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Chapter Fourteen

BIODIVERSITY LOSS: A Problem or Symptom of Our Time?

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INTRODUCTION

On the banks of the Sucusari, a tributary of the Napo River in the lowland rainforest of the Peruvian Amazon, lies a small village of Orejone Indians. Like many indigenous people in this region, until recently they coexisted with nature harvesting only enough meat, fish, fruits, and plants to sustain themselves. The Orejone, under external influences, have stepped up their hunting and gathering efforts to beyond subsistence levels and currently are selling fruits and meats to markets in nearby Iquitos, Peru (population of approximately 650,000). The animals they capture and harvest are rare, and in many cases are endangered and illegal to hunt. Fruits from trees such as the Moriche palm (*Mauritia flexuosa*), Leche Caspi (*Couma macrocarpa*), and a host of other edible fruit bearing species are harvested by cutting the entire tree, a practice apparently acquired from Spanish explorers hundreds of years earlier. Harvest rates of animals and plants for Orejone village subsistence and export to Iquitos for cash have greatly exceeded the rates of resupply; consequently, these resources have become increasingly scarce in areas adjacent to their village. To maintain their way of life, the Orejone now hunt and forage unsustainably on adjacent lands. The situation is further complicated because bordering all sides of their land is the Amazon Biosphere Reserve that was recently created to protect one of the most

unique and biologically diverse areas on the planet. Consequently, the reserve is now experiencing a loss of plant and animal species the ecological significance of which is currently unknown. Attempts to convince the Orejone to relinquish their unsustainable harvest practices on the reserve have met with little success. To date, the situation remains unresolved and this places the future of the Orejone as well as the Amazon Biosphere Reserve in jeopardy.

The conflict described above is easily dismissed as an example of an indigenous people whose way of life is out of step with the modern world. However, it is much deeper. The state of the Orejone is very much like the state of the developing world in microcosm. "External" market influences encourage short-term overexploitation of resources and environmental degradation to the point that local subsistence becomes tenuous at best. Further, how different is this from the state of the developed world where market forces affect the same trends?

Our point is that at the root of every environmental dilemma now facing humanity, whether local, national, or global in scale, is a people out of step not with modern world technologies and economies, but with the natural world and the ecological reality of natural economies. Within "environmental crises" exists the deeper questions of human connections to the Earth and all living things. Environmental crises reveal the present nature of our own species - what we value, our place in nature, and the kind of world we want to create for ourselves and for our children.

This chapter examines the underlying causes that promote and ultimately threaten our greatest of resources - biological diversity. We examine the historical significance relative to the current disappearance of species and examine the need to promote measures that will lesson species extinction. Additionally, we provide some insight into the problems that surround the complex issues of preserving species and explore the rationale for lessening the current crisis by creating educational programs that will empower the greatest of human resources, our children.

THE PROBLEM OF BIODIVERSITY LOSS

By most accounts, we are currently experiencing a loss of species worldwide which rivals anything documented in the history of the planet. There exists controversy with regard to just how fast species are disappearing but it is likely that biodiversity is being eroded at a rate several orders of magnitude greater than anything experienced in geologic history (Mann 1992), and rates of species extinction are projected at 2.8% over the next ten years (Reid 1992). More specifically, an estimated fifth of all species of all groups may likely disappear in the next 30 years in warmer areas of the globe where human populations are likely to double (Raven and Wilson 1992). Depending on estimates of global species diversity, this could amount to the elimination of millions of species worldwide. The 50% of all terrestrial species native to tropical forests are especially at risk.

These currently are being eliminated by unsustainable practices employed in agricultural and timber harvests. An estimated one half of these forests will be gone by the year 2020. This is especially disturbing when one considers that the extent of area covered by tropical forests is currently a scant 7%, a reduction of nearly one half the original area. If most of the tropical forests become degraded as anticipated to a mere 10% of their original extent over the next 50 years, the number of species driven to extinction will rise dramatically. Countries such as Ecuador, Brazil, the Philippines, Madagascar, and a multitude of others in central Africa and South and Central America are well ahead of schedule in this regard.

