Why Should You Care About Biological Diversity?

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Nora Bynum directs the global activities of the CBC's Network of Conservation Educators and Practitioners (NCEP). Dr. Bynum has extensive experience teaching conservation biology and environmental science at the graduate and undergraduate levels, and has specialized in the design and implementation of intensive, student-active, and field-based learning experiences. She is also an Adjunct Associate Professor at the Duke University Nicholas School of the Environment and Earth Sciences, and at the Center for Environmental Research and Conservation at Columbia University. In her previous position as Academic Director for the Organization for Tropical Studies (OTS), Dr. Bynum provided academic leadership for a program of more than twenty graduate, undergraduate, and environmental policy field-based courses in several countries. She has worked extensively in the fields of tropical ecology, conservation and education in Latin America and Asia. Dr. Bynum can be reached at elb@duke.edu.

Melina Laverty is the International Field Program Manager at the American Museum of Natural History's Center for Biodiversity and Conservation. She manages planning and logistics for field expeditions to various CBC project countries. Ms. Laverty has also been developing biodiversity conservation curriculum materials which she helped pilot with university educators in Bolivia. Before coming to the Museum, Ms. Laverty worked for the World Conservation Union (IUCN) office for Meso America in San Jose, Costa Rica. Ms. Laverty has a Master's degree in marine environmental science from the Marine Sciences Research Center in Stony Brook, New York. She speaks French and Spanish and has international field experience in Barbados, Canada, Tanzania, Sweden, Madagascar, and Mesoamerica.

Ian Harrison is the coordinator for the US-based activities of the Center's Network of Conservation Educators and Practitioners project. He joined the museum in 1997, as a post-doctoral fellow in the Department of Ichthyology. He has helped develop scientific educational resources on the World Wide Web for students and educators and has served as an adjunct professor for City University of New York, teaching classes in ichthyology. He contributed to a CBC project investigating extinctions within the last 500 years. Dr. Harrison has conducted scientific research on the taxonomy and biogeography of marine, brackish, and freshwater fishes, including fieldwork in Europe, Central and South America, West Africa, and the Philippines. He has studied aspects of British fisheries history and current fisheries management, while working at a Fisheries Museum on the North Sea coast of England. Dr. Harrison received his Ph.D. in 1987 from the University of Bristol, England, where he studied the implications of small body size on the biology of fishes.

Sacha Spector manages a number of projects related to developing scientific resources and practical approaches for invertebrate conservation. He also oversees the CBC's Invertebrate Biodiversity Laboratory and serves as the scientific coordinator of the Center's projects in Bolivia. Sacha's research focuses on understanding the patterns of insect communities' distributions across landscapes and their relationships with plant communities in order to define large scale conservation plans that benefit insect species. He has worked extensively in Latin America since 1994, doing both field research and conducting field workshops for training local entomologists in rapid biodiversity survey techniques. Dr. Spector also serves as an adjunct assistant professor at Columbia University, where he teaches conservation biology to undergraduates. He earned his Ph.D. in Ecology and Evolutionary Biology at the University of Connecticut.

Why Should You Care About Biological Diversity?
A SENCER Backgrounder

There is broad consensus in the international scientific community that the world is facing a biodiversity crisis-the accelerated loss of animal and plant species brought about by human activity. Academicians and practitioners alike agree that to stem the loss of biological diversity, we need to engage theoretical and applied perspectives from the natural sciences, social sciences and humanities. In addition, we need to teach our students from this integrated perspective in order to facilitate student understanding of the biodiversity crisis and its solutions. Each one of us can play a role in mitigating the effects of human population growth and over-consumption of natural resources on the loss of biological diversity. Fortunately, this is a topic that interests students and can easily enter into diverse areas beyond traditional biology courses, from statistics to law, from medicine to public policy.

Humans depend upon biodiversity in obvious as well as subtle ways; we need biodiversity to satisfy basic needs like food, medicine, services that the environment provides such as watershed protection, and to enrich our lives culturally or spiritually. Yet in an increasingly technological world people often forget how fundamental biodiversity is to daily life. When we hear about species going extinct or ecosystems being destroyed, we somehow assume that other species or ecosystems are around to take their place, or that technology will invent a solution, or that in the end it doesn't really affect us. We rarely feel individually culpable for the loss of biodiversity, although human activities are the leading threat to the earth's biodiversity.

What we do not think about are the inter-connections in the natural world: any change in an ecosystem can cause a chain of reactions reverberating throughout the system. Immersed in our managed environments and virtual worlds, surrounded by houses and offices, streets and shopping malls, our direct contact with “nature” consists of aquaria in our living rooms or manicured parks to which we drive in private automobiles.. In the U.S., it is hard to remember that food in the grocery store did not spring forth packaged, ready to cook and serve.   Yet if we were to put a bubble over the managed environments of our cities and towns and tried to survive with no input from the natural world, we would quickly perish.

Students of today are challenged to try to make sense of a bewildering array of information and misinformation about environmental issues. This is certainly the case with biodiversity loss and species extinction. In order for the next generation of adults and voters to make intelligent choices about biodiversity, they will need to understand what the consequences are of their individual and collective actions. They need to know what biodiversity is, to understand the relationship between human beings and biodiversity, and they need to understand what threatens biodiversity. Finally, students need to have a sense of what they can do about the biodiversity crisis at the individual and collective levels. In this document we will treat each of these topics in turn.

What is Biodiversity?
The term biodiversity, a contraction of biological diversity, is relatively new to our vocabulary. It was born in the late 1980s, as scientists gathered together to find a collective solution to the escalating loss of wildlife and wildlands around the world. As one could imagine with such a broad and complex topic, definitions emphasizing one aspect or another of biodiversity litter the scientific and lay literature (see Gaston, 1996: Table 1.1). The term can be inclusive enough to mean all of life on earth – the living, or biotic part of the environment. Some scientists prefer to elaborate on this definition, emphasizing that biodiversity can be divided into different spatial, temporal, and organizational levels (e.g. genes, organisms, populations, species, communities of species, ecoystems, landscapes, etc.). Other scientists think the definition should also encompass the complex interconnections that exist between and within these levels. For the purposes of this paper, we define biodiversity as:

> *the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain this variety*

One important, but controversial, aspect of biodiversity is whether or not one defines humans as part of biodiversity. If we take the position that humans are part of biodiversity, then human cultural diversity and the way that humans use or otherwise interact with wildlife and wildlands are a component of biodiversity as well; these interactions may then be subject to protection under frameworks designed to protect biodiversity.

