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Feature Article

Facing Extinction: 9 Steps to Save Biodiversity

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Red-eyed tree frog. Jan Pietruszka/Sebastian Duda

In Brief

Human history has followed a pattern—which began in Africa but is now global in scope—of exploiting nature and depleting resources. As we have expanded our influence over the world, we have also extinguished species and populations at an alarming rate. Despite attempts to reduce biodiversity loss, the trend is likely to continue: nearly 20% of all humans—more than a billion—now live within biodiversity hotspots, and their growth rate is faster than the population at large. This article presents nine steps to reduce biodiversity loss, with a goal of categorizing human-caused extinctions as wrongs, such as the slave trade and child labor, that are unacceptable to society. These steps include developing a system of parks that highlight the planet's biological legacy, much as historical landmarks celebrate human history. Legal prohibitions that are fairly and capably enforced will also be essential in protecting rare and declining species. Biodiversity endowments—from national governments, nongovernmental organizations, and private enterprises—can help support parks and native species in perpetuity. Like a good sports team, conservationists need to defend extant wilderness areas, but they also need to play offense by restoring ecosystems, reclaiming keystone and umbrella species, and making human landscapes more hospitable to biodiversity. In the long run, the most effective forms of conservation will be those that engage local stakeholders; the cultivation of sustainable ecosystems and their services must be promoted along with conservation of endangered species and populations. The emerging field of ecological economics can unite these goals by revealing the connections between human well-being and conservation.

In 2008, the Royal Society for the Protection of Birds in the UK announced a final call to find the slender-billed curlew, a one-time resident of Europe, the Middle East, and North Africa, last seen in 1999. Meanwhile, scientists in Australia pronounced the white lemuroid possum extinct; a native of mountain forests in Queensland, the possum was the first mammalian extinction blamed exclusively on global warming. Two critically endangered frog species were declared extinct, despite their protection by a Costa Rican national park. More than 140 species of mammals, 24 birds, 6 reptiles, and 5 amphibians deteriorated in conservation status, moving from lower to higher risk categories of concern on the IUCN Red List of Threatened Species, the global authority on the conservation status of the world's animals and plants.[1] Only 37 mammals improved during this period, along with two birds and one amphibian.

Unfortunately, the year 2008 was not exceptional in these respects.

The biodiversity crisis is by now as well known as it is tragic. The species extinction rate is of great concern. At least 76 mammal species are known to have gone extinct since 1500, with several others on the verge.[2] The baiji, a freshwater dolphin of the Yangtze, will almost certainly join the list soon. The Scimitar-horned oryx and Pere David's deer now probably exist only in captivity. Marine mammals are in severe danger, especially in northern oceans. Things are even worse for other, less celebrated, taxa. More than 70% of North America's freshwater mussel species are on the edge of extinction.[3] Since the Polynesians first arrived on Hawaii 1,600 years ago, more than 70% of the islands' native birds have disappeared.[4] Since 1850, the extinction rate for the world's birds has been about 100 times higher than the background rate in the fossil record. More than 10% of all bird species remain threatened. Seabirds have been in special jeopardy—rats took out many island colonies, and about 130 of the 450 remaining species are threatened with extinction—but forest birds aren't faring much better. If deforestation continues at the present pace, so many birds may disappear that their extinction rate will increase by more than an order of magnitude by the end of the century.[5]

The problem is much bigger than species loss. The diversity of life spans many levels, from strands of DNA within an individual to entire ecosystems comprising billions of organisms and thousands of species. Extinction occurs adaptation by adaptation, population by population, habitat by habitat. The disappearance of a population is often a prelude to species extinction,[6] but species can lose their ecological relevance long before they go extinct, as their numbers dwindle and they no longer remain key players in the system. Many extant species are now absent from more than half of their historic ranges. As organisms disappear, we lose our natural capital--the ecological goods and services that enrich and sustain our lives. That deforestation and overgrazing can lead to erosion and desertification is as obvious as the Sahel, but other connections—such as the rise of malaria and hemorrhagic fevers in disturbed lands—are becoming more apparent as our ecological footprints and understanding of diseases expand. There is a growing recognition that our natural heritage is at risk, irreplaceable, and central to our well-being.