When compared to countless episodes that have historically impacted spatial and temporal variation in biological diversity, the disappearance of species over the past 100 years reveals a distressing pattern. If current estimates are correct, we are losing as many as 27,000 species every year due to anthropogenic activity resulting from habitat destruction and fragmentation (Wilson 1994). This rate exceeds the geological background extinction rate due to natural causes by 100 to 1000 times, and over the next 10 years could total as much as 15% of all species on Earth (Primack 1993). Although the number of estimated species worldwide ranges from 3-30 million (Erwin 1982, May 1992, Sittenfeld and Villers 1993), these represent a mere fraction of all organisms that have passed through Earth's history (Raven and Wilson 1992). Although comparisons between present conditions with the fossil record are hindered by temporal and taxonomic (phylogenetic) scale a few generalizations can be drawn from what data exist. We have reasonable evidence that at least five mass extinction episodes occurred during the Paleozoic and Mesozoic eras. Four occurred during the Ordovician, Devonian, Triassic, and Cretaceous (at 440, 365, 210, and 65 million years ago, respectively), and during each of which 12% of the marine families worldwide were eliminated (Wilson 1994). The fifth, which accounted for the disappearance of some 54% of marine families or an estimated 77-96% of all marine animal species (Erwin 1990), occurred during the Permian some 245 million years ago. A corresponding decrease in terrestrial species accompanied their marine counterparts but documentation in the fossil record is far less comprehensive. The disappearance of species at these levels redirected the course of evolutionary history on a global scale. The radiation of species into open niches that followed mass extinctions allowed levels of biological diversity to return to pre-extinction levels, if not higher; however, biodiversity recovery is thought to have taken several million years (World Resources Institute 1994). When placed in this context the time frame for biodiversity recovery is far too long to be of any significance to humans. One of the best documented examples of mammalian extinction took place during the Pleistocene where the elimination of large mammals spanned about 9,000 years (Martin and Kline 1984). Mammalian diversity has never approached levels that existed during this period nor will they in the foreseeable future due to human occupation. Whatever the extent of the current crisis past records provided by fossils suggest that the recovery rate will be in the order of at least thousands of years even under circumstances that suggest no further disturbance (Jablonski 1991).

Does this warrant concern? If one examines the fossil record certain patterns become apparent. Species appear and persist on average from one to ten million years before succumbing to forces such as climate change, the introduction of a competitor species, natural disaster or other agents of change (Wilson 1994). The introduction of humans into tropical regions has increased extinction between 1000 and 10,000 times considering a reduction in area alone (Wilson 1994). The combination of other factors resulting from the proliferation of humans further augments the rate of species loss. The net effect is the loss of species at levels never witnessed in geologic history. Since 1950, one third of the forests has been cut without replacement and one fifth of all topsoil has been lost (Raven 1994). As we progress toward 6 billion people, 75 billion metric tons of topsoil are lost annually (Pimentel et al. 1995). This jeopardizes the basic fabric of our living endowment that provides us with stability, viability, and productivity. Perhaps most distressing is our lack of understanding relative to the ecological relationships which will vanish before recognition.

Why is the magnitude of the current episode so profound? Unlike the extinction spasms caused by natural forces, the current situation is being orchestrated by anthropogenic activity. The advent and expansion of human settlement has promoted the extinction of species on every continent in relatively little time. Unsustainable harvesting practices, deforestation/forest fragmentation, the displacement of species due to habitat destruction, the introduction of exotic species, overgrazing, and human overpopulation along with resultant pollution represent problems that affect the loss of planetary biodiversity. Independently or often synergistically, these act as a formidable barrier that can reduce the biotic potential of species thus hindering their ability to survive and reproduce at levels that foster stability.

The social, economic, and political details of the causes of these losses are as complex and multifaceted as are the labyrinths of legislation and international accords proposed in remediation. Yet, most extinctions share a common theme - they occur when intact primary forest is clear-cut and/or otherwise severely degraded on a large scale during the initial stages of habitat management by humans. The currently accelerated rate of global biodiversity loss especially in the tropics is largely a proximate consequence of these "development" activities occurring in primary forest and the use there of heavy machinery and other capitally intensive technologies to cut and process trees very efficiently.

HOW MANY SPECIES AND WHY DOCUMENT THEM?

Despite the more than 250 years of taxonomic research our best estimates suggest that between 3-30 million species exist on the planet (Erwin 1982, May 1992). The lack of an archival system which is centralized prevents us from being able to determine the exact number of those identified to date. However, current documentation suggests that approximately 1.4-1.8 million species have been identified (Ehrlich and Wilson 1991, Raven and Wilson 1992, May 1992), most of which occur on land in the tropical and temperate regions of the Earth. In some cases we know a great deal about these organisms but in other cases we know almost nothing. Information regarding mammals, birds, fish, and some plants are fairly well documented. The more obscure groups such as insects and microorganisms (bacteria, fungi, protozoans, and viruses) are the least well documented and understood. We have recently come to realize that these are far more numerous than once realized.