To effectively conserve biodiversity, we must define what we want to conserve, identify where biodiversity currently occurs, settle on strategies to help conserve it, and monitor over time whether or not these strategies are successful. While this sounds quite straightforward in abstract terms, each step of the way presents challenges. For instance, in defining what we want to conserve, we have the choice of concentrating on different levels of biodiversity – such as genes, species, ecosystems, etc. Choosing a strategy that will effectively conserve one of these levels does not necessarily mean the other levels will be conserved. Moreover, actively choosing one conservation target essentially means choosing not to conserve something else. However, in the world of biodiversity conservation there is almost never one right answer; each solution has its short-and long-term costs and benefits. Our role as educators is and should be to help students develop the skills they need to identify and assess the different options in a particular situation and to choose from the set of best options available.

Conservation at the gene level
Variability at the genetic level is crucial to adapting to an ever-changing world. The greater the diversity of alleles, the larger the potential for evolution of new combinations of genes, leading to a greater capacity for evolutionary adaptation to different environmental conditions. Small populations are more likely to have genetically, anatomically, and physiologically homogenous individuals in contrast with larger

populations. This renders the small populations less able to adapt to changing environmental conditions.

Conservation efforts at the genetic level are often focused on one or a few populations within a single species. While these are extremely important, in a world of scarce resources for conservation and research, we cannot invest this amount of effort on all of the existing species with small or declining populations (much less species heading for these categories). Therefore, genetic work needs to be undertaken in combination with conservation at larger scales.

Conservation at the species level
The species level is a traditional choice for conservation measures. However, many people argue that species-level conservation is problematic. First, not everyone agrees on how to define a species. For instance, some definitions rely on knowing whether or not individuals of a population can interbreed and produce viable offspring (the biological species concept), which can be quite difficult to determine for populations isolated geographically. Other definitions rely on highly-trained specialists being able to identify a suite of unique characteristics that are appropriate to "diagnose" a species and that show a pattern of ancestry and descent (the phylogenetic species concept). The latter definition generally leads to a greater total number of recognized species than some of the other species concepts, which has significant implications for conservation efforts.

A second problem we confront at the species level relates to setting a value for species. Again, in the triage world of conservation, choosing to concentrate on one species often means risking the possibility of losing another. How does one measure the relative worth of one species over another? Scientists have attempted to identify species that can serve as "proxies" for other elements of biodiversity and by investing resources in them you conserve a broader spectrum of species. Just to name a few examples, "umbrella" species are species for which conservation efforts need to be undertaken at a large scale, for instance species with large home range sizes. "Flagship" species are often charismatic, large-bodied, familiar species that tug at peoples' heart and purse strings and can attract attention to conservation efforts in a particular area.

Another problem we encounter at the species level is estimating just how many species there are on Earth. Scientists have named and described between 1.5 and 1.75 million species so far (LeCointre and Guyader, 2001; Cracraft, 2002). (Differing opinions on how to define a species prevent us from narrowing this estimate further.) Scientists anticipate that these known species represent a tiny percentage of the world's species. Estimates of the total number of species on Earth vary wildly, ranging from 3.6 million up to 117.7 million, with 13 to 20 million being the most commonly accepted range (Hammond, 1995; Cracraft, 2002). While it is vexing to realize how far we are from knowing and understanding the world's species, it is clear that we need to move forward with conservation efforts before we ultimately solve this problem.

Our efforts to conserve species are also confounded by spatial gradients in biodiversity. Often, areas of high concentration of knowledge and other resources for conservation are spatially isolated from the areas with highest concentrations of species. For instance, with a few exceptions, low altitude, warm tropical ecosystems encompass greater numbers of species than high altitude, cold temperate environments (see Gaston and Williams, 1996, for general discussion). Scientists still do not understand exactly why there are so many more species in the tropics, though many hypotheses have been discussed (see Blackburn and Gaston, 1996; Allen *et al*., 2002).

Altitude is another gradient over which biodiversity changes. For many mountainous areas, mid-elevation levels seem to harbor the most biodiversity. High elevation areas (often quite cold and either highly humid or extremely arid) are frequently quite low in species diversity. A different trend appears in oceans, where species richness declines with increasing depths below sea level, until one arrives at the sea-bed where greater ecosystem heterogeneity may foster a rise in species richness. For further discussion on altitudinal variation in species and ecosystem diversity see Walter (1985) and Gaston and Williams (1996: 214-215).

Conservation above the level of species (community, ecosystem, landscape, etc.)
Conservationists have increasingly concentrated scarce resources on larger scale initiatives, the idea being that if you can conserve large areas you also conserve lots of species, population, and genetic diversity. As at all the other scales, choosing which areas to conserve can be complex and conservationists select sets of criteria to help them set priorities among candidate areas. For instance, areas with a high number of species found nowhere else in the world (called endemic or restricted-range species) regularly feature prominently in conservation efforts because it is easy to see that if we lose these populations, whole species will disappear from the face of the earth. Areas of high endemism are also often associated with high species richness (see Gaston and Spicer, 1998 for references), and therefore serve as potentially effective proxies for other biodiversity.

Some conservationists have focused their attention on areas that have high levels of endemism and species diversity that are also experiencing a high rate of loss of habitat; these regions are *biodiversity hotspots* The concept of hotspots was originally developed for terrestrial ecosystems, and a *terrestrial biodiversity hotspot* is defined, more precisely, as an area that has at least 0.5%, or 1,500 of the world's ca. 300,000 species of green plants (Viridiplantae), and that has lost at least 70% of its primary vegetation (Myers *et al*., 2000; Conservation International, 2002). *Marine biodiversity hotspots* have been defined for coral reefs, based on measurements of relative endemism of multiple taxa (species of corals, snails, lobsters, fishes) within a region and the relative level of threat to that region (Roberts *et al*., 2002). Because biodiversity hotspots are characterized by localized concentrations of biodiversity under threat, they represent priorities for conservation action (Sechrest *et al*., 2002).

Of course, biodiversity hotspots are not the only method used by conservation groups and governments to prioritize conservation efforts. Some efforts to prioritize are local or national in scope and may involve setting aside protected areas (see section on protected areas below in **What Can We Do**?). Other efforts, such as The Nature Conservancy's

Ecoregional Planning (Groves et al. 2000), or the World Wildlife Fund for Nature's Global 2000 (Olson and Dinerstein 1998) attempt to prioritize conservation on a global scale through criteria that include species diversity, species endemism and *representation*, where examples of every ecosystem type are targeted for conservation.

Why is Biodiversity Important?

As one can see, conservation efforts are highly skewed by what we choose to conserve, and what we choose to conserve is based on what we value. The "value" of biodiversity is a highly subjective concept that is at times difficult to understand and often causes fierce debate. There are two main categories of value for biodiversity:

- *Utilitarian/instrumental or extrinsic value*
- *Intrinsic or inherent value*

A living thing's utilitarian value is determined by its practical use or application. Usually we frame this in terms of its use for humans, such as for medicine or food, but it could also represent the value of an organism to other living things. Native bees, for example, serve as pollinators for many plants. Utilitarian values are often categorized as goods, services, information, spiritual, cultural, aesthetic, and recreational. In contrast to utilitarian value, intrinsic value describes the inherent worth of an organism, independent of its value to anyone or anything else. Those who believe in intrinsic value argue that all living things have intrinsic value – essentially a right to life – regardless of their potentially additional extrinsic value. Below we review both utilitarian and inherent value.