Key Concepts

- **Extinction is likely to be one of our longest-lasting legacies.**
- **To address this crisis, we will need landscape-level management of wilderness and human-impacted areas, community involvement, legislation, economic incentives, bioliteracy, unified conservation science, and attention to the prime drivers of extinction: growth of the human population and its aggregate consumption.**
- **The new field of ecological economics, which synthesizes human activities and natural processes, can quantify the costs and benefits of biodiversity protection.**
- **We need a social transformation, through education and ecological literacy, to make human-caused extinction a thing of the past, like the slave trade, apartheid, and the Iron Curtain.**

There are potential remedies for these problems, but they will take effort and determination. The financial crisis made front-page news every day in early 2009. The global extinction crisis barely was mentioned. Yet economic recessions are a blip in history, whereas the effects of runaway extinction will linger for millions of years. Paleontologists have identified long lags in the evolution of new organisms following major extinction events, largely because diversity begets diversity. Extinction chips away at the genetic and ecological engines of speciation. With fewer genetic lineages, there is a reduction in the raw material of evolution: variation in DNA. A reduction in ecosystems and unique niches means fewer opportunities for new organisms to evolve. The drop in the number of species, genera, and families on the planet is likely to be a long-lasting legacy of human activities. We will be poorer without a rich store of biodiversity—in spirit, in health, and even in our pocketbooks. Here are nine tactics that could help moderate human-caused extinctions. Most of these suggestions have been made before, repeatedly, but they warrant our continued and ever-more-urgent attention.

Landscape

1. Biodiversity Parks

Many countries have national parks that feature special landscapes and geological formations: the volcanic caldera of Yellowstone, the Grand Canyon, Mount Kilimanjaro. In addition to these traditional and essential parks, there is a need to protect a carefully designed network of reserves on each continent and in every ocean. This global series, or archipelago, of biological refuges—biodiversity parks—will preserve key features of the Earth's biological legacy inherited from the evolutionary past into the future. Such parks, in effect, would celebrate and honor the evolutionary heritage reflected in biological diversity, just as traditional national parks and monuments preserve special geological features or honor important historical events in human affairs. Rather than merely constructing museums that memorialize biocide, biodiversity parks would offer explicit protection for endangered species and

evolutionarily distinctive ecosystems. The task is not as insurmountable as it might appear. By preserving and endowing just 25 biodiversity hotspots (less than two percent of the earth's land area) we could help protect 44% of vascular plant species and 35% of all species of mammals, birds, reptiles and amphibians for $500 million a year[7]—less than 0.1% of the funds allocated to the United States' Troubled Asset Relief Program (TARP) to bail out incompetent financial institutions.

One difficulty with many current park systems is that reserves often tend to be on residual lands that are not very valuable for resource extraction or human subsistence. A study of new reserves in Australia showed that they were typically gazetted on steep and infertile public lands, areas least in need of protection.[8] Without proper planning, ad hoc reserves can be ineffective, often occupying less productive land, making the goal of protecting biodiversity more expensive and less likely to succeed. Well-placed networks of sanctuaries, designed with an awareness of ongoing climate disruption and the unique biotic facets of the sites, can help shepherd many species through the extinction crisis.

In discussing parks, we often think of landscapes, but the biodiversity crisis affects aquatic systems as well. Protection of the oceans requires safeguards against overfishing and networks of marine reserves that include rich nearshore habitats (such as coral reefs and upwellings) as well as deep-sea vents and abyssal plains. As on land, these protected areas should range from strict nature reserves where fishing and extraction are forbidden to seascapes that are managed for their cultural and ecological value. Areas that are open to exploitation should be managed sustainably to meet the long-term resource needs of local communities, while providing natural services such as recreational opportunities and water purification.[9]

2. Ecologically Reclaimed and Restored Habitats

Humans need to play conservation offense as well as defense. Beyond the immediate concern with the loss of a particular population, species, or ecosystem, a focus on long-term recovery and biological revival is also essential. Scientific research can inform the restoration of local habitats and help renaturalize entire ecosystems by uniting scattered fragments.