The importance of being able to document species can provide us with a means of determining species richness. This reduces the guess work in trying to designate which areas are the most biologically diverse. We can then use this information to develop policy about conservation management. By designating preserves and refuges in areas where endemism is high we protect the active processes that drive contemporary evolution. This is especially important as we look to these areas in the future for finding new or improving existing agricultural stocks using the genetic resources from natural populations. To destroy these areas is to eliminate the biological nurseries of the planet. The unfortunate fact that tropical forests continue to be exploited at ever increasing rates puts 40-90% of the world's species at risk (World Resources Institute 1994).

WHAT IS BIODIVERSITY AND OF WHAT VALUE IS IT?

The term biological diversity or "biodiversity" has gained considerable attention since the mid-1980's and has been equated with species richness. Its meaning is as varied as the different cultures that have collectively advanced through time by exploiting it. Biodiversity represents biological variety, a "richness" in different kinds of species, and a diversity of interactions within and between organisms collectively at work in the environment. It is ever-changing because of the dynamic interactions among species with each other and with the physical environment. Extant biodiversity is the outcome of eons of ecological interactions of the past, and holds the future evolutionary directions for all life forms on the planet.

One somewhat narrow way to determine the "value" of biodiversity is to assess the economic value of the products of industries designed to exploit it - i.e., of what utility is biodiversity? Biodiversity can be viewed as a form of "natural capital" available in the environment for exploitation by us. Other forms of natural capital include other naturally occurring resources such as raw materials (fossil fuels and minerals), clean water and air, agricultural land (e.g. adequate soil and other conditions for crops, livestock, etc.), fisheries, forests, sunlight, wind, geohydrodynamic, geothermal, etc. In fact, essential human needs are met by technologies developed to exploit biological wealth either from living organisms (e.g. food, fibers for textiles, wood and paper, etc.) or the fossilized

products of previously living organisms (coal, oil, and natural gas). As with many of the other forms of natural capital, biodiversity is renewable as long as its exploitation does not degrade its capacity for resupply. However, biodiversity is unlike other forms of natural capital in that its "value" in terms of the goods and services provided are extremely difficult to quantify. Below, we describe several ways in which biodiversity serves as natural capital.

Firstly, all of our domesticated plants and animals originated from wild stocks, and currently only three grains (corn, wheat, and rice) provide the basis for meeting the vast majority of the caloric needs of the world's population (Brown and Kane 1994). The tremendous diversity of plants that remain untapped as potential food sources leaves us with many agronomic opportunities for expanding food outputs. Our future innovations in agricultural staples to meet the needs of our growing world population must consist of plants and animals directly bred from existing wild stocks and perhaps also our existing staples may be genetically engineered to include important adaptations inspired by, or lifted from, current wild stocks (e.g., adaptations to drought, heat and insect resistance, or to high salinity and seawater inundation).

Secondly, currently a large fraction of all pharmaceuticals, many of which are important anti-cancer drugs, were originally isolated directly from seemingly insignificant plants and animals, mostly tropical in origin (McMichael 1993). After research, development, and marketing, the "value" of these products is clear, yet the market value of the plot of land where a rare plant population occurred within which an important pharmaceutical was discovered was obviously unaffected by this unknown benefit *a priori*. The current market costing scheme is simply unable to incorporate the "value" of organisms whose unique medicinal or agricultural benefits have yet to be discovered. Who would have thought that an extract from the blood of the American horseshoe crab (*Limulus polyphemus*) would provide us with an efficient way of detecting bacterial sepsis and endotoxemia in humans? Horseshoe crabs were once treated as a scientific curiosity and a nuisance, however this medical discovery has elevated the status of this lowly form to that of a valuable commodity.

Thirdly, for many of the Earth's ecosystems high biodiversity is a fair indicator of intact biogeochemical cycles and pathways of energy flow. Furthermore, there is much support for the idea that high biodiversity confers a buffering to environmental perturbations and thereby contributes to ecosystem stability. Certainly, sudden biodiversity losses indicate major ecological disturbances. Regardless, our point here is that a proximate result of these intact ecosystems is the purification of drinking water and air, and the generally habitable temperature of our planet. These services are performed by the natural ecosystems of the Earth free of charge. The cost of these services to the 263,000,000 people in the U.S., if borne entirely by our technology, is staggering, even in comparison to our present national debt. Yet, the value of an intact hectare of forest in the Catskills in New York is affected much more by the market value of its board-feet and/or by its potential for development as vacation property than for its role in purifying the drinking water for the millions of people in New York City. A correctly formulated economy of natural capital use should account for all of the above concerns.

