewage treatment did not completely solve the problem. Nutrients (mainly nitrogen and phosphorus) from treated sewage and from other sources (farms, cities, suburbs) continue to cause organic overloading. Now, however, the problem usually occurs downstream or offshore from its point of origin.

The causes and effects are fairly straightforward. Nutrients enter waterways through the discharge of treated sewage, via runoff from farms and other managed landscapes (agricultural fields, yards, parks, golf courses). The nutrients increase the rate of photosynthesis by single-celled algae called phytoplankton, causing their populations to increase beyond normal levels. At this point, several things can happen (depending on the severity of the nutrient increase).

The increased plankton concentrations can shade plants that grow below the surface. Submerged aquatic vegetation (SAV) provides food and a place for many organisms (including commercially valuable animals) to live. Loss of SAV due to shading can profoundly affect aquatic ecosystems.

The increased nutrient concentrations can cause a shift in the types of phytoplankton that occur in an area. Shifting the types of phytoplankton, which are basic to the food chain, can affect the species that depend on them for food. Sometimes harmful species become more prevalent. "Red tide" and other undesirable organisms appear to occur more frequently in coastal areas experiencing nutrient enrichment.

When conditions are right, nutrient enrichment can cause an explosive growth in phytoplankton, called a "bloom." The bloom will eventually subside when one or more nutrients are used up (often a minor nutrient not being supplied). When this limiting nutrient is exhausted, the phytoplankton die, sink to the bottom, and are digested by aerobic bacteria. The bacteria, now experiencing their own population increase, can quickly use up the available oxygen in the water. This can lead to fish kills and greatly altered ecological systems.

The process of nutrient overenrichment, called eutrophication, has become a widespread problem in the world's water bodies. On the east coast of the United States, the Chesapeake Bay has experienced eutrophication with associated habitat loss and species alterations. In the northern Gulf of Mexico, eutrophication has resulted in a persistent area of low oxygen, called the "dead zone," of approximately 7000 mi^2. There are numerous other examples. Nutrient enrichment caused by humans is already causing widespread degradation of essential regenerative cycles.

Consequences of Eutrophication for Ecological Systems

- Eutrophication can destabilize existing aquatic systems. Complex and enduring regenerative cycles can be altered or disrupted.
- The abundance and diversity of organisms may decrease.
- In extreme cases, die-offs and habitat loss may occur.

Consequences of Eutrophication for Humans

- Loss of commercially important species
- Loss of jobs
- Introduction of nuisance species
- Aesthetic damage

Global Warming—The Greenhouse Effect

There has been an ongoing debate about the extent of human involvement in the general warming trend of the last 50 years. The complexity of atmospheric processes and uncertainty in the data have fueled skepticism about the involvement of human activities, but the consensus in the scientific community is swinging strongly toward at least some human complicity in the earth's warming. Our opinion is that the circumstantial evidence that warming is at least partly due to human activity is strong enough to accept.

The term "greenhouse effect" is based on the perceived similarity of earth's atmospheric processes to the workings of a greenhouse. In a greenhouse, the glass allows most of the visible light from the sun to pass through. Because most of the sun's radiation to earth is in the visible range, most of the incident solar radiation gets into the greenhouse, where much of it is absorbed by the plants and other solid objects. The absorbed solar radiation causes the solid objects to heat up. Some of the absorbed heat is then reradiated to the surroundings (all objects on earth radiate to their surroundings; the warmer they are, the greater the energy they radiate), but this time the radiation is called "long-wave" or infrared radiation. We can't see it, but we can measure it. Glass is not transparent to long-wave radiation. It absorbs it and reradiates much of it back in to the greenhouse. This is why greenhouse temperatures become elevated during the day.

"Greenhouse" gases in our atmosphere are analogous to the glass of a real greenhouse. They allow short-wave (visible) solar radiation from the sun to pass to the earth's surface but absorb a portion of the long-wave radiation that the earth radiates back toward space. Constituents of the atmosphere that behave this way include water vapor, carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons, among others.

The earth's atmosphere has behaved like a greenhouse from its early history (water vapor and carbon dioxide have long been present). In general, this has been a good thing. Trapping and holding solar radiation has helped to moderate and stabilize the earth's climate, which has been beneficial to life. In the vast coldness of space, being able to hold onto heat can be very helpful.