Young fir tree. Matt Niebuhr

In Costa Rica, scientists, businesspeople, politicians, and the local community helped regenerate 700 square kilometers of a tropical forest system—an area assaulted by ranching, hunting, logging, and fires for almost 400 years. They purchased large tracts of land, stopped the farming and fires, and let nature take back its original terrain.[10] Restoration relying on successional recovery is not always so predictable, however. The reintroduction of fire to sand barren prairies that had been overgrown with willow was not enough to restore the prairie. The woody vegetation was resistant to the fire regime.[11] For that reason, restoration ecologists are often needed to ensure the recovery of degraded lands.[12] Thousands of species have been eradicated or imperiled by the construction of ill-conceived dams throughout the world. It is too late for the many freshwater mussels and fish that have gone extinct, but for others the damage still can be reversed. The removal of the Edwards Dam from the Kennebec River in Maine restored large numbers of eels, sturgeon, and striped bass to upstream habitats, where they had been absent for more than 150 years. The U.S. Fish and Wildlife Service funds competitive grants for private stewardship of lands, with an emphasis on endangered species habitat. Dozens of federal grants support restoration projects such as prairie streams for the Topeka shiner in Iowa, aquatic systems for Arctic grayling in Montana, grasslands for a threatened milk-vetch and other plant species in Oregon, and habitat for sage grouse in Colorado.[13]

The reintroduction of individual species can play an important role in rewilding parks and their surrounding ecosystems. Large animals are especially prone to extinction, yet they are often key to ecological dynamics. The return of a megafaunal species to its historic range can yield many benefits: undo a population extinction, make habitats more interesting and exciting for locals and visitors, and restore ecological interactions (often with positive system-wide consequences). There have been several successful examples of repatriation, though far from enough. Bald eagles now nest in every state in the continental U.S., and populations have increased by more than an

Sandhill cranes. Jill Fromer

order of magnitude since their lows in the 1960s. Przewalski's wild horse has been reclassified from Extinct in the Wild to Critically Endangered, with more than 300 free-ranging individuals now roaming Mongolia. After several decades of absence from the park, gray wolves released by the Yellowstone Wolf Recovery Team in 1995 produced some surprising changes: survivorship of pronghorn fawns increased fourfold, as coyote densities declined where wolves were present;[14] streamside vegetation returned as elk browsing declined; and tourists flocked to the region, spawning a new type of ecotourism—wolf watching—now a $35 million a year industry.[15]

Some have argued that one way to restore ecological interactions that were lost with the extinction of the Pleistocene megafauna would be to introduce analogs, or modern counterparts, from elsewhere. For example, bringing Asian elephants to North America might provide seed dispersers for certain plants that co-evolved with mastodons.[16] There is no scientific or ethical consensus about the wisdom of such expensive and transformative action. Yet the possibility that genetic engineers might one day be able to bring extinct megafauna such woolly mammoths to life from frozen ancient DNA[17] should prompt us to consider whether, if such efforts are successful, mammoths are something worth restoring to landscapes that have not seen them in 11,000 years.

Community
3. The Fabric of Local Communities

As scholars, biologists mostly observe. They build models, experiment, and—on good days—make new empirical or conceptual connections: the effects of pesticides on egg development, the role of disease in amphibian declines, or the effects of biodiversity on ecosystem function. Such studies take place on the modest spatial scale of a Petri dish, a common garden, or perhaps a local landscape, and at the modest temporal scale of a few years. To ameliorate the extinction crisis, though, science must move beyond such focused analyses—important and fascinating as they are—and attempt to draw broader connections between species conservation and ecosystem roles in sustaining human communities and well-being.