In sum, biodiversity loss resulting from forest management for wood products, whether in the tropics, in temperate ecosystems, or elsewhere, represents a squandering of irreplaceable natural capital. A sustainable management plan for any particular natural area, forest, park, watershed, airshed, etc., should involve no net loss of natural capital. That means no reduction in the goods (i.e., no local extinctions resulting in decreased biodiversity) and services (i.e., no degradation of the plant and animal communities in the soils and waters that would risk dysfunction of the purification activities of their biogeochemical cycles) provided by the ecosystem due to its management to meet our needs. Biodiversity is not just about the number of different living things to which our science has assigned different names. Biodiversity is the cause of our existence, and the careful management of biodiversity is key to a sustainable future.

GETTING AT THE ROOT OF THE BIODIVERSITY CRISIS

The global loss of biodiversity is merely one of a lengthy list of symptoms of the way in which we have designed our way of life and of the consequences of inadequate effort at ecological education for our global community. By way of life we refer to that of the developed world, which numerically represents a minority of about 10% of humanity, but accounts for the vast majority of the economic, social, political, and ethical values that collectively account for global ecological crises such as biodiversity decline. Few have provided as concise a rendering of our time as has David W. Orr (1994, p. 7):

> "If today is a typical day on planet earth, we will lose 116 square miles of rainforest, or about an acre a second. We will lose another 72 square miles to encroaching deserts, the results of human mismanagement and overpopulation. We will lose 40 to 250 species, and no one knows whether the number is 40 or 250. Today the human population will increase by 250,000. And today we will add 2,700 tons of chlorofluoro-carbons and 15 million tons of carbon dioxide to the atmosphere. Tonight the earth will be a little hotter, its waters more acidic, and the fabric of life more threadbare."

By all accounts we have an unsustainable society and a seriously degrading environment to show for it. If these trends are not soon reversed, especially if our population size fails to level off early in the next century, we will create a wake of ecological destruction that cannot be repaired within a time frame that is of any significance to human beings. Let us quickly add that we are optimistic that this situation can be turned around provided that our global community can overcome the first main hurdle - denial. Our collective denial is manifested in many ways of which we list six.

(1) Too many people deny the validity of many of the aforementioned facts of

environmental degradation, and the vast majority of our global population, as well as our social, religious, political, and business leaders, are unaware, indifferent, disemplowered, resistant, or for some other reason are unable to envision and implement corrective action (Orr 1994).

(2) Too many people deny the possibility that our exponentially growing population and our insatiable demands upon the Earth's delicate biogeochemical systems *could* cause catastrophic perturbation to the global environmental conditions that permit our lives, and our domesticated plants and animals, to continue. Further, too many people are too easily swayed by unscientific arguments put forth by those with little or no scientific training regarding the science of global climatic and ecosystem modeling.

(3) We are denying a viable future to countless organisms worldwide in a mass slaughter justified by short term economic gain. In the words of Herman E. Daly, a former World Bank economist, "there is something fundamentally wrong in treating the earth as if it were a business in liquidation" (quoted in Miller 1994). Not only are non-human species driven to extinction because their current market value is insignificant, but native peoples, especially those in tropical and subtropical areas, are finding their ways of living dispatched into oblivion with equal rapidity and dispassion. Arguments for a more accurate costing of natural resources aside (see above), there is an undeniable ethical issue at stake - what right do we have to sacrifice one kind of wealth for another? This question is no less important now as it will be when and if the world population exceeds 10 billion next century.

(4) With notable exceptions, many biologists, ecologists and environmental scientists, who are among the most highly educated members of our global society, are denying responsibility for the appropriate use of discipline-specific scientific and technological knowledge by society. This includes the advancement of environmentally destructive technology and, more importantly, sidestepping the responsibility of meeting the ecological educational needs of non-scientifically trained science policy makers, implementors of technology in agriculture and industry, and voters. For many scientists, there is the perception that silence in the socio-political arena is the price of maintaining a level of political neutrality required to maintain scientific "objectivity." However, as Rutherford and Ahlgren (1990) enjoin in an important monograph *Science for All Americans*, pure objectivity is a false goal for science because scientists are people and personal subjectivity enters many aspects of healthy scientific endeavor. In fact, important advances in science have occurred when different individual scientists brought different subjective perspectives to the same research question (see also Lewontin 1992, and Keller 1983). That scientists are truly objective is a naive view of what science is and a potentially insidious view of what science should contribute to society. According to David Suzuki (quoted in Campbell 1993, p. 243):

> "The traditional scientific paradigm is that scientists look at objects from a distance. We try to be objective and detached because if we feel an emotional

involvement in what we are examining, it colors the way we look at it. The problem with that idea is that by distancing yourself from nature, you no longer care . . . I think that's one of the great problems that we face in science: by virtue of looking at the world from a distance, we no longer have any sense of involvement."