Utilitarian Value

<u>Goods</u>

The earth provides an abundance of goods essential to human life including food, timber, fuel, fiber, and medicine, to name a few. Some highlighted examples follow.

Food. Humans have spent most of their existence as hunter-gathers dependent on wild plants and animals for survival. Around 10,000 years ago the first plants were cultivated, marking a fundamental shift in human history towards regular access to stationary resources. Biodiversity continued to play a central role, providing the original source of all crops and domesticated animals. Today, people still depend on biodiversity to maintain healthy, sustainable agricultural systems. World crop exports alone were worth an impressive $432 billion in 2000 according to the Food and Agriculture Organization (FAO). Unlike agriculture, where wild species have been domesticated, the world's marine fisheries are still dominated by wild-caught fish, representing 73.7 percent of the 125.2 million tons produced in 1999 according to the FAO.

Though humans have used over 12,000 wild plants for food, twenty species now support much of the world's population (Burnett 1999). It is still unclear why certain species were cultivated and not others. Of all the plants that we depend on, none are more important than the grass family, Gramineae. The grass family includes the world's principal staples: wheat, rice, and corn (maize). Rice and corn formed the basis of civilizations in the Far East and the Americas, while wheat together with barley formed the basis of the civilizations of the Near East.

Humans only cultivate a small fraction of the plant and animal species on earth. To ensure that we can sustain these systems, we depend on biodiversity, especially the wild counterparts of cultivated food and domesticated animals, as a genetic library that we can use to create new varieties or breeds better able to combat pests or disease, and more suited to certain environmental conditions. Thus biodiversity acts as a kind of insurance for agriculture. For instance, corn (*Zea mays*), along with wheat and rice, is one of the world's most important cultivated plants. The annual global market for corn is nearly $60 billion, yet this crop is susceptible to several viral diseases. In the late 1970s, teosinte (*Zea diploperennis)*, the closest wild relative of corn, was discovered and found to be resistant to viral diseases that infect *Z. mays*. The new species has the same chromosome number as *Z. mays* and can therefore hybridize with it. When this occurs, some of the viral resistance is transferred to domestic corn. Four viral-resistant commercial strains have since been produced, highlighting the importance of wild counterparts to cultivated food crops.

Wood and Forest Products. The worldwide production of timber and related products is a multi-billion dollar industry. As we know, wood is used to construct homes and furniture and made into mulch, chipboard, paper and packaging. The wood from each tree species has unique characteristics, suitable for different purposes: white ash is used for baseball bats; locust and cedar, both very rot-resistant, are valued as fence posts; Brazilian rosewood is favored for guitars; and black walnut has been used for gunstocks, due to its strength and decay resistance. Fabric manufacturers harvest wood for its fiber, using wood cellulose to make tencel™ and rayon for clothing. Other useful tree products include cork, rubber, latex, resins, as well as fruits, nuts and oils. According to the World Resources Institute <www.wri.org>, 63 percent of all harvested wood is used as fuel, either burned directly or after being converted to charcoal.

Medicine. Approximately 80 percent of the world's population still uses plants as a primary source of medicine (Farnsworth *et al.* 1985). Many Western medicines were developed from a plant or an animal source; 57 percent of the top 150 most-prescribed drugs originate from living organisms (Grifo *et al.* 1997). For example, the antibiotic penicillin is derived from a fungus (*Pencillium notatum*) that is a common bread mold. Aspirin and common acne medicines are derived from salicylic acids, first taken from the bark of willow trees (*Salix sp*.). Although these drugs are now synthesized more efficiently than extracted from the wild, we still depend on the chemical structures in nature to guide us in developing and synthesizing new drugs (Newman 1998).

<u>Services</u>
Ecosystems, and the plant and animal species that comprise them, provide a host of services to all living things. These services include the regulation of atmospheric gases that affect global and local climates including the air we breathe; maintenance of the hydrologic cycle; control of nutrient and energy flow through the planet, including waste decomposition and detoxification, soil renewal, nitrogen fixation, and photosynthesis; a

genetic library, maintenance of reproduction, such as pollination and seed dispersal, in plants we rely on for food, clothing or shelter; and control of agricultural pests. Often the values of ecosystem services are not considered in commercial market analyses, yet they are critically important to human survival. Humans can rarely replace these services or, if they can, it is only at considerable cost. For example, an estimated 90 percent of flowering plants depend on pollinators, such as wasps, birds, bats, and bees, to reproduce. Without these pollinators, many plant species would face extinction. Plants and their pollinators are increasingly threatened around the world (Buchmann and Nabhan 1995; Kremen and Ricketts 2000). Yet pollination is critical to most major crops and virtually impossible to replace. For instance, imagine how costly orange juice would be (and how little would be available) if its natural pollinators no longer existed and each orange flower had to be fertilized by hand.

Regulation of Global Processes. Biodiversity plays a critical role in regulating the earth's physical, chemical, and geological properties, from influencing the chemical composition of the atmosphere to modifying climate. The earth's atmosphere has a unique composition, primarily made up of nitrogen (77 percent) and oxygen (21 percent), unlike the atmospheres of Venus and Mars, which are almost entirely composed of carbon dioxide (95 percent). Initially, like Venus and Mars, the earth's atmosphere lacked oxygen. About 3.5 billion years ago, early life forms (bacteria) helped create an oxygenated atmosphere through photosynthesis, taking up carbon dioxide from the atmosphere and releasing oxygen (Schopf 1983; Van Valen 1971). Eventually, these organisms altered the composition of the atmosphere and paved the way for organisms that use oxygen as an energy source (aerobic respiration). Thus, organisms and their environment evolved together, achieving a balance between living and nonliving things, a state known as homeostasis.

The atmosphere is continually influenced by biodiversity. Phytoplankton (or microscopic marine plants) in our oceans play a central role in regulating atmospheric chemistry. The oceans are the major reservoir for carbon on the planet and regulate carbon levels in the atmosphere; carbon is continually exchanged between the atmosphere and the oceans. Phytoplankton transform carbon dioxide into organic matter during photosynthesis. This carbon-laden organic matter settles either directly or indirectly (after it has been consumed) to the deep ocean, where it stays for centuries or even thousands of years. This movement of carbon through the oceans removes excess carbon from the atmosphere and regulates the Earth's climate. Over the last century, humans appear to have affected the atmospheric balance by releasing large amounts of carbon dioxide. The excess carbon dioxide, along with similar "greenhouse" gases, is believed to be heating up our atmosphere and changing the world's climate. Besides influencing global climate by modifying the atmosphere's composition, biodiversity affects climate in other ways. The extent and distribution of different types of vegetation over the globe, for example, modifies climate by affecting the reflectance of sunlight (radiation balance), through the release of water vapor (evapotranspiration), and by changing wind patterns and moisture loss (surface roughness).

