Ecological Services
and Ecological Release

Living things perform a host of indispensable ecological services that are useful for us - a kind of "free work" that has virtually irreplaceable economic and ecological value. If living systems had no economic value whatsoever, the very fact that such systems are critical to maintaining life on our planet would be sufficient reason to protect them. However, if we do nothing more than evaluate earth's biota in a completely selfish way, looking for the economic and practical benefits they afford us, we begin to understand that earth's living systems provide important *ecological services* that some theorists erroneously assume constitute "business as usual."

Some such ecological services provide us with <u>food</u> and <u>oxygen</u>, while others moderate our climate, generate our <u>rainfall</u>, *pollinate* the plants that produce our food and oxygen, and <u>fertilize</u> our soils. Still others help break down, cleanse, and recycle wastes. These and many other types of "free work" have practical economic and environmental value. And they have taken place for so long and are so ubiquitous that most of us simply take them for granted. Like many important things in our lives, however, we will miss them most when they are gone.

Food, Oxygen, Pharmaceuticals, and Rainfall

Through photosynthesis, plants produce the food that we eat and the *<u>oxygen that we breathe</u>*. Each year, in addition, they help combat the greenhouse effect by removing billions of tons of carbon dioxide from earth's atmosphere. Wild plant populations also constitute a vast repository of genes and genetic information that scientists can use to impart disease resistance, drought-tolerance, abundant yields, vigor, salt-tolerance, and temperature-tolerance to our crops.

The plants of earth's rainforests and their pollinators also help maintain nature's genetic storehouse of pharmaceuticals. For example, one species of rainforest plant synthesizes D-tubocurarine chloride, a chemical used as a muscle relaxant during open-heart surgery (Raven, et al., 1986). And the unimposing, weed-like flower called the "periwinkle" (*Catharanthus roseus*) produces vincristine and vinblastine. In the 1960s, these plant compounds were found to be powerful weapons in treating Hodgkin's lymphoma and acute leukemia. Before researchers discovered the lowly periwinkle's medicinal secrets, approximately 80% of patients afflicted with Hodgkin's lymphoma died, while today 90% of such patients survive (ibid). Sylvia Mader (1996) notes that "one-fourth of the medicines we currently use come from tropical forests," with still others, of course, derived from marine organisms and/or microbes.

Forests, as well as vascular plants in general, also help generate rainfall and maintain climate. <u>Rainforests, for example, make their own rain each day</u> by the transpiration of tons and tons of water. During the summer in temperate latitudes, an average-sized maple tree releases 200 liters of water per hour into the atmosphere (Campbell, et al., 1999). This transpiration process is so efficient, that water that is in the soil in the morning can enter a plant's roots, travel up the plant body, and be pulled from its leaves and into the atmosphere in time to fall as rain that same afternoon. Water moves up through the plant bodies at rates up to fifteen meters *per hour* (ibid). Thus, when we cut down the trees of a rainforest, transpiration of water into the atmosphere is diminished accordingly and the rainforest further deteriorates as the climate becomes ever drier. We thus see an ecological service in which undisturbed ecosystems help maintain both rainfall and climate.

The Lungs of the World

The vast Amazon rainforest and other wet tropical forests of the world are so old, and so extensive in area, that they are sometimes described as "the lungs of the world" – taking in many billions of tons of carbon dioxide from the atmosphere and, through their photosynthesis, "exhaling" billions of tons of the atmospheric O_2 that we breathe. In addition, they are home to earth's greatest store of biodiversity – from lowland gorillas and chimpanzees to forest elephants and Sumatran rhinos. Just one corner of Peru's Manu National Park, for example, is home to 1300 species of butterflies.

Yet, as biologist Edward O. Wilson writes, mathematical models "suggest that a tipping point exists that…could cause the forest ecosystem to collapse" (2002). He notes that the moist tropical forests of Indonesia "may be closely approaching the critical damage levels predicted by theory. Eighty percent of the forest cover has been committed to logging and replacement by oil palm and other plantations, and rapid clearing is underway." Similarly, referring to the forests of Borneo in 2002, Wilson reports that "many of the dipterocarp species have failed to reproduce at all since 1991, even in completely protected reserves" (ibid).

Estuaries, Aquifers, and Fisheries

Marine estuaries such as salt marshes and tropical mangrove estuaries act as "nurseries" for a host of important marine creatures such as shrimp, oysters, crabs, clams, and fish. At the same time, wild northern rivers, when undisturbed, sup-port massive annual salmon runs. In other words, marine, estuarine, and freshwater biomes produce shrimp and other seafood for us each year. We do not have to plant, tend, or fertilize these systems, but simply harvest their produce each year. *All these systems carry out all this work for us for free* – if we just leave them alone, and if we do not over-harvest the biota that they produce.