To Orr (1994) this lack of a sense of involvement held by many practicing scientists is a key explanation for the scientific advancement of environmentally destructive technology - "without sufficient precautions, education can equip people merely to be more efficient vandals of the earth" (p. 5). Orr continues noting that the global environmental crisis "is not the work of ignorant people. Rather, it is largely the results of work by people with BAs, BSs, LLBs, MBAs, and PhDs. Elie Wiesel made the same point, noting that the designers and perpetrators of Auschwitz, Dachau, and Buchenwald - the Holocaust - were the heirs of Kant and Goethe, widely thought to be the best educated people on Earth. But their education did not serve as an adequate barrier to barbarity" (p. 7).

(5) The way of life in the developed world denies a very basic part of our evolutionary heritage - our affiliation and connectedness with the natural world and our innate *philos* for the life forms in it. E.O. Wilson (1994) refers to this as "biophilia," although "ecophilia" might be more apt. Humans have evolved over several million years to interact with the complexities of nature, and in the flash of time since domesticating ourselves, a basic piece of humanness has been eviscerated. It seems plausible that *that* missing interaction could cause critical needs of our conscious and unconscious mind to go unfulfilled (or subject to manipulation) by our present lifestyle. Would a deeply-rooted sense of incompleteness in our lives be expressed as a kind of mass selfishness and ecological denial a result of which is the environmental crises of today?

(6) Finally and most importantly, we are denying our children the promise of a future even as remotely comfortable and full of life as many of ours are now. The fact is, our children may not have sufficient supplies of adequate drinking water, breathable air, relatively inexpensive plant and animal products to eat, affordable housing and durable goods, and dirt cheap energy. Moreover, our children may never experience a rainforest. They may never wander in a wilderness unspoiled. And they may never have the opportunity to become enveloped in the sense of awe, respect, and wonder about nature that only immersion can bring. Writes Orr (1994, pp. 45-46), " I believe that most of us do what we do as environmentalists and profess what do as professors because of an early, deep, and vivid resonance between the natural world and ourselves . . . We are not likely to fight to save what we do not love." Thus, global environmental degradation will enlist fewer, not more, people whose love of nature compels them to action, and this may deny humanity its only chance to steer clear of the environmentally self-destructive path many view us now to be upon.

THE ROOT CAUSE OF BIODIVERSITY LOSS: AN UNSUSTAINABLE LIFESTYLE

Human societies transduce natural capital from the environment into human capital using technology. Of necessity, we generate waste which is returned to the environment for natural remediation and/or dilution. Three key assumptions are required for this system, and us along with it, to continue: (1) that there is an inexhaustible supply of natural capital, (2) that there is an unlimited capacity for the environment to degrade, dilute, or conceal our wastes, and (3) that our technology is rapidly and infinitely advance-able to guarantee the perpetual validity of assumptions (1) and (2), no matter how great the human population becomes. Although there may be shortages of specific types of natural capital, our technology will rapidly advance to allow us to replace the diminishing resource with another more plentiful substitute that is equally capable, if not better, at satisfying consumer needs (possibly even one from our wastes). Further, if any backups occur in the ecological biogeoseptic systems in our air, land, or water, our technology will step in to reduce our wastes and remediate the problem.

However, the idyllic era when natural capital appeared limitless no longer exists in the global economy of today. For example, the principle energy sources for the developed world are all non-renewable fossil fuels. Technological improvements in energy efficiency can postpone the rate of fossil fuel depletion, however, the basic fact of that impending depletion is unaffected. Similarly, even if our technology were to enable us to meet our energy needs by renewable energy sources such as solar energy (in the form of photovoltaic electricity or alcohol from fermented plants) the upper limit on that power source is just as finite as the amount of coal in a seam. As long as the global population grows exponentially, no amount of energy efficiency and no advancement of alternative technologies to exploit renewable resources will evade the fact that demand will eventually exceed supply. This is a basic ecological principle. The solution to attain global economic and ecological sustainability cannot be to assume and require infinite resource supply - rather it must be by living within finite demand.

The idyllic era when global biogeochemical cycles appeared to have infinite capacity to degrade, dilute, or conceal our wastes also appears to be over. As with assumption (1), this assumption is inconsistent with well-known ecological principles. A good example of this is the carbon cycle. Burning fossil fuel releases carbon dioxide back into the atmosphere that was relatively slowly removed by living organisms millions of years ago. The biogeochemical cycles and ecosystems of the Earth have stabilized to do without this carbon over a very long time. However, the fact that global CO_2 levels are on the rise coincident with the massive CO_2 output from industrialized countries suggests very strongly that the photosynthetic biota of the Earth (terrestrial and aquatic) simply cannot take up this excess carbon fast enough. These organisms must therefore have some other limitation(s) on their populations, and the carbon cycle has backed up into the atmosphere.