Ecosystem Services. Biodiversity is also important for services such as pollination, seed dispersal, and soil and water protection. For example, terrestrial vegetation in forests and other upland habitats helps maintain the water quality and quantity of the hydrologic cycle and helps control soil erosion. Plant leaves slow the descent of raindrops, so by the time the water reaches the ground it is less likely to wash soil away and more likely to percolate into the ground. Roots hold soil in place, which increases water absorption and decreases soil erosion during heavy rains. Plants pump water from the soil back into the atmosphere, completing the cycle. In watersheds (land areas drained by a river and its tributaries) where vegetation has been removed, flooding prevails in the wet season and drought occurs in the dry season. Soil erosion is also more intense and rapid, causing a double effect: removal of nutrient-rich topsoil, and siltation in downstream riverine or ultimately oceanic environments. This siltation can harm riverine and coastal fisheries as well as damage coral reefs. In the Mississippi River delta ecosystem, for example, a build up of sediment and pesticides has created an anoxic area (an area without oxygen), known as the "dead zone," in the Gulf of Mexico (Turner and Rabalais 1994).

Wetlands, natural communities linking land and water, are also instrumental for the maintenance of clean water and erosion control. Wetlands are defined as lands where water is present at or near the surface of the soil or within the root zone, all year or for a period of time during the year, and are characterized by vegetation adapted for these conditions. Microbes and plants in wetlands, some of the most productive ecosystems on earth, absorb nutrients and in the process filter and purify water of pollutants before such pollutants can enter coastal or other aquatic ecosystems. Wetlands help reduce flood, wave and wind damage. They slow the flow of flood waters and accumulate sediments that would otherwise be carried downstream or into coastal areas. Wetlands also serve as breeding grounds and nurseries for fish and support thousands of bird and other animal species.

Nutrient cycling is yet another critical service provided by nature. Fungi and microbes in soil help break down dead plants and animals. This process converts elements—such as nitrogen and phosphate—into nutrients that most plants use, and thus enriches the soil. Nitrogen-fixing bacteria, for example, transform atmospheric nitrogen into nitrates or nitrites. Nitrogen is essential for plant growth, and an insufficient quantity of it limits biomass production in both natural and agricultural ecosystems. In addition to decomposition, microbes detoxify waste, changing waste products into forms less harmful to humans.

Agriculture. Agricultural pests (principally insects, plant pathogens, and weeds) destroy an estimated 37 percent of US crops (Pimentel and Levitan 1986). Destruction varies depending on the crop, where it is grown, and the type of pest. According to Oerke et al. (1994), production losses due to pests, pathogens, and weeds amount to 15 percent, 14 percent, and 13 percent on average for the principal cereals and potatoes. Without natural predators that keep pests in control, these figures would be much higher. Natural pest control saves farmers billions each year (Naylor and Ehrlich 1997), and pesticides are no replacement for the services provided by these crop-friendly predators.

Community Stability and Resilience. The relationship between biodiversity and species diversity and community stability and resilience (the ability to adapt and respond to changing environmental conditions) is complex. Natural communities are dynamic systems, in which component species can have complex interrelationships. It appears that in many cases species diversity increases an ecosystem's stability and resilience. In other cases, this direct relationship cannot be demonstrated. This may be partially explained by the fact that many ecosystems have built-in redundancies so that two or more species' functions may overlap. Because of these redundancies, some changes in the number or type of species may have little impact on an ecosystem. On the other hand, if enough species are removed, there is a good chance of disrupting ecosystem function. In addition, it is extremely difficult to predict which species are redundant and what the effect of removing any one species would be on a system.

Species that have important ecological roles that are greater than one would expect based on their abundance are called *keystone species*. Removal of one or several keystone species may have ecosystem-wide consequences immediately, or decades or centuries later (Jackson *et al.* 2001). Ecosystems are complex and difficult to study, thus it is often difficult to predict *a priori* which species are keystone species. However, there are some clear examples in the ecological literature.

For example, kelp "forests" (composed of a brown seaweed of the family Laminariales), found in shallow, rocky marine habitats from temperate to subarctic regions, are important ecosystems for many commercially valuable fish and invertebrates. In the northern Pacific, prior to hunting by humans, these communities encompassed vast forests of kelp and other marine plants. The kelp was eaten by herbivores such as sea urchins (Family Strongylocentrotidae), which in turn were preyed upon by predators such as otters (*Enhydra lutris*). Hunting during the 18^{th} and 19^{th} centuries brought sea otters to the brink of extinction. In the absence of sea otters, sea urchin populations burgeoned. Sea urchins grazed down the kelp forests, at the extreme resulting in "urchin barrens," where the kelp was completely eradicated. Other species dependent on kelp (such as abalone *Haliotis spp.*) were affected as well. Legal protection of sea otters in the 20^{th} century led to partial recovery of the system. Unfortunately, more recently sea otter populations in Alaska seem to be threatened by increased predation from killer whales (*Orcinus orca*). It appears that whales may have shifted their diet to sea otters when populations of their preferred prey, seals and sea lions, declined. The exact reason for the decline in the seal and sea lion populations is still unclear, but seems to be due to declines in their prey in combination with increased fishing and higher ocean temperatures. As a result of the loss of sea otters, increased sea urchin populations are grazing down kelp beds again.

Interestingly, a similar scenario in kelp forests in Southern California did not show immediate effects after the disappearance of sea otters. This is because the system was more diverse initially. Other predators (California sheephead fish *Semicossyphus pulcher* and spiny lobsters *Panulirus interruptus*) and competitors (abalone) of the sea urchin helped maintain the system. However, when these predators and competitors were over harvested as well in the 1950s, the kelp forests declined drastically as sea urchin populations boomed. In the 1970s and 1980s, a sea urchin fishery developed which then enabled the kelp forest to recover. This left a system with little diversity; the interrelationships among these species and the changes that reverberate through systems as species are removed are mirrored in other ecosystems on the planet, both aquatic and terrestrial.

Information. We value biodiversity for its ability to inspire creativity and to help us solve problems. The term "biomimicry" is used for research into how humans use models from the natural world to solve problems in agriculture, medicine, manufacturing, and commerce. Humans have long drawn inspiration from the wild for commercial products. For example, Velcro was patterned after cocklebурs that attach to clothes as people walk through a meadow. A closer look at hedgehog spines, whose supple, strong structure enables them to bend without breaking, led to the development of lightweight wheels in which the tires have been replaced with an array of spines that effectively absorb shock. Millipedes, invertebrates with multiple pairs of legs fringing their long bodies, are being studied to help design robots to carry heavy weights in cramped conditions where significant twisting and turning is necessary (Beattie and Ehrlich 2001). Halobacteria that thrive in the salt ponds of San Francisco Bay contain a molecule called bacteriorhodopsin that may revolutionize computer optics.