But all is not well in our rivers, lakes, oceans, and seas. In America's Midwest, the underground waters of the Ogallala aquifer are used to irrigate America's "breadbasket of the world," yet aquifer water levels are falling as water is pumped faster than it is replenished (Cohen, 1995). And in China, for example, beginning in 1972, "the Yellow River channel has gone bone dry almost yearly through part of its course in Shandong Province, as far inland as the capital, Jinan, thence down all the way to the sea," and, in 1997, "the river stopped flowing for 130 days, [and] then restarted and stopped again through the year for a record total of 226 dry days" (Wilson, 2002). And at the same time, between 1965 and 1995 the water table beneath Beijing fell 121 feet, while up to 80% of [China's] major rivers no longer support fish (ibid).

Meanwhile, marine fisheries underscore a straight-forward biological principle: When we harvest any population faster than its ability to replenish itself, the population collapses. In his recent book, THE WORLD ACCORDING TO PIMM (2001), biologist Stuart Pimm examined the historic Grand Banks cod fishery off the coasts of Canada and New England. How does one go about destroying a fishery that has been thriving for nearly four hundred years?

First, increase the number of fishermen and the number of nations that exploit the resource. Then provide each group with modern boats, sonar, and equipment, and then be sure that your fleets become more efficient at finding and catching the fish than the fish are at reproducing and maturing. Utilizing this recipe, an annual cod catch that historically hovered near 200,000 tons per year grew to 800,000 tons and then precipitously. By 1991, the catch dropped to approximately 130,000 tons, forcing Canada's Department of Fisheries and Oceans to announce a two year closure of the cod fishery (ibid). This, in turn, added 19,000 fishers and plant workers to an unemployment rate that already stood at 22%, drove young people from their villages in search of better futures elsewhere, and sent unemployment benefits rocketing to half a billion dollars. As we add our 7^{th}, 8^{th}, and 9^{th} billions in the years ahead, the collapses that have characterized the cod and whale fisheries are harbingers of similar things to come. As Pimm asks, "Why do we destroy what we should keep?”

Plankton, Cycling, and Genetic Libraries

Ocean studies also remind us that assorted phytoplankton produce more than half of the O_2 that we breathe and play important roles in earth's temperature and cloud cover regimes. For example, Prescott, et al. (1999) explain that the cycling of sulfur in the world’s oceans includes dimethyl sulfide (DMS), an algal osmolite [that] can be released to the atmosphere and comprises 90% of the volatile sulfur compounds in the sulfur cycle. When oxidized, its “products can influence...earth's temperature and cloud formation.”

Microorganisms are essential components of every ecosystem and perform a host of ecological services, "playing roles in biogeochemical cycling, decomposition processes, and successional interactions" (Prescott, et al., 1999). Several genera of bacteria, for example, lock atmospheric nitrogen into nitrates that are utilized by plants, thereby *fertilizing* earth's crops, soils, and wildlands – for free. This service supplies the nitrogen atoms needed to synthesize the very molecules of life such as DNA, RNA, amino acids, proteins, enzymes, and a host of others. In addition, microbes and fungi help cleanse, decompose, and recycle our wastes and play other "essential roles in the transformation of carbon, nitrogen, sulfur, and iron" (ibid).

Organisms are also repositories of a vast genetic library that is housed in the DNA of all living things. With the advent of DNA sequencing, we can now access and read thousands of genes of potential use in agriculture, industry, and medical genetics. And many of these genes also constitute remnants of ancient metabolic pathways. Caution alone counsels conservation of the wilderness, reefs, microbes, and forests that house and sustain these storehouses and not allow them to be destroyed for short-term economic gain. Earth's biota have provided such services to our planet and to humanity for millennia and they will continue to do so in the future -- so long as we leave them alone *and do not destroy the web of life that allows them to exist.*

There are also other practical benefits that humanity derives from life's metabolic diversity. Today, for example, the biotechnology known as the polymerase chain reaction (PCR) is used to synthesize multiple copies of tiny DNA samples. A bacterium, *Thermus aquaticus*, gave us the enzyme used in polymerase chain reactions (Prescott, et. al., 1999). Another process called bioleaching employs populations of the bacterium *Thiobacillus ferrooxidans*, that allow us to recover "…up to 70% of the copper in low-grade ores." Recent estimates indicate that about ten percent of U.S. copper is obtained by “bioleaching ore through the activity of bacteria such as *Thiobacillus*...." (ibid).

