Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions

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The threats to the future of biodiversity are many and well known. They include habitat conversion, environmental toxification, climate change, and direct exploitation of wildlife, among others. Moreover, the projected addition of 2.6 billion people by mid-century will almost certainly have a greater environmental impact than that of the last 2.6 billion. Collectively, these trends portend a grim future for biodiversity under a business-as-usual scenario. These threats and their interactions are formidable, but we review seven strategies that, if implemented soundly and scaled up dramatically, would preserve a substantial portion of global biodiversity. These are actions to stabilize the human population and reduce its material consumption, the deployment of endowment funds and other strategies to ensure the efficacy and permanence of conservation areas, steps to make human-dominated landscapes hospitable to biodiversity, measures to account for the economic costs of habitat degradation, the ecological reclamation of degraded lands and repatriation of extirpated species, the education and empowerment of people in the rural tropics, and the fundamental transformation of human attitudes about nature. Like the carbon ''stabilization wedges'' outlined by Pacala and Socolow [Pacala S, Socolow R (2004) Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. *Science* 305:968–972] (1), the science and technologies needed to effect this vision already exist. The remaining challenges are largely social, political, and economic. Although academic conservation biology still has an important role to play in developing technical tools and knowledge, success at this juncture hinges more on a massive mobilization of effort to do things that have traditionally been outside the scope of the discipline.

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The fate of biological diversity for the next 10 million years will almost certainly be determined during the next 50–100 years by the activities of a single species. That species, *Homo sapiens*, is ≈200,000 years old. It has been fabulously successful by ecological standards: it boasts as-yet-unchecked population growth and a cosmopolitan distribution, and it has vanquished its predators, competitors, and some of its parasites. The fossil record suggests that the typical mammal species persists for approximately one million years (2), which puts *Homo sapiens* in mid-adolescence. This is a fitting coincidence, because *Homo sapiens* is now behaving in ways reminiscent of a spoiled teenager. Narcissistic and presupposing our own immortality, we mistreat the ecosystems that produced us and support us, mindless of the consequences.

The state of biodiversity today is a reflection of that abuse, but the reflection is hazy because we know neither the total number of populations or species nor how many have gone extinct. Our best information is on the rate and extent of habitat destruction and degradation. For example, we know from long-term monitoring that coral cover in Jamaican reef ecosystems declined from >50% to <5% between the late 1970s and 1994 (3). From remote-sensing studies, we know that the rate of selective logging in the Brazilian Amazon ranged from 12,000 to 20,000 km^2/year between 1999 and 2002 (4) and that the rate of deforestation in the Peruvian Amazon averaged 645 km^2/year from 1999 to 2005 (5). Likewise, we know from global mapping studies that nearly 50% of all temperate grasslands, tropical dry forests, and temperate broadleaf forests have been converted to human-dominated uses worldwide, whereas only 4–10% of those biome types are formally protected (6).

Of the total number of species on Earth, we still cannot say much more than that it is likely to be "of the general order of 10^7" (7). Estimates of species extinction rates—often based on estimates of habitat loss in conjunction with the species–area relationship—are similarly imprecise (8, 9) and are sensitive to multiple assumptions (e.g., refs. 10 and 11). The number of animal and plant extinctions certified since 1600 is only slightly greater than 1,000 (8), but our pitiful knowledge of biodiversity's extent and the inherently inconspicuous nature of extinction ensures that this figure is a small fraction of the true number. Although no scientific consensus is forthcoming on the exact rate of extinction for any region or group of organisms, much less for global biodiversity, there is a consensus that current extinction rates vastly exceed background ones, perhaps by two to three orders of magnitude (12, 13).

Although species loss occupies an overwhelming proportion of the literature, genetically distinct populations are also an important component of biodiversity. Estimates of population diversity and extinction rates are even more uncertain than those for species, but even these crude estimates are alarming: of perhaps one to seven billion populations worldwide, 16 million may be extinguished each year in tropical forests alone (14). Trends in key parameters of well studied populations are consistent with this picture of decline. Amphibian populations have declined locally and globally in recent years (15, 16), and many mammal species worldwide exhibit range-size contractions indicative of heavy population loss (17).

When we were first asked to prepare a paper addressing the question "Where does biodiversity go from here?" a variety of cynical answers leapt to mind. The principal threats to biodiversity—direct overexploitation of organisms, habitat destruction and degradation, environmental toxification, climate change, and biological invasions, among others—have been known for decades. Yet despite a ballooning number of publications about biodiversity and its plight, there has been dispiritingly little progress in stanching the losses—so little that some commentators have characterized applied ecology as "an ever-more sophisticated refinement of the obituary of nature" (18).