Spritual, Cultural, Aesthetic, and Recreational Value. Although many of the utilitarian values discussed previously have an economic basis, biodiversity is valued for non-economic reasons as well. Most cultures place distinct aesthetic, spiritual, or recreational values on natural areas. People look to the natural world as a source of inspiration, beauty, and rejuvenation (Kellert and Wilson 1993). They seek out natural areas to relax, surrounded by the sights, sounds, and smells of nature. Some people believe that individual living organisms are valuable for their beauty, rarity, complexity, and adaptations (Rossow 1981 reprinted in van DeVeer and Pierce 1998 Nature provides insight and understanding of our role in the world. Biodiversity plays a central role in human spiritual traditions. Religions help define the relationships between humans and their environment. Nature is used in religious imagery and many religious traditions view the contemplation of nature as an important spiritual value (Chevalier *et al.* 1997).

The natural world also provides a rich source of symbols used in art and literature. Plants and animals are central to mythology, dance, song, poetry, rituals, festivals, and holidays around the world. Natural areas provide a source of inspiration and a place to relax. Because of this, forests, lakes, mountains, and beaches provide venues for commercially valuable outdoor activities like eco-tourism, fishing and hiking. Costanza et al. (1997) estimate that the total recreational value of the world's resources could be as high as $800 billion annually. The growing ecotourism industry generates an enormous amount of money and is fast becoming a lucrative industry for some developing nations. For example, in Costa Rica, tourism has expanded rapidly since the mid-1980s and is now the leading source of foreign revenue, surpassing the banana industry .

Intrinsic or Inherent Value

Intrinsic value is a frequently misused term. Some believe that values not easily defined, such as aesthetic values, are intrinsic values. As discussed earlier, aesthetic value is a kind of extrinsic/utilitarian value. Others believe a species' value to the structure and function of an ecosystem (such as an invertebrate decomposer's ability to cycle nutrients) is its intrinsic value because it does not have any obvious value to humans. However, the correct definition of intrinsic value is *the inherent worth of something, independent of its value to anyone or anything else*. One way to think about intrinsic value is to view it as similar to inalienable rights to life. The Endangered Species Act in the United States protects many species that are not "valuable" to humans in any readily definable way (for instance, the dwarf wedge mussel [*Alasmidonta heterodon]* or the swamp pink [*Helonias bullata*]). These species are protected based on the idea that they have a right to life, just as all humans do. Aldo Leopold is one of the most famous supporters of the idea that wildlife and wildlands hold value in and of themselves (Lorbiecki 1996).

The concept of intrinsic value is one of the most difficult to understand, as it is essentially philosophical. Many economists and some ethicists believe that intrinsic value does not exist, arguing that all values are human-centered. Generally, two contrasting ideologies frame a continuum along which our beliefs fall. On one extreme is the idea that humans are the center of the universe and that nature exists (and is used) for human benefit (a view called anthropocentrism); at the other is the notion that life is the center of the universe and humans are a separate but equal part of nature (biocentrism, or ecocentrism). The latter viewpoint, forwarded by the deep ecology movement (Naess 1989, Devall and Sessions 1985), holds that all species have intrinsic value and that humans are no more important than other species.

That humans have no right to wantonly destroy biodiversity is an assertion justifiable from certain religious standpoints. If God or some other deity or sacred process created the natural world alongside humans, then all creatures are imbued with sacredness: all have intrinsic value. This "most fundamental" postulate of all—that biotic diversity has intrinsic value, irrespective of its utilitarian value—is key to many motivations for biodiversity conservation. If one accepts the idea that biodiversity has intrinsic value, then species conservation requires less justification.

Why Do Values Matter?

We cannot possibly design conservation strategies that take into account ALL species and their interconnections – we just do not have the resources or knowledge to do so. Thus, we make choices when we measure biodiversity or set conservation priorities. These choices depend upon what we currently hold as valuable. What we value today will influence the scope of the natural world for future generations, as laws, policies and conservation decisions are based on our current value system.

The issue of what elements of biodiversity are most valuable arises at different scales, from individual to global. For instance, conservationists often have to decide in which countries a non-governmental organization should invest its resources. Within a country or region, one has to decide which areas should receive conservation attention and which to include within a protected area system. Globally, nationally, and regionally, we need to decide which species or populations to study, monitor, and manage. In deciding where to place our resources, we face questions such as: Should we value areas with greater numbers of species over those with many endemic species (those that are found only in that one place in the world)? Would it be better to value conservation of phylogenetic diversity (species that are maximally different from an evolutionary standpoint) over degree of threat to a species? Would it be better to plan for greater security for one type of ecosystem in case of catastrophic events by conserving two or more representatives of that ecosystem, or would it be better to have a greater representation of more types of ecosystem? Should we give priority to a species/ecosystem that is nationally endangered, but globally common or to a species/ecosystem that is nationally common and globally rare? There are no correct answers to these questions. The responses depend upon what decision-makers value most at the moment they are making the decision.

The responses also depend on the information available to make decisions. Scientists working with the National Centre for Ecological Analysis and Synthesis in the U.S. have recently raised the question of whether there might also be an inadvertent scientific bias toward "cute, unique, or spectacular" species. In most countries, conservation efforts focus on the species listed as endangered and threatened, although these lists to date include mainly vertebrates and vascular plants. Since we know so little about other components of biodiversity (invertebrates, non-vascular plants, microbes etc.), our current endangered species lists may be omitting information critical to better decision-making about our imperiled species.

Extinction and Threats to Biodiversity
It is important to remember that extinction is a natural process. The flora and fauna that form today's biodiversity are a snapshot of the Earth's approximately 3.8 billion year history of life, representing just 0.1% of all the species that have ever lived. Thus, 99.9% of all the life that has existed on Earth is now extinct[i] (Raup, 1991*);* a species is assumed to be extinct when there is no reasonable doubt that the last individual has died (IUCN, 2002). Extinction (the complete disappearance of a species from Earth) is an important part of evolution and has not occurred at a constant pace through the Earth's history. There have been at least five periods when there has been a sudden increase in the rate of extinction, such that the rate has at least doubled, and the extinctions have included representatives from many different taxonomic groups of plants and animals; these events are called mass extinctions

Each of the first five mass extinctions represents a significant loss of biodiversity with recovery on a geologic time scale of millions of years. Mass extinctions are apparently followed by a sudden burst of evolutionary diversification on the part of the remaining species, presumably because the surviving species started using habitats and resources that were previously "occupied" by more competitively successful species that went extinct. However, this does not mean that the recoveries from mass extinction have been rapid; they have usually required some tens of millions of years (Jablonski, 1995).