How can we promote awareness of the many values of nature? In urban areas, mounting evidence links the health of city dwellers to biodiversity and green spaces.[18,19] In rural areas, the old idea that conservation displaces people, putting fences between nature and people, seems increasingly outmoded. Businesses have thrived in the American West, even as environmental protections have increased.

Where local populations increase around protected areas, a key challenge will be to mitigate the inevitable impacts by weaving the protected areas into the fabric of local communities, thereby promoting traditions of stewardship. In Peru,

villagers are literally weaving palm branches from Amazonian trees into baskets for sale in overseas markets. The goal is to make conservation productive, bettering the lives of local weavers while shifting communities away from large-scale consumption. The establishment of biological reserves can be tied to training for local and professional park staff, taxonomists, research assistants, and tourist guides. Computers and on the job training can help transform conserved wildlands into on-site graduate schools.[20] The Guanacaste Conservation Area in Costa Rica trains and employs local taxonomists and ecologists. Five full-time biologists are composing an on-line Yellow Pages for each of the 6,000 to 7,000 plant species in the park, including taxonomy, natural history, and where to find the plant. Likewise, establishing scholarships for students from local communities to work toward college degrees would pay long-term educational dividends. Even basic contributions such as Internet access and local-language publications of park reports and wildlife guides can be tremendously valuable in developing countries.

Ecotourism has helped promote conservation efforts in many countries. Gorilla watching has become one of Rwanda's biggest economic engines, with tourists shelling out $1,000 to spend an hour with the rare and habituated apes. Diving and other environmentally friendly tourist activities in the Caribbean island of Bonaire provide about 40% of the island's GDP. In recognition of the importance of clear water and coral reefs, all the nation's waters are protected to a depth of 60 meters.[21]

The high commercial value of wildlife is hardly confined to small and underdeveloped countries. In the United States, federal agencies interview hunters, fishers, and wildlife enthusiasts every five years to study the economic impact of wildlife recreation. Each year, 34 million hunters and fishers spend about $77 billion in the U.S. There are even more dedicated wildlife watchers. In 2006, 71 million Americans spent $46 billion dollars observing and photographing wildlife. That is more than was spent on watching professional football; indeed, it is more than was spent on all spectator sports, amusement parks, casinos, bowling alleys, and ski slopes combined. This passion for wildlife produced more than a million jobs and about $18 billion dollars in tax revenues. In Florida, the city of Homosassa gets almost all of its tourist revenue from people in search of manatees. And the figures for birdwatchers alone are staggering: among the 48 million people in the U.S. who watch backyard birds at feeders, 20 million also traveled for about two weeks a year in search of birds.[22] Just as cities compete for sports arenas, communities should and often do tout the many recreational opportunities that their nearby unspoiled natural areas provide. That said, recent studies suggest that interest in nature tourism may be flagging in many developed countries.[23] Nature education and bioliteracy may be one cure for this decline.

4. Diversity in Human Landscapes

Pick a square kilometer of land at random and the odds are high that people live or work on it and that they have quick access to many others via road or stream. Chances are also good that at nightfall you will see artificial light emanating from that patch of land. Less than a fifth of the world's land surface has escaped the direct touch of *Homo sapiens*.[24] Humanity now utilizes almost half of everything that grows on the planet, consuming more than 40% of the Earth's net primary productivity.[25]

Clinton Cunha

Early wilderness advocates may have bristled at the thought of managing nature, but given our vast population, we now must accept the role of planetary steward to the wild. Human density is a good predictor of conservation conflict: nearly 20% of all people—more than a billion—now

live within biodiversity hotspots, and their growth rate is faster than the human population at large.[26] To complement gains from preservation and restoration, they must focus more attention on countryside biogeography, the endeavor to make the human landscape—four-fifths of the planet—more hospitable to biodiversity. Research indicates that some well-managed agricultural areas in the tropics can help sustain many of the birds, mammals, and other organisms native to original forests.[27,28]

In many ways, agricultural and even urban areas can be made friendlier to wildlife. Living hedges support bats, farmland birds, and other animals around agricultural plots.[29] Specimen rainforest trees left in tropical pastures can help support forest bird species. Endangered species such as whooping cranes forage comfortably on ranches in Florida, where cattle may help keep predators such as the bobcat at bay. Even top carnivores such as pumas, jaguars, cheetahs, and wolves can coexist on ranch and agricultural lands when owners manage their properties in economically rational ways that allow for a coexistence of business with wildlife. Privately owned properties such as the Mpala Ranch in Laikipia, Kenya, support lions, leopards, hyenas, and wild dogs, in addition to healthy populations of native and domestic herbivores.