The theoretical consequence of this is clear - greenhouse warming. Indeed, data indicate some minimal warming this century in terms of average land surface temperature that would be consistent with climatic response to increased atmospheric carbon dioxide concentration, however, clearer understandings of key factors such as the hydrological cycle of the tropics are needed (Graham 1995). The concern is not so much about whether the Earth has warmed to date, but for how much longer can we continue to overwhelm the global biotic capacity to remove carbon dioxide before climatic perturbations such as warming, drought and sea level rise occur to our peril?

The third assumption, that our technology can rescue us from any environmentally imposed constraint on our needs, has been quite accurate for centuries if not thousands of years. Ingenious advancements in energy technology, engineering, and material sciences have consistently met exponentially growing energy demands. However, as was mentioned above, no amount of improvement in energy use efficiency can escape the fact that demand must be finite because energy supply is finite. The laws of thermodynamics impose a balanced energy budget for humanity. In addition, there is no technological fix for the problem that burning fossil fuels releases CO_2, a potent greenhouse gas. Clearly then, the most needed technologies in energy use involve the substitution of fossil fuels with renewable sources and the logistic attainment of steady-state demand. In fact, many of these alternative technologies are currently available and await an environmentally literate consumer to stimulate public policy toward their improvement and implementation (Flavin and Lenssen 1994).

An additional manifestation of our faith in technology stems from the doubling and tripling of agricultural yields throughout the world during the past few decades. According to Brown and Kane (1994), these yield increases have been due to huge increases in fertilizer use, pesticide use, irrigation, wide distribution of high yield varieties of crop plants, and triple cropping in the developing world where longer growing seasons are common. However, these authors present extensive data indicating a recent leveling off of these yield increases due in part to the difficulty in further improving already high yield crops through biotechnology. They conclude that "despite the astounding gains in molecular biology . . . [and] biotechnology, expansion of food output though this new technique thus far has been limited" (Brown and Kane 1994, p. 140). Nonetheless, even if yields could again be increased per hectare, the total agricultural land area is shrinking rapidly due to unsustainable farming practices leading to aquifer depletion and soil erosion (Pimentel et al. 1995). As above, our point is that as long as the global population increases exponentially, and places increasing food demands on a decreasing area of agricultural land, no amount of improved agricultural efficiency can escape the fact that *per capita* yields will eventually begin to decline if these are not already doing so (Brown and Kane 1994).

The discussion above underscores a fundamental lack of understanding of basic ecological principles by the vast majority of our global community. This mass environmental illiteracy collectively blinds us to the inherently ecologically flawed economic, social, and political systems we have devised to interact with the natural world to sustain ourselves. Clearly, these institutions successfully have led us to where we are today, but these must change if we are to continue. Too many people are unaware of how unsustainably we live our lives, and of how deeply changes will have to be made, in order to make the transition to a sustainable society.

The single-most damaging facet of environmental illiteracy in our culture has to do with the very nature of our collective conception of the "environmental" crisis itself. The "environmental crisis" is viewed to include such things as greenhouse warming, ozone depletion, acid rain, deforestation, desertification, biodiversity loss, etc.; however, these are not the problems. These are the symptoms. Firstly, referring to these as "environmental crises" confirms the attitudes of "biophobes" that there is something wrong out there in the natural world from which we need to better insulate ourselves. Secondly, the root symptom of the above, an exponentially growing population, is not an environmental problem either. No population can grow exponentially indefinitely in any environment. Sooner or later limitations in resource availability, the accumulation of toxic wastes, etc., will change demography to reduce population growth rate to zero or lower. This is true regardless of what environment is occupied. Thus, human overpopulation is not a problem with the environment. This is a symptom of a deeper problem within us.

One may offer that the symptom of excessive human population growth stems from a problem of a lack of education about ecology. But there's more to it than just a few missing content pieces of ecological curriculum in our world, because in fact the key pieces of content have been known since near the beginning of the industrial revolution from the publications of Thomas Malthus, and probably long before that. Understanding why this ecological information is mostly globally unheeded (leading to almost 6 billion people now, and possibly double that by midway through the next century) involves a complex analysis of deeply rooted social, educational, political, religious, and economic perspectives affecting control over family size. Our point is that all of these factors have very little to do with the natural world. These stem from the basic fabric of our culture and our collective view, not of our environment, but of ourselves.