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As conservation-oriented scientists, we are responsible for biodiversity. Its loss is our failure.

We draw on the literature to sketch a brief and incomplete answer to the question posed to us, assuming that society continues business as usual. Because that outlook is bleaker than we are willing to accept, we then outline a more hopeful set of answers. These amount to a portfolio of strategies for combating biodiversity loss.

Business as Usual: Where Does Biodiversity Go from Here?

There are ≈6.7 billion people in the world as we write this, a number that is projected to grow (according to a mid-range forecast) to 9.3 billion by 2050 (19). The continued growth of the human population displaces biodiversity directly, as land is developed to create living room. In one recent example, Venezuelan president Hugo Chavez aims to translocate 100,000 people into a brand new city in El Avila National Park to alleviate overcrowding in Caracas (20). Providing a huge global populace with the resources necessary for survival (much less comfort) also displaces biodiversity. A recent spatially explicit analysis showed that humanity already appropriates nearly a quarter of global terrestrial net primary productivity, and up to 80% in large regional swaths (21).

Supplying the consumption of the next 2.6 billion people will almost certainly have a greater environmental impact than supplying the last 2.6 billion added since 1975. Our species has already plucked the lowest-hanging resources and converted the richest lands. To maintain the pace, metals will have to be won from ever-poorer ores, and oil, natural gas, and water will need to be obtained from ever-deeper wells and transported farther—all requiring accelerating energy use. So-called "marginal lands," often the last holdouts of biodiversity, are the final frontier, awaiting conversion into more human biomass. Whenever biodiversity preservation poses a threat to human livelihood, comfort, or convenience, the politically expedient choice is usually to liquidate the natural capital. In sum, every increment in the human population accelerates competition with other organisms for Earth's primary production. And, of course, not only do the present poor need more consumption, the present rich also demand it—as certainly will the newcomers. This is all in the face of signs that average per capita consumption is already unsustainable in developed regions (22), indicating a stark tradeoff between today's consumption and the basic human rights of future generations.

A major byproduct of human consumption is the toxification of Earth's ecosystems. Human agriculture and fossil-fuel combustion have multiplied the emission and deposition of nitrogen in recent decades, with negative consequences for biodiversity in grasslands (23) and aquatic ecosystem (24). Widely used herbicides such as atrazine and glyphosphate harm amphibians (25, 26), potentially contributing to global amphibian decline, and the use of antiinflammatory drugs such as diclofenac and ibuprofen to treat livestock in India has ravaged scavenging birds, for which cattle carcasses are a major food source (27, 28).

Anthropogenic climate change stems from a special case of toxification: carbon pollution. Many biological impacts of global heating are evident, as animals and plants undergo changes in phenology, distribution, and local abundance (29). More alarming, anthropogenic heating has already been directly implicated in several extinctions (30) and seems likely to precipitate others. In the oceans, heating is already reducing the extent and altering the structure of coral reefs via breakdown of the coral–algal symbiosis (31). Moreover, rising CO_2 concentrations are lowering oceanic pH, with potentially disastrous consequences for coral reefs and other marine ecosystems (32, 33).

Direct exploitation of wildlife species by human beings takes a variety of forms, from subsistence hunting (34) to the harvesting of wild plants and animals for conversion into luxury goods and pets (35, 36). Large mammals and fish suffer disproportionately from direct human predation. Many of these vertebrates (e.g., apex carnivores, large ungulates, etc.) are strongly interacting species in their native ecosystems (37–40), and overharvesting them may have destabilizing effects on biodiversity and ecological processes such as seed dispersal, nutrient cycling, and even primary production. In oceans, top piscivores suffer disproportionately as fleets fish down the food web (41). Industrialized fisheries have often devastated community biomass of predatory fish within a few decades (42), with even sharper declines common among the apex predators (43).

Nonnative species introduced by people into naive ecosystems have occasionally wrought havoc on local biodiversity via predation, competition, and the disruption of co-evolved interactions. Biotic interchange is likely to increase with increasing mobility in an increasingly globalized world; under business as usual, biogeography will be increasingly homogeneous.

A cryptic yet critical threat to biodiversity is the loss of future evolutionary potential. Extinction of genetically distinct populations, decreases in effective population sizes, and homogenization of habitat types are all likely to have negative effects on future biodiversity (13, 44). The positive relationship between speciation rate and habitat area (45) indicates that decreases in species geographic ranges will diminish future speciation rates, which in turn will impoverish future diversity (46). Speciation of large vertebrates, which are highly mobile and require large habitats, may cease entirely (13), and biodisparity—the range of morphological and physiological variety on Earth—will decrease as phylogenetically distinct, species-poor branches are pruned from the tree of life (47).