The implementation of this mixed-land-use approach is likely to be specific to particular environmental and economic settings. The recent movement toward biofuel provides an example. In theory, renewable fuels could benefit biodiversity by helping to mitigate climate change. However, all fuels are not created equally. Monocultures of oil palm, soybeans, and sugarcane for biodiesel and ethanol have replaced forests throughout the tropics, from the Brazilian Amazon to Indonesia. These fuel crops are a tremendous, and widely underestimated, threat. By contrast, alternative strategies that employ native grasslands on degraded lands have the potential to be a win-win situation, reducing carbon emissions and preserving biodiversity.[30,31]

Economic incentives, such as the U.S. Department of Agriculture's Conservation Reserve Program, have been used successfully to encourage biodiversity-friendly practices on private lands. Funds for such programs are often more dependable than those for protected species. They have the added advantage of helping populations of common species stay healthy—rather than ending up in conservation's equivalent of an intensive care unit.

Nearly 20% of all humans—more than a billion—now live within biodiversity hotspots, and their growth rate is faster than the population at large.

5. Legislation

A vast and discouraging literature documents the depletion of harvested species ranging from cod and cacti to passenger pigeons and whales. Stacks of buffalo bones once towered over the boxcars of the Santa Fe and other rail lines in the late nineteenth century, awaiting transport to fertilize plants (for phosphorus) and sugar refineries (carbon) in the eastern U.S. One newspaper quipped, "Buffalo bones are legal tender in Dodge City."[32] A species that once spread across a continent and numbered in the millions was reduced to tens of individuals in isolated reserves. Overharvesting continues today, of course, for many species and for many reasons. Examples are legion. After industrial overfishing in Ghana caused a collapse of fish stocks, local demand for bushmeat protein increased, resulting in a sharp decline of 41 species of mammals.[33] And for at least two millennia, hunters, in search of economically valuable wildlife products such as rhinoceros horn, elephant ivory, and civet glands for perfume, have devastated particular species.[34]

Present laws, commissions, and treaties, when fully enforced, may be best able to handle the direct exploitation of wildlife species. Treaties such as the Convention on International Trade in Endangered Species and the International Whaling Commission's moratorium on commercial whaling have helped lower trade in rare and declining species. Domestic laws, such as the Endangered Species Act in the United States, are explicitly designed to stop anthropogenic extinctions. The act has been successful in reducing the extinction rate and recovering several high profile species, such as the alligator, bald eagle, and gray whale. Many other species including the Carolina elktoe mussel, the Louisiana prairie vole, and 13 Hawaiian plants went extinct while they waited to be listed.[35] Legislation and economic disincentives should be strengthened and enforced on local, national, and international levels, with the latter designed especially to exert pressure on noncompliant nations. Incentives, economic and otherwise, are also essential. Payments for the ecosystem services provided by habitat protection can be used to help fund communities near conservation areas, thereby making biodiversity protection both more appealing and profitable.

Hardin[36] famously identified the challenge to such regulatory approaches: "Prohibition is easy to legislate (though not necessarily enforce); but how do we legislate

temperance?" Since 1986, after a moratorium on commercial whaling went into effect, whale numbers have increased. Elephant populations have expanded since the ivory ban was imposed in 1989. By contrast, despite regulations and treaties, many marine fish stocks have continued to decline. The push toward moderation has been depressingly slow and ineffective, but moderation is the only way to achieve a sustainable future for both the industry and the fish stocks that it has overexploited. Much the same can be said for many human interactions with nature. One possible way forward is a rights-based approach for biodiversity. Ecuador recently established constitutional rights for nature. Rather than simply regulating environmental destruction, the new law gives Ecuadorans the right, and obligation, to protect ecosystems, even if they are not directly injured themselves. This approach may offer a promising new path.