It is hypothesized that we are currently on the brink of a 'sixth mass extinction,' but one that differs from previous events. The five other mass extinctions predated humans and were probably the ultimate products of some physical process (e.g., climate change through meteor impacts), rather than the direct consequence of the action of some other species. In contrast, the sixth mass extinction is the product of human activity over the last several hundred, or even several thousand years.

Humans dominate the planet to an extent never before seen. Our rapidly expanding populations and economies place staggering demands on the world's limited resources. To meet these needs, one-third to one-half of the planet's land surface has been substantially altered by human activity (Vitousek *et al*. 1997). Many species barely manage to survive on a fraction of their former range and in increasingly fragmented landscapes. Ecosystems, such as tropical dry forests and grasslands, have almost completely disappeared from our planet, taken over for agriculture. Dams disrupt freshwater ecosystems, while overfishing, pollution, and habitat destruction threaten the marine world.

Humans are also transporting plants and animals around the globe both deliberately and unintentionally. These "invaders" threaten other species or change entire ecosystems. Our planet is increasingly made up of species that can only survive in human-modified landscapes. Human influence reaches even the farthest corners of the globe: the Arctic and Antarctic are contaminated by pollutants created tens of thousands of kilometers away and carried through the atmosphere. We are changing the earth's very atmosphere through the industrial release of carbon dioxide, which may dramatically alter the earth's climate, and diminishing the ozone layer through the production of chloroflurocarbons. The choices human beings have made individually and collectively to date have had significant consequences for our fellow inhabitants of the planet.

Only by understanding the principal threats to biodiversity can we hope to meet the challenge of conserving biodiversity. Direct threats to biodiversity include ecosystem loss and fragmentation, invasive species, pollution, overexploitation, and global climate change. Although the direct or proximate threats to biodiversity are and will remain of great concern to conservation biologists, the underlying or ultimate causes of biodiversity loss deserve equal attention , while often more difficult to understand and address. In general, the underlying causes of biodiversity loss can be grouped into one of three categories: 1) human population growth, 2) consumption patterns, and 3) governments and institutions that facilitate or allow direct threats to biodiversity (Wackernagel *et al.* 2002, Woods *et al.* 2000, Ehrlich and Ehrlich 1997, Vitousek *et al.* 1997).

Human population changes affect biodiversity through growth in terms of raw numbers of people (Ehrlich and Ehrlich 1997). Global population estimates exceeded 6 billion people in 1999 (United Nations 2001), with estimates for 2050 ranging from 7.9 billion to 10.9 billion. All things being equal, greater numbers of people will require more resources. In order to accommodate a growing population, communities must expand into new areas on the landscape or intensify existing efforts. Such expansion usually results in the conversion of habitat and alteration of local ecosystem functions, often in ways detrimental to both humans and other species (Vitousek *et al.* 1997).

Population growth also directly affects consumption patterns by initially increasing the use of all resources (Ehrlich *et al.* 2003), and subsequently by requiring a reallocation of resources. Humans appropriate over 40% of the net primary productivity on the Earth each year (Vitousek *et al.* 1986, Rojstaczer *et al.* 2001), consume 35% of the oceans' productivity (Pauly and Christensen 1995), and utilize about 55% of the accessible freshwater runoff worldwide (Postel *et al.* 1996). Consumption patterns can also be measured in terms of land use (e.g. Waggoner et al. 1996), energy consumption (e.g. Schipper 1996, EIA 2002), food consumption (e.g. Grigg 1999, Putnam & Allshouse 1998) and industrial materials use (e.g. Matos & Wagner 1998). A popularized conceptual way of thinking about the impact of consumption patterns on the Earth is the human "ecological footprint" (Wackernagel and Rees 1996), which attempts to exact the amount of biologically productive land and water resources required by humans on a per capita basis. One recent study (Wackernagel and Rees 2002) indicated that human populations since the 1980's have been using more resources in terms of land, water and goods than is being replenished naturally. In other words, we are drawing down the "principal" of biodiversity rather than living on the interest.

Finally, governments and institutions can indirectly affect biodiversity in several ways, such as by providing economic disincentives that work against conservation, setting priorities that address short term concerns but do not provide for long term sustainability, and not enforcing environmental regulations (Repetto and Gillis 1988, O'Didia 1997, Woods et al. 2000, Jiménez 2002).

The complexity of the connections between and among the direct and underlying causes of biodiversity loss continues to mar our ability to address them. However, understanding these connections is crucial to the decisions we make about biodiversity, at an individual and collective level.

What Can We Do?

Just as governments must make regional and national decisions that affect biodiversity, individual citizens and communities make decisions that affect biodiversity as well. Should a person eat swordfish at the sushi bar? Should a person vote for a representative who is in favor of accepting an international treaty on the use of biodiversity? Should a village sell the timber from their forested lands or should they preserve the forest for its non-timber products (e.g., fruit and nuts, animal products, medicinal plants, shade)? Should a municipality permit development or protect open space?

Solutions can be found at many levels of the problem. This means that an effective approach will involve actors as diverse as international organizations, individual nations, non-governmental organizations, academic institutions, local grassroots groups and, most importantly, individuals. As individuals, our power lies in our everyday actions through which we elect to either contribute to the problem or to the many possible solutions.

What follows is a collection of several of the most urgent and most promising steps that we must undertake if we are to preserve the world's biodiversity. There is, in fact, no precedent that we know of for the type of concerted, global change that must be achieved by the generation of students that we are currently teaching if the tide of biodiversity loss is to be stemmed. This only emphasizes the importance of broad civic engagement in dealing with the issue of biodiversity loss. Below we have suggested collective and individual responses to the biodiversity crisis in terms of 1) actions that address the direct causes of biodiversity loss and 2) actions that address the underlying causes of biodiversity loss.

Responses and Actions that Address the Direct Causes of Biodiversity Loss

Establish and manage protected areas. Conserving biodiversity where it exists, or *in situ*, is the centerpiece of conservation strategies. A broad spectrum of biosphere reserves, parks, wildlife reserves, forest reserves, indigenous peoples' territories are already in place around the world. Increasingly, protected areas are being managed for sustaining complete and functioning ecosystems in order to maintain a full range of ecological processes and the habitats and species that depend on them. Many scientists and conservation organization have suggested that protecting a targeted 10-12% of each nation's land area in this way would effectively conserve a large percentage of the world's species. However, more recent analyses are indicating that the land area necessary to conserve and protect most components of biodiversity may actually be closer to 50% (Soulé & Sanjayan 1998). Barely 5% of tropical rainforests, the world's most diverse ecosystems, are protected; our opportunities to achieve even the earlier goal of 10% are fast vanishing. Twenty-nine out of 63 Asian, African and Latin American countries already have lost more than 80% of their natural habits (Soulé & Sanjayan 1998). We must rapidly move to protect the remaining tracts of the world's wildlands and stitch them into an interconnected network of biodiversity reserves. Studies have suggested such a course of action is feasible scientifically and financially (Pimm et al. 2001) and is essential to the near- and long-term persistence of all levels of biodiversity.