Being a greenhouse can become a problem, however, if the earth retains too much heat. The regenerative cycling of nutrients, gases, and water often includes essential biological components (plants, bacteria, and other organisms). Many organisms thrive only within fairly narrow temperature ranges. Shifting temperatures out of these ranges can seriously impair cycle functioning. The impairments may be temporary (until the population adapts or is replaced by another population that fulfills the same ecological role). There may be permanent impairment (if replacement species function at a significantly different level or if the original population persists impaired). There may be complete loss of function (if no other species fulfills a similar role in the cycle or if other factors change the nature of the habitat).

In addition to directly affecting living organisms, warming may indirectly alter habitat and cycle functions. Temporary changes in ocean currents, blamed on ocean warming, have reduced nutrient contents in areas that have historically supported large populations of fish. Loss of the nutrients reduces the amount of food that supports such populations, thus decreasing population numbers. This phenomenon, characterized by a flow of unusually warm waters, called "El Nino," has caused temporary declines in fisheries located in the eastern Pacific (mainly Peru, Ecuador, and Chile).

As discussed earlier, the large human population and high degree of specialization in our cultures make us particularly susceptible to the effects of disruptive events. Impairment of agricultural production, for the same reasons mentioned, is also a cause for concern in the event of warming. Rosy scenarios ("production will increase due to carbon dioxide enrichment"; "the corn belt will become the rice belt") ignore the interdependence of many factors inherent in agriculture. Complex interdependent systems, such as agriculture, may take more time to recover from perturbations than humans can afford. It should also be noted that this argument ignores the catastrophic scenarios that are often included in discussions of global warming (melting ice caps that may cause loss of coastal habitat; increasingly violent weather patterns due to the increased energy content of the lower atmosphere; increased prevalence of droughts and floods).

Consequences of Global Warming for Ecological Systems

- Loss of populations and diversity as temperatures exceed species' tolerance
- Population shifts with uncertain effects on the previous habitat functions
- Altered weather patterns and ocean currents

Consequences of Global Warming for Humans

- Potential disruptions to agriculture
- Potential disruptions to fishing
- Some loss of habitat
- Increasingly violent weather patterns

This chapter has discussed two ways in which human activities can affect regenerative cycles. There are many other examples (heavy metal pollution, the effect of DDT on various systems, and degradation of the protective ozone layer, among others). But this book is not about "gloom and doom." It is about finding ways to live within the rules that govern regenerative cycles or, failing that, to minimize the extent that we stray from those rules.

LEARNING TO LIVE WITHIN EARTH'S LIMITS: SUSTAINABILITY AND SUSTAINABLE PRACTICES

Sustainability literally means the ability to persist; the capacity to continue. When applied to the relationship of humans with their environment, sustainability means the ability to persist for an extended time period; for as far as we can see into the future.

There are (at least) two aspects of sustainability to consider. First, to persist as a species, we must meet our basic needs (food, water, shelter, and so on). Second, to be indefinitely sustainable, we must avoid "killing the goose that laid the golden eggs." We must, as Wendell Berry pointed out, *make the effort to know the world and to learn what is good for it . . . to cooperate in its processes, and to yield to its limits.* Only by learning to live within these limits can we achieve sustainability.

The remaining chapters of this book address sustainable practices. A sustainable practice is a method to meet a basic human need that is consistent with sustainability. The practices presented in this book are quite diverse, but they share common elements, including:

- Use of resources that are renewable
- Creation of wastes that become resources for other processes
- Use of resources and creation of wastes at rates that are consistent with the rates at which resources become available and wastes can be processed

Environmentally sustainable practices are like the pieces of a puzzle that, taken as a whole, can help to make us sustainable.

Can we learn to *cooperate in* [the earth's] *processes, and to yield to its limits?* Of course we can. Humans are remarkably adaptable creatures. The knowledge base of "how to" information is broad and growing. The good news is that many sustainable practices are relatively easy and inexpensive to implement. The real question is: are we willing to change our habits? We believe that, with knowledge, all things are possible. The purpose of this book is to put useful knowledge before the reader in a form that is convenient to use. The chapters provide references to a broad range of materials on sustainable development and regenerative practices. We believe that people want and need this information. The measure of this book's success will be whether it proves to be a good conduit for its delivery.