Economy

6. Ecological Economics

In the seventeenth and eighteenth centuries, economic relationships were seen as a reflection of the natural world. The scholar and philosopher David Hume regarded economic processes as part of nature. His contemporary Carl Linnaeus praised the "economy of nature" in a treatise on self-regulation in animals and plants. Thomas Malthus worked within the tradition of the natural sciences. For these and other thinkers of the Enlightenment, human reason was understood as a derivative of natural instincts; nature was a benevolent force in creating wealth.[37]

This view began to lose ground in the midnineteenth century, most famously with the work of John Stuart Mill. Mill supported women's rights, opposed slavery, and lamented a world that was empty of wild animals and plants. Yet, he also saw nature as unjust and cruel, proposing that human economy was separate from the natural order. Instead, the rational behavior of man and individual utility were paramount.[37] To many Victorians, the economy became a product of human deliberation, divorced from nature. Ecology was relegated to the sidelines of economics until recent years.

The relatively new field of ecological economics is a grand synthesis of human activity and the natural world. Within this sphere, there is plenty of room for discourse on individual human behavior, economic activity, ecology, and global change. For those working in this discipline, nature is seen as benevolent: the provider of goods and services, a protector against catastrophes such as hurricanes, droughts, and floods.

The Mossman Gorge in the Daintree Rainforest in Tropical North Queensland, Australia. The Daintree is a UNESCO World Heritage Site. Jeremy Edwards

Great strides have been made in valuing these services. Economists can estimate an ecosystem's value by the carbon it sequesters, the waste it absorbs, the water it provides, or the air it cleans. One species might provide pollination services and another might be valued for its appeal to tourists. These values can be calculated in various ways. One is to put a price tag on ecosystem services through replacement value. How much would it cost to treat wastewater and agricultural runoff if you removed the wetlands that filter them naturally? You can also use straightforward travel costs to estimate the economic value of species and habitats. How much will people pay to see a bald eagle or a manatee? In his global survey of whale watching in 2001, Erich Hoyt estimated that more than a billion dollars a year was spent on whale watching in 87 countries.[38] Most people will never see a humpback in the ocean, a tiger in the forest, or a blind salamander in a Texas cave, but many people are willing to pay to keep such species alive. The price they are willing to pay is known as existence value.

When addressing the value of an ecosystem, the account should entail whole-system benefits: an intact mangrove forest versus a shrimp farm in Thailand, a virgin forest versus a farm in Cameroon, or a wetland versus a landfill in Canada. In many cases, expensive technologies would be required to replace the services supplied by these ecosystems—costs that will outweigh the short-term gains of habitat conversion.[39] Understanding the relationship between biodiversity and ecosystem function will be helpful in making these determinations.

Perhaps the biggest crisis facing ecological economists is resolving the disparity in income and consumption between the wealthy industrial West and the rest of the world. The ecological footprint of our species began to exceed the Earth's regenerative capacity in the 1980s. We have now overshot the total biocapacity of Earth—its ability to fully meet and absorb the results of our actions—by about 30%.[40] We would need several planets to support humanity if everyone consumed as much as Americans.