Monitor biodiversity. Conserving biodiversity requires that we understand its distribution and status in space and time. Changes in the threats to biodiversity (human activities, climate shifts, disturbances, and pollution) means that we need a system that provides us with updates on where biodiversity is and how it is faring. As Noss (1990) points out, the hierarchical nature of biodiversity dictates that we monitor biodiversity at many levels: from mapping the way that animal and plant communities are distributed across landscapes to identifying the composition of those communities, tracking the increase or decline of species' populations, and measuring the genetic structure of those populations. Designing such a comprehensive monitoring protocol continues to be a challenge that we must meet. However, only with such broadly gathered information can we design conservation strategies that reflect the most current threats to biodiversity.

Enact legislation. Laws, and the legislative process through which they are made, are a society's means to codifying its principles, aspirations, and structures. From the standpoint of biodiversity conservation, establishing the protection of biodiversity in legal frameworks at global, national and regional levels is essential on both philosophical and practical levels. International agreements with the force of law, like CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna), simultaneously signal the world's commitment to end the trafficking of endangered wildlife and provide mechanisms for the convention's signatories to use in achieving that common goal. National laws, like the U.S. Endangered Species Act, which very clearly articulates that species have "esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people," are equally critical in protecting species and their habitats. Conservationists must continue to understand and involve themselves in the legislative process at all levels in order to protect the environmental laws that already exist, encourage additional legal protections for biodiversity, and foster the inclusion of conservation ethics in all laws.

Conserve habitats and species on private lands. In many areas of the world, large percentages of the land are in the hands of private owners. In countries like the US, where government involvement in the management of private lands is strictly limited, conservation efforts must therefore involve the local landowners if species and habitats are to be managed at all. Finding incentives and mechanisms that bring landowners into the process of planning and implementing conservation strategies is crucial to this effort. Organizations like the Malpai Borderlands Group—a collection of landowners, scientists, and other stakeholders dedicated to maintaining the health of a million-acre region in southern Arizona and New Mexico—are leading the way in this effort. Other important initiatives on this front include the development of "Safe Harbor" agreements between governments and landowners that promote current conservation efforts on private lands and assure landowners' future options for developing their land.

<u>Responses and Actions that Address the Underlying Causes of Biodiversity Loss</u>

Stabilize global population size. If any sustainable balance between the world's biodiversity, ecological systems, and humans is to be found, we must stabilize human population growth. While the consumption of the world's resources is dominated by the minority of people living in the rich, developed countries, the needs of the growing billions living elsewhere are nevertheless taking an enormous toll on the global environment. Fortunately, there are many actions that we can take that will help bring about demographic transitions in the fastest growing nations and bring us closer to attaining a stable population size on Earth. The following is a partial list of some of those actions:

- *Improve the educational and political status of women*
- *Improve the survival and health of children*
- *Provide easy access to family planning resources*

Turning the tide of population growth has been a highly politicized topic in much of the world. Some argue that encouraging family planning goes against the tenants of a number of the world's religions. Others make the point that developed nations ought not demand that the people in developing nations have fewer babies while the environmental impact of a single child gobbling energy and resources in the U.S., for example, is equal to dozens of a children born to villagers in Cambodia. While these may be valid arguments, few arguments can seriously call into question the goals of alleviating poverty, increasing the health and survival of children and mothers, and reducing the rate of population growth in the poorest nations.

Reduce consumption. Any discussion of solving the problem of a swelling global human population must be accompanied by a parallel discussion of the patterns of human consumption of Earth's resources. Heavily consumptive habits are engrained in our daily lives in the US. Often they are almost imperceptible to us, but cumulatively they wreak havoc on the natural world. Urban sprawl, for example, chews up one million acres of open space in the U.S. each year, fragmenting wildlife habitat and isolating populations of species (Sierra Club Sprawl Index). This dispersed pattern of settlement also requires residents to use more energy to get to work, shopping, and school (it further requires increased energy use for garbage pickup, mail delivery, and goods and services provision) that, in turn, contributes to reduced air quality and global climate change.

The way that we eat reflects the increasing amounts of resources we use in our daily lives as well as the large disparities in the resources it takes to feed a single person in different societies. For example, the Audubon Society recently reported that the Earth could feed 10 billion people eating as the citizens of India do, 5 billion who eat as the Italians do, but just 2.5 billion eating as the citizens of the US (remember that there are already 6.1 billion people). Nowhere is this more apparent than in the world's meat consumption. As economies grow and populaces become more affluent, meat consumption tends to increase. In 1900, 10 percent of the world's grain went to feed animals. By the 1990s that proportion had risen to 45 percent (Riebel & Jaconsen 2002, pg. 14). As we transition to meat-heavy diets, it takes almost 4 times more calories to feed each person, with most of those calories cycled through animals (Riebel & Jaconsen 2002, pg. 25). Rather than consume local produce, we eat food that is transported huge distances before it arrives on our tables—a hamburger served in Seattle, Washington contains meat from Texas and Colorado, lettuce and tomatoes from California, wheat from Idaho, corn from Nebraska, and salt from Louisiana (Riebel & Jaconsen 2002, pg. 12). This is not to mention the ingredients for the side order of French fries and soda!

Of course, consumption also creates tremendous quantities of waste. In the early 1990s, the annual global output of hazardous wastes from chemical production, mining, paper factories, energy production, etc. was about 400 million tons, with about three quarters of that coming from the industrialized nations. If we are to lessen the impact that each one of us has on the Earth each day, we must simultaneously reduce the amount of goods and services that we consume daily and develop new, appropriate technologies that create goods and services at smaller cost to the global environment.

Develop methods to assess the economic value of biodiversity. The value of biodiversity and ecological processes and the costs of their loss are generally excluded from commercial markets. Though we know that biodiversity and the services it provides to society are crucial to human welfare, actually calculating a dollar value of processes like nutrient cycling or pollination, to name a few, remains an elusive prospect. Yet, in order to capture the value of biodiversity in pricing systems, assess damages when the environment is degraded and evaluate the worth of natural capital, we must develop techniques to appraise the economic "worth" of biodiversity. While we are at the early stages of this effort, the early results suggest that the global value of 17 ecosystem services may be as high as US$33 trillion per year (Costanza et al. 1997). This estimate dwarfs the global gross national product total of US$18 trillion per year - in effect signaling that we cannot afford to lose the subsidy that Nature provides each year (even if it were for sale). Studies like Costanza et al's are just the beginning and we must continue to refine resource economic if we are to reform the way we value the natural world.