Recently, too, techniques have emerged that utilize plant hybrids to help decontaminate soils and mine tailings polluted with heavy metals and various organics. As an example, sites that are "...so contaminated that not even weeds grow have been planted with 3100 hybrid poplar trees" (Dobson, et al., 1997). This use of plants to remove metals and radionuclides from soils is known as *phytoextraction*. Repeated crops are grown on the contaminated soils, and, when harvested, the biomass is incinerated, allowing the contaminants to be recovered from the ash. Strontium-90 and cesium-137, along with metals such as cobalt, lead, zinc, and copper have been recovered in this way, providing an imaginative tool for the emerging discipline of restoration ecology (ibid).

Pollinating Crops and Rainforests

Other important ecological services involve the role of bees, butterflies, hummingbirds, and similar organisms in the pollination of essentially all of earth's flowering plants. Today, life on earth would be profoundly different without the tireless "free work" of such species. As an example, imagine attempting to pollinate, each year, the bulk of earth's 250,000-plus species of flowering plants (including many forest trees, and plants such as orchids, many agricultural crops, and the rainforests of the world) - by hand. Or try to imagine the cost of pollinating by hand, each year, all the vegetables in California's truck farms, all the orange groves in Florida, all the cacao trees in Africa, all the coffee trees in Brazil, and all the olive trees in southern Europe. All of this work represents an ecosystem service that benefits humans and all other life on earth, and it is accomplished free of charge, *as long as we do not destroy the species and systems* that allow it to occur.

Jackrabbits, Sea Otters and Ecological Release

Living things also help control pest populations. During one summer not too long ago, a population explosion of jackrabbits occurred in Wyoming. Newspapers ran the story along with a photograph of a family attacking a swarm of jackrabbits with baseball bats, brooms, rakes, and shotguns. What had happened? Many ranchers were concerned because coyotes were occasionally killing some of their sheep. To reduce these losses, ranchers put out poisoned carcasses to kill the coyotes. When the coyotes died, however, local jackrabbit populations soon underwent a population explosion. One lesson this offers is this: Even though coyotes kill an occasional sheep, it turns out that jackrabbits are one of their primary foods.

The above account of jackrabbit numbers illustrates a biological phenomenon known as **ecological release -** a population explosion that occurs when a key predator or competitor is removed from a system. During the dust bowl years in Oklahoma, dust storms suffocated cattle when their lungs became coated with dust. Archival film footage from the era also depicts similar outbreaks of thousands of jackrabbits resulting from an ecological release that occurred when severe dust storms suffocated not just the region's cattle, but also its coyotes.

During the mid-1900s, as fleets of mechanized whale ships decimated earth's populations of baleen whales (driving many whale species to near extinction), populations of tiny, shrimplike *krill* underwent ecological release as a result. The krill were the principle food of the baleen whales, and in the absence of predation, their numbers increased explosively.

Another example of ecological release took place in California. In the mid-twentieth century, when populations of California sea otters began to decline, many of the state's offshore kelp beds also began to disappear. How could fewer *sea otters* possibly reduce *kelp beds*? It turns out that sea otters feed on a number of marine organisms, but among their favorites are sea urchins, which are pincushion-like animals that crawl about on the sea floor grazing on things such as kelp. Because sea otter populations fell, sea urchin populations underwent an ecological release. Then, as the urchin population skyrocketed, thousands of urchins began to decimate offshore kelp beds (Duggins, 1980; Estes and Palmisano, 1974).

Humans and Ecological Release

These accounts of ecological release in the natural world help us to understand ourselves. Having seen ecological release in other species, we can now see that this same thing has happened to our own species over the past two centuries. For our ancestors, many predators and competitors existed. An example of important competitors are those insect populations that compete with us for our crops. But the predators that did most to hold our past numbers in check were the pathogens that cause disease. With each advance in agriculture and medicine, and with each new pesticide and antibiotic, our species has escaped the natural influences that once controlled our numbers. As Mader points out, the world's most developed countries "doubled their populations between 1850 and 1950. This was largely due to a decline in the death rate" (Mader, 1996). Today, however, many of the world's poorest nations are doubling their populations in as little as 25-30 years. Thus, while most Western nations had essentially 100 years to adjust to their population growth, today, in many parts of Asia, Africa, and the Middle East, some nations, which are behind already, are faced with both improving ***and*** DOUBLING every aspect of their societies in short *two-or-three decade spans of time*.

A sure recipe, it would seem, for poverty, humanitarian crises, chaos, lawlessness, instability, and failed states.

Ecological release often has unanticipated ramifications and impacts. We just saw, for example, that when California's sea urchins underwent release, their exploding thousands began to destroy the offshore kelp beds in which they lived. While the sea urchin population explosion was enormous, it was at least localized. And even though its effects were also enormous, they too were localized. The problem, however, is this: Our own population explosion is not a localized event. Instead, it is planet-wide in both its scope and implications.