So, what to do? Proceed with business as usual, striving to elevate everyone to Western levels of consumption? This outcome is certainly unsustainable, if not unattainable; it would likely result in more environmental catastrophes. Alternatively, nations such as China and India and the rest of the developing world could be blocked from achieving Western living standards. This outcome is also unrealistic, not to mention unjust. A third alternative seems to offer the only viable course: wealthy nations must learn to live sustainably, without co-opting much more than a fair share of Earth's bounty. This means reducing material consumption in rich countries, stabilizing the human population, and if possible humanely decreasing it.[41]

Avoiding disaster can *begin* as simply as skipping a bacon cheeseburger or going an extra year with an aging car, but ultimately it requires changing a system currently based on the presumption that endless growth is possible. Academic institutions and businesses can take the lead on this effort by converting their facilities to zero emissions. Religious leaders and churches can take a proactive role in getting the message out. The Bishop of London has told his vicars to preach sermons on the moral obligation of Christians to lead ecologically friendly lives: "There is now an overriding imperative to walk more lightly upon the earth, and we need to make our lifestyle decisions in that light." The church's environmental policy director added, "Indiscriminate use of the earth's resources must be seen as profoundly wrong, just as we now see slavery as wrong." [42]

7. Endowment: Biodiversity Trusts

One innovative way to establish and maintain protected areas is by creating conservation trust funds. There is an urgent need for such endowments, especially in the tropics, where human numbers and consumption are burgeoning and populations of many wildlife species are in decline. In these developing countries, money to maintain national parks is often short. In many cases, expenditures are less than five percent of those deemed necessary to establish and maintain a viable reserve network.[43] Unlike taxes, user fees, and debt swaps, endowments provide sustained funding and are relatively resilient to the fluctuations of power and tourism.[44] Permanent funds, ideally administered by a board of qualified trustees, will be critical in maintaining conservation areas in perpetuity. As of 2000, conservation trust funds had been established in 40 countries, with nine nations boasting endowments of $10 million or more.[44] This modest beginning is an important first step. Costa Rica is aiming to create a $500 million endowment fund to consolidate 25% of the country into eleven conservation areas. One hundred million dollars would be spent to consolidate the areas, and annual revenue from the remaining $400 million would be divided among the conservation areas to cover operating costs. Five hundred million dollars is a large sum for a small country, but it is achievable put in the context of other institutions such as research universities, which sometimes have endowments in the billions of dollars. Costa Rica's green image abroad is enhanced by these efforts, increasing its appeal as an ecotourist destination, and Costa Ricans nurture a sense of pride in their world-leading reserve network.

We should think about how tourists and benefactors might contribute to national and global conservation trusts. Could visitors to national parks around the world become alumni to those areas, recruited to support their favored reserves? Companies that are involved in bioprospecting in conserved areas should contribute to preserving the habitat from which they profit. Local communities, while they may not benefit directly from these discoveries, should be taught the value of ecosystem services coming from these protected areas. It is also possible to use trust funds for individual charismatic species, such as tigers, pandas, or manatees, to preserve the habitat where those species live. Such megafauna could help protect the many species that lack the charm to inspire large contributions.

Giraffe in Kruger National Park, South Africa. David Hartstein

Education and Science

8. Bioliteracy

Since people only protect what they value, the most important—and perhaps most difficult—step in slowing biodiversity loss will be transforming human attitudes about nature. As a society, we need to establish an ecological identity that helps foster a love of nature. Biologists can convey the excitement of natural history and the joy of scientific inquiry to students and the general public. Social scientists can help make the connection between wildlife conservation and human well-being. Great places to start are in the home and in elementary school. "See spot run" should be replaced by "See the plant grow in the sun." Many authors have written convincingly on the need for environmental literacy and outdoor education, to take students directly into parks, farms, and shorelines. There is evidence that students who receive such place-based education typically outperform their peers.[45]

Ljupco Smokovski

How do we enhance the devotion to biodiversity and increase the awareness to threats we have created? There's great value in seeing animals in the wild: gorillas in the Virungas, humpbacks on Stellwagen Bank, regent honeyeaters in the Australian outback, wolves in Yellowstone. Not everyone will be able to visit remote sites, but most people will be able to access green spaces housing charismatic species nearer to home: a snowy owl on a wintry day in Jamaica Bay in New York City, a peregrine falcon on the John Hancock building in Boston, orcas in Puget Sound, or sea otters in Monterey Bay. For many these are defining moments—"radioactive jewels," as one psychologist has put it—of life experience that are visited and revisited, "emitting energy across the years of our lives." [46] We need to integrate these moments into a broader societal dedication to conservation. There is considerable hope along these lines, indications that education programs on whale-watch tours and even on nature television influence people's behavior and increase their environmental consciousness.[47]