Convert to a steady-state economy. Classic economic theory measures economic progress with continuous gains: gains in production, gains in consumption, gains in profits. Yet as Paul Hawken asks, "What is the logic of extracting diminishing resources in order to create capital to finance more consumption and demand on those same diminishing resources? (Hawken 1993, pg.5)" The current economic paradigm is that the economy is isolated form the natural world, with exchanges circulating between business and consumer endlessly. The energy and materials consumed by the economy do not actually enter the system; they merely exist external to the economy. Some economists, however, have envisioned a different, open arrangement in which the economy exists together with the resources it uses and wastes it produces in a balanced steady-state (Daly 1997). Rather than growth, the steady-state economy's drive is to foster development of a better quality of life within the bounds of the ecological system of the Earth.

Include the true costs of products in the cost to the consumer. The market economy as we currently know it fails to account for many of the costs associated with the production and consumption of many products. For example, when one drives a car and burns gasoline, it is not clear who is paying for the costs associated with the respiratory illnesses from the poor air quality caused by auto pollution. Similarly, who pays for the costs of a changing climate to exacerbated by the CO_2 and NO_x coming from the tailpipe of this same car? These costs to the collective society—created by a product both when it is made and consumed—are rarely included in the price paid by consumers. Alfred Pigou, an economist in the first half of the 1900s, formalized our thinking about these *externalities*, that is, costs that are left out of the modern economy. Following this logic, biodiversity and the environment are not protected because their value (or the cost of their loss) is not included in the pricing structures that shape consumers' behavior (Meffe and Carroll, 1997). The idea of *market failure* has spurred much research into how the hidden costs of our consumption can be adequately included in the prices that we pay. The essence of most proposed solutions is charging the producers of goods for the resources their products degrade and the wastes their products create. The producers, of course, would then pass on those costs to consumers who would then be able to evaluate the true costs of the products they buy. Products that were more efficiently made which create less waste would be cheaper than energy-intense, polluting ones, finally reflecting their true environmental and social costs.

Change our measures of economic progress to include the use and degradation of resources and natural systems. Many of the most commonly used metrics of economic output continue to ignore the diminishment or degradation of the natural resources and processes that sustain human endeavor. The most basic and widely used of those indicators, gross national product (GNP), is no exception. As natural resources are consumed and environments' ability to support healthy ecosystems is reduced, our ability to keep using those resources is also diminished, but the current calculations of GNP do not reflect this. For example, an aging factory with outdated or broken machinery is not worth as much under the current accounting schemes as a gleaming production line that promises to churn out goods for years to come. Likewise, through a comprehensive system of Natural Resource Accounting that tracks both depreciation and depletion, we should, for example, be assessing the reduced ability of eroded fields and polluted groundwater to grow and irrigate future crops.

Abolish perverse subsidies and incentives. Governments around the world constantly try to influence the behavior of their citizens and the shape of their cultures by manipulating the economic playing field. Imposing taxes to prevent undesired actions or offering tax exemptions to engender desirable actions are among the most apparent strategies that governments employ. Often these interventions by governments wind up encouraging or even paying for environmentally destructive practices. The US Forest Service, for example, in fulfilling its mandate to provide the logging industry with access to the National Forests, winds up spending more on building roads than it recovers in logging concession fees. This results in what is effectively a windfall for the logging companies, which don't have to pay for their roads. In Brazil, a government policy designed to encourage settlement of the Amazonian frontier gave pioneers free land if they cleared more than half of the forest from their properties. It is estimated that the global sum of all of these destructive subsidies is *US$ 2 trillion annually* (Myers & Kent 2001). The net effect of these incentives and subsidies is to further twist the "free" market away from reflecting the environmental degradation caused by human activities.

Change the time horizon for economic decision-making. One of the most problematic economic practices involves the *discounting* of future income and resource availability. Discounting allows us to compare the gains and losses that occur over time and evaluate different courses of action. For example, we might want to compare the value of clear-cutting a forest now, essentially taking all of our profits immediately and moving on to another venture (ignoring the costs of degraded lands and watershed), to managing the same forest sustainably, cutting a small number of trees each year, and receiving smaller profits indefinitely. Under current discounting practices that heavily favor immediate profits over long-term profits, destructive activities like clear-cutting nearly always come out ahead on the balance sheet. In practice then, the current discounting methods essentially make biodiversity resources worthless when projected far into the future. Several alternative methods for discounting future or present alternatives exist which favor the long-term sustainability of option. We must adopt these alternative economic formulae to incorporate the long-term impacts of what we do today and make our indicators more effectively guide us toward reaching our societal goals.

Empower individuals. Some feel that governments and corporations have the most influence on local and global biodiversity, rather than individuals. However, governments and corporations are organized and run by individuals. In democratic societies, at least, individuals have the responsibility to understand the ramifications of their choices on biodiversity along with the responsibility to participate in local decision-making. The actions of individuals, whether acting alone or in concert with others, will have the most profound effects on the future of biodiversity.

Some of the most critical priority setting is done everyday by individuals in their own lives—decisions of where to live, what to buy, what to do on and with their land, or even how to vote. While polls show that while 70 percent of U.S. citizens are concerned with the environment, exit polls record that only 28 – 29 percent of voters actually consider the environment when voting (Dowrie 2001/2). Many people support biodiversity by contributing to conservation organizations, yet many of these organizations focus mainly on charismatic megafauna, for example, large furry mammals. This could be at the expense of ecosystem-level action or support for less charismatic or less well-known groups upon which the charismatic fauna depend.

Few individuals truly realize the impact of their daily decisions. In the book Stuff, the Secret Life of Everyday Things, authors John Ryan and Alan Durning trace all the environmental costs included in drinking a daily cup of coffee. The decision to drink coffee at all, what brand to purchase, how that coffee was grown and harvested, shipped and distributed, packaged and prepared all come under consideration. Because many of the steps in coffee production occur elsewhere in the world, there are global ramifications to an individual's decision to drink a simple cup of coffee.

Given the number of choices we all make every day, about what we eat, where we live, what we drive, what we buy, it is very clear that each one of us is making decisions that affect biodiversity. Ultimately, each of the decisions people make, consciously or not, is based on what they as individuals value, and these are the values that will be learned by their children. As Mark Sagoff (1988) writes, "if individuals in the future have no exposure to anything we consider natural or unspoiled, they will not acquire a taste for such things. What they want will be more or less what we leave to them." However, it is not merely a question of what we want. We must never forget that biodiversity is vital to human survival. It is essential for the future of life on the planet that we realize this value and transmit this knowledge to our students.

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