Thus, the global "environmental crisis" is mis-associated with the environment - the crisis lies within each of us who, due to our shortsighted consumer and disposer decisions, lead our lives without care for our children and grandchildren. We rationalize the silent protests of our descendants as tacit approval of our liquidation and degradation of their inheritance, and we will be long gone before their protests echo in a hollowed world.

At the root of every environmental crisis exists the deeper questions of our existence to the Earth and all living things. These crises are symptomatic of essentially philosophical and ethical proclivities which reveal the fundamental nature of our own species, what we value, our place in nature, and the kind of world we feel is acceptable. These are reflected in our actions toward our own species as well as others we encounter. We must first consider these issues before applying science to help us solve the dilemma of preserving biological diversity. What will be needed to make the jump to a sustainable society will have to be a mass ecological enlightenment. This includes not only content knowledge about the economy of nature to which the global human economy must adhere, but also empowering knowledge about how to go about transforming the roots of our ecological ethic from exploitative and destructive to symbiotic and sustaining. Considerable energy will have to be dedicated if this change is to occur.

SOLUTIONS: EDUCATION OF A CERTAIN KIND

According to Orr (1994), "the kind of education we need begins with the recognition that the crisis of global ecology is first and foremost a crisis of values, ideas, perspectives, and knowledge, which makes it a crisis *of* education, not one *in* education" (p. 126). Thus, educating an ecologically literate public and building an educational paradigm to envision and implement the technologies of a sustainable society will involve exhuming and scrutinizing the deeply buried cultural assumptions upon which our present unsustainable environmental ethic is based. These efforts are beyond the scope of any single academic discipline and will require interdisciplinary curricula from social science, political science, and the humanities just as much as curriculum from the natural sciences. Yet, few universities have the institutional flexibility or interest in the kinds of renovations to make that vision possible. We offer two suggestions for University faculty in this regard.

(1) Organize interdisciplinary curriculum (college and pre-college) that bridges the disciplines of natural, social, and political science, economics, law, and public policy in a way to educate students about the whole issue of a transition to a sustainable society. One name for this curriculum could be "social ecology."

(2) Create a non-majors environmental science course and engineer it as a requirement for all undergraduates. Many non-majors courses are simply watered down versions of discipline-specific curriculum, and thus it should be little surprise that these are rarely effective. Instead, and especially in the case of non-majors environmental science curriculum, we should be teaching how to responsibly use the knowledge that our discipline is responsible for creating. Such a course should teach ecological literacy, and those who pass this course should at least understand the basics of ecological economics and the bases of educated consumer and disposer decisions.

In addition, Universities must play a greater role in educating a public that in many cases is lost with regard to ecological literacy. There is a tremendous need for scientists and science educators to become involved in multicultural environmental education which will address the critical underlying issues necessary to assure that species are around for our children to enjoy. While no simple answer exists with regard to solving the current biodiversity crisis, we can begin by instituting the following:

(3) Design and offer pre- and in-service programs to teach teachers about *tropical ecology in the tropics* as part of a larger biodiversity curriculum by immersion.

(4) Design and offer pre- and in-service programs to teach teachers how to apply global environmental issues locally and engage students *outdoors* in their schoolyards and communities. Also, volunteer to mentor pre-college environmental science research projects and serve on environmental science fairs. Volunteer time and expertise to environmentally-oriented concerned citizens groups to help them understand the science of ecology and how to channel their energies into sound and productive activity. Lastly, aid in establishing networks of environmental education or contributing to local networks already in place (e.g., county science teachers associations).

(5) Work toward creation, passage and implementation of state-wide mandates for environmental education for all grades, K-12, that include coherent mission statements about ecological literacy.

University departments in the natural sciences and education can offer much in the way of addressing the biodiversity crisis by providing teacher training institutes, summer institutes, and workshops that address key issues. The multiplier effect is significant and teachers can immediately import newly acquired materials into existing curriculum. There also exists the need for teacher training facilities and institutes in developing countries to train teachers from around the world who feel it important to invest in the future by preserving our biological wealth. The value of an immersion experience at this level is critical to constructing an understanding of how to teach the scientific process and content relative to conservation issues. The excitement in making contact with nature at this level is almost overwhelming and remains engrained in constructive images for a lifetime. The establishment of the Amazon Center for Environmental Education and Research (ACEER) in the upper Amazon basin in Peru provides one such example through their International Rainforest Workshops for teachers. Teachers immerse themselves in structured workshops conducted by scientists to further their understanding of the rainforest. This is a model that warrants replication in all countries and especially those which harbor rainforests.

Education will not be enough to arrest the ever-increasing progression of our environmentally destructive ways. It is, however, a start and one which we can not afford to overlook. If we save only one species as a result of our efforts, then the world will remain that much richer and it may provide us with a window at which to look more deeply into ourselves.