Bioliteracy can entail far more than an appreciation of wildlands and whatever large animals they might contain. It can help students explore the role of biodiversity in human well-being. Recent studies indicate that biodiversity loss, invasive species, and habitat destruction can be drivers in the ecology of diseases, by helping pathogens and vectors spread quickly around the world. Yellow fever, dengue, malaria, and West Nile encephalitis are a few of the diseases that have breached geographical barriers through human transport. Many emerging infectious diseases come from wildlife, typically jumping from animals or their carcasses to humans, as habitats are opened up or otherwise abused. We now know that chimpanzees were the source of HIV-1; the Ebola virus can jump between gorillas, chimpanzees, humans, and even small antelopes; and severe acute respiratory virus (SARS) came from a crowded wildlife market in Guangdong Province in China.[48] One might expect that more diverse habitats support more diseases, but low diversity habitats—disturbed habitats—often pose the greater risk. Biodiversity loss and habitat transformations have increased the prevalence of various vector-borne diseases, including Lyme disease from ticks, and malaria and West Nile virus from mosquitoes.[49] Mice and other rodents are important reservoirs of hanta viruses and other hemorrhagic fevers. As diversity decreases, overcrowding of one species—usually an opportunistic one such as the deer

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Baboons in Kruger National Park, South Africa. David Hartstein

mouse *Peromyscus maniculatus*—leads to fights, especially among males. The virus is then transmitted quickly through the population. Greater transmission in rodents increases risk to humans.[50] A better understanding of the protective role of nature and biodiversity will ultimately benefit conservation efforts.

9. Toward Zero Extinction

The goal needs to be made clear: to reverse the current trend and add anthropogenic extinction to the injustices—slavery, child labor, apartheid, the Iron Curtain—found abhorrent by civilized people. Achieving such a social and ecological transformation will require ingenuity and initiatives that are global in scope, yet regional in implementation. The Endangered Species Act mandated the end of species extinction in the United States in 1973. Its record has been good, but not perfect. Twenty species, including the Peregrine falcon, have recovered and been delisted. Nine others, including the dusky seaside sparrow of Florida, have also been delisted, but only after they had gone extinct. Some threatened species probably would not have survived without the legislation; others are likely to remain permanently reliant on conservation efforts. Still, hundreds of species and populations have been left unprotected, and underfunding has been a chronic problem. An intensive search of remote forest pockets in Queensland for the lemuroid white possum, thought to be one of the first mammalian victims of climate change, turned up three individuals this year. There is still hope, however slight.

It is clear that an unprecedented international effort is needed, one that develops new attitudes and institutions. The Convention on Biological Diversity was ratified by 188 countries in 1994 (the U.S. signed on but has still not ratified the treaty). The CBD's target for 2010, endorsed by the United Nations General Assembly is to reduce the rate of biodiversity loss significantly by 2010. There is still a long way to go. One of the biggest challenges for conservation biologists will be launching and sustaining this effort in a politically sensitive and cost-effective way.[6] Nonprofit groups such as the Nature Conservancy, Sierra Club, and World Wildlife Fund play an important role in species and habitat conservation. So, too, do associations gathered around a single taxon, such as Polar Bears International or the Gopher Tortoise Council, or many taxa, such as the Xerces Society for Invertebrate Conservation and the Center for Plant Conservation. The Alliance for Zero

Extinction states its conservation goal in its title. International organizations such as the IUCN and Diversitas can help bridge the efforts between national governments, raising the level of urgency in the public eye.

Ideally, the yearly additions of species to lists of threatened and endangered taxa must decline and, eventually, approach zero long before the planet's biodiversity has been irreversibly gutted. Indeed, the human stewards must look forward to a time when no species are marked with an EX for newly extinct.

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