An Experiment With "Biosphere 2"

Suppose that we label our functioning planet earth with its life, its multitudes of interacting species, and its climatic stability as a self-contained "BIOSPHERE 1." *How resilient are its living and environmental systems?* And could a miniature, enclosed, self-contained duplicate be built that might support a team of astronauts on, for example, the surface of Mars? Could human ingenuity construct a miniaturized system that would mimic the functioning of the earth's living systems as a whole?

As an experiment to test these ideas, a 3.15 acre enclosed dome called BIOSPHERE 2 was constructed in Arizona beginning in 1984. Over the next few years, the closed system was fitted with miniaturized versions of rainforests, ponds, deserts, oceans, grasslands, and marshes. Finally, in 1991, eight human "biospherians" entered the enclosure to begin a two-year sojourn physically sealed off from the outside world. The air, food, water, and waste-cleansing machinery that they would need to survive would have to come from the plants, animals, and microbes that inhabited Biosphere 2 with them. In an article entitled *Biosphere 2 and Biodiversity: The Lessons So Far* (1996), researchers Joel Cohen and David Tilman reported the initial findings, some of which we summarize below: In sixteen months, oxygen levels fell from 21% to 14% so that before the experiment ended in 1993, oxygen had to be pumped in. Meanwhile, carbon dioxide levels skyrocketed, with large daily and seasonal oscillations even as N_2O levels in the atmosphere rose to concentrations that could impair or damage the human brain.

Services That Most People Take for Granted

During the experiment, more than 75% of the vertebrate animal species went extinct as did a majority of introduced insect species. Shockingly (your author's term) *every one of the pollinator species became extinct*. This meant that every plant species dependent upon insect or animal pollinators (in other words, almost all of them) "had no future beyond the lifetime of the individuals already present" (ibid). (If all pollinator species become extinct, the ecosystem involved faces looming collapse.)

On the other hand, populations of certain species such as katydids, cockroaches, and especially crazy ants (*Paratrichina longicornus*) were running everywhere. And the vines were so aggressive that they threatened to overgrow and kill other plant species including the food crops needed to support the humans. To survive and complete the experiment, the biospherians "had to make enormous, often heroic, personal efforts to maintain ecosystems services that most people take for granted in natural ecosystems," yet, "even these efforts did not suffice to keep the closed system safe for humans or viable for many nonhuman species" (ibid). Cohen and Tilman thus report their major retrospective conclusions as follows: "At present there is no demonstrated alternative to maintaining the viability of the earth. No one yet knows how to engineer systems that provide humans with the life-supporting services that natural systems produce for free."

Ecological Services – Ecological Release

We thus see that living things perform a host of ecological services that help maintain life, natural systems, and moderate conditions on our planet. They provide the oxygen that we breathe and the food that we eat. They remove billions of tons of carbon dioxide from earth's atmosphere. They generate clouds and rainfall and moderate our climate. They help fertilize earth's soils, pollinate our crops and rainforests, and cleanse and recycle wastes. They control pests and provide the genetic resources that we employ to impart drought-resistance, abundant yields, and vigor to our crops. They provide us with compounds that benefit agriculture and serve as pharmaceuticals. Finally, when studied with ingenuity, they provide us with tools we can use in fields as diverse as biotechnology or restoring polluted soils.

These examples underscore the following: The ecological services presently performed by earth's biota have economic, medical, genetic, agricultural, climatic, and survival value. Other species have provided services like these to our planet for millions of years – and they will continue to do so in the future so long as *we do not destroy the web of life that allows them to exist.*

Despite their importance, today earth's systems are under unprecedented assault as we log and clear-cut forests, strip-mine the sea of its living resources, consume the products of civilization, and pollute earth's air, water, and soils with our societal wastes. And all of these impacts will assuredly worsen as we add a seventh, eighth, and ninth billion by 2050. Finally, this chapter has introduced examples of *ecological release*. Advances in medicine, health care, and agriculture have allowed our species to temporarily escape the biological pressures of disease that once held our numbers in check, and the population explosion we have experienced in the last 180 years constitutes a classical example of ecological release.

In his famous book, *Principles of Political Economy* (1848), the British philosopher John Stuart Mill wrote with eloquence about another important ecological service:

> A population may be too crowded, though all be amply supplied with food and raiment. It is not good for man to be kept perforce at all times in the presence of his species. A world from which solitude is extirpated is a very poor ideal. Solitude, in the sense of being often alone, is essential to any depth of meditation or of character; and solitude in the presence of natural beauty and grandeur, is the cradle of thoughts and aspirations which are not only good for the individual, but which society could ill do without. If the earth must lose that great portion of its pleasantness... that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger but not a better or a happier population, I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it.

A continuation of today's demographic tidal wave *may constitute the greatest single risk that our species has ever undertaken.*

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- Ecosystem services and Ecological release
- J-curves and Exponential progressions
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