CONCLUSION: IS THERE TIME?

If we are to be successful in our pursuits to preserve biological diversity on a global scale, an aggressive agenda needs to be employed during the next several years that is local, regional, and international in scope. More organizations like the Nature Conservancy will be needed to augment our chances of protecting species by purchasing tracts of land where endemism is high. Although we remain optimistic, it is with great reservation that we believe that the ongoing wave of species extinction can be curtailed in a reasonable time period (within the next ten-twenty years). This seems especially true for areas blessed with extraordinary biological resources but plagued by poverty and uncontrolled population growth. The issue of just how to maintain the unique wealth of the planet is perhaps the most critical we as a species will face. We have everything to lose and nothing to gain by ignoring the current crisis. And finally, what can be said is that the loss of species is a folly for which our descendants are unlikely to be forgiving (E.O. Wilson from Sawhill 1994).

DEDICATION

To Alwyn Gentry and Theodore Parker III, true pioneers and legends in their own time whose love, dedication, and pursuit of knowledge of tropical biodiversity cost them their lives. They are an inspiration to the best of those who pursue the tropics.

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REFERENCES

Brown, L.R. and H. Kane. 1994. Full House. W.W. Norton and Co., New York, NY. 261 pages.

Campbell, N.A. 1993. *Biology.* 3rd edition. Benjamin/Cummings Publ. Co., Inc. Redwood City, CA. 1190 pages.

Ehrlich, P.R. and E.O. Wilson. 1991. Biodiversity studies: science and policy. *Science* 253:758-762.

Erwin, T.L. 1982. Tropical forests: their richness in Coleoptera and other arthropod species. *Coleopterists Bulletin* 36:74-75.

Erwin, D.H. 1990. The end-Permian mass extinction. *Annual Review of Ecology and Systematics* 21:69-91.

Flavin, C. and N. Lenssen. 1994. *Power surge: Guide to the Coming Energy Revolution.* W.W. Norton and Co. New York, NY. 382 pages.

Graham, N.E. 1995. Simulation of recent global temperature trends. *Science* 267:666-671.

Jablonski, D. 1991. Extinctions: a paleontological perspective. *Science* 253:754-757.

Keller, E.F. 1983. *A Feeling for the Organism.* W.H. Freeman and Co., New York, NY 235 pages.

Lewontin, R.C. 1992. *Biology as Ideology: The Doctrin of DNA.* Harper-Collins. New York, NY. 128 pages.

Mann, C.C. 1992. Extinction: are ecologists crying wolf? *Science* 253:736-738.

Martin, P.S. and R.G. Kline. 1984. *Quarternary Extinctions.* University of Arizona Press, Tucson, AR.

May, R.M. 1992. How Many Species Inhabit the Earth? *Scientific American.* October 1992, 267:42-48.

McMichael, A.J. 1993. *Planetary Overload: Global Environmental Change and Health of the Human Species.* Cambridge University Press, Cambridge, England. 352 pages.

Miller, G.T. 1994. *Environmental Science,* 4th ed. Wadsworth Publ., Belmont, CA.

Orr, D.W. 1994. *Earth In Mind: On Education, Environment, and the Human Prospect.* Island Press, Washington, D.C. 213 pages.

Pimentael, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R. and R. Blair. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science* 267:1117-1123.

Primack, R. 1993. *Essentials of Conservation Biology.* Sinauer Assoc. Sunderland, Mass.

Raven, P. 1994. Defining biodiversity. *Nature Conservancy* 44:11-15.

Raven, P. and E.O. Wilson. 1992. A fifty-year plan for biodiversity surveys. *Science* 258:1099-1100.

Reid, W.V. 1992. How many species will there be? Pages 55-73 *in Tropical Deforestation and Species Extinction.* T.C. Whitmore and J.A. Sayer (eds.). Chapman and Hall Publ., New York, NY.

Rutherford, F.J. and A. Ahlgren. 1990. *Science for All Americans.* Oxford University Press, New York, NY. 246 pages.

Sawmill, J.C. 1993. The Nature Conservancy and biodiversity: 1993 in review. *Nature Conservancy.* January/February. Pages 5-10.

Sittenfeld, A. and R. Villers. 1993. Exploring and preserving biodiversity in the tropics: the Costa Rican case. *Current Opinion in Biotechnology* 4:280-285.

Wilson, E.O. 1994. *The Diversity of Life.* W.W. Norton & Company, New York, NY.

World Resources Institute. 1994. *World Resources: 1994-1995.* Oxford University Press. Oxford, England. 401 pages.