Loss of microevolutionary potential will also limit the capacity of populations to adapt to changing environmental conditions, highlighting another important point: The drivers of biodiversity loss will often act synergistically in imperiling populations and species. Habitat loss and fragmentation compound the effects of climate change, as species are unable to track their thermal niches spatially (48). The interactions among logging, fire, and climate change threaten to transform the Amazon rainforest into savanna (49, 50). Such positive feedbacks seem to be a rule, rather than an exception, and they make it impossible to generate precise estimates of future biodiversity.

In short, although there are many uncertainties about the trajectories of individual populations and species, we know where biodiversity will go from here in the absence of a rapid, transformative intervention: up in smoke; toward the poles and under water; into crops and livestock; onto the table and into yet more human biomass; into fuel tanks; into furniture, pet stores, and home remedies for impotence; out of the way of more cities and suburbs; into distant memory and history books. As biodiversity recedes, we also lose the stories that go with it and many ways of relating to the world in which we evolved.

We now consider what might happen if humanity changes the way it does business. Ours is not a comprehensive treatment of this issue. The Millennium Ecosystem Assessment (51) contains a thorough and colorful summary of the state of biodiversity, and it provides important (and necessarily overarching) recommendations for softening human impact on ecosystems—things like increasing governmental accountability, eliminating environmentally malign subsidies, and reducing greenhouse-gas emissions. However, the breadth and complexity of these objectives, and the considerable political clout required to enact them, can engender the misconception that only governments can determine where biodiversity goes from here. That misconception, in turn, is a recipe for paralysis among concerned individuals. Therefore, we try to focus more narrowly on seven more-or-less concrete sets of actions that individuals or small groups have already set in motion. If implemented more broadly and scaled up dramatically, these actions would collectively enable a different, more appealing fate for biodiversity.

Although each of the following strategies is being used somewhere, none is yet realizing its full potential. Some may not be achievable in all times and places, but none is exclusive of any other. Most of these strategies are familiar to most people in the conservation community; the notion that they are all "correct" ways to conserve biodiversity is perhaps less so. Indeed, squabbles over strategy are endemic within the conservation community, perhaps because different strategies are seen as competing for funding and for primacy in the scholarly idea-scape. The alacrity with which international conservation nongovernmental organizations have "branded" themselves (52) and the sometimes absurdly acrimonious exchanges between conservation academics seem to manifest a widespread "either–or" belief that there are absolutely right and wrong ways to protect biodiversity (53). Ostrom *et al.* (54), in a recent PNAS Special Feature, wrote of the need "to go beyond relying on abstract cure-all proposals for solving complex problems related to achieving sustainable social–ecological systems." By emphasizing a portfolio of partial solutions, we hope to reinforce the idea that maximizing future biodiversity will require a plurality of approaches in creative admixtures that are tailored to local realities. Each place needs a different mixture.

Business as Unusual: Where Else Might Biodiversity Go from Here?

Into a Less Peopled, Less Hostile Planet. The human impact on biodiversity is a product of three root factors, summarized in the heuristic I=PAT identity (55). The overall *I*mpact (encompassing all of the drivers of biodiversity loss discussed above) is the product of *P*opulation size, per capita *A*ffluence, and the *T*echnologies (and socioeconomic–political systems) used to generate affluence. "Affluence" in this context is simply per capita consumption, and "socioeconomic–political systems" refer to the strictures that regulate technology use.

Tangible steps to reduce any of these factors will lessen their product and help produce a more hospitable future for biodiversity. A current example that integrates all three factors is the drive to produce biofuel (*T*) to satisfy the expanding energy consumption (*A*) of a growing population (*P*). Unchecked biofuel production has the potential to destroy all moist-tropical biodiversity that lacks conservation status. Biologically impoverished monocultures of oil palm, soybeans, and sugarcane for biodiesel and ethanol are devouring swaths of Brazilian Amazon and Cerrado, Indonesian, and Malaysian tropical rainforests and other vast reservoirs of biodiversity (56, 57). However, the production of biofuels from native grassland perennials on agriculturally degraded lands has the potential to reduce carbon emissions without displacing food production or converting native habitats (58). In this case, an innovative *T*echnological adjustment would reduce overall *I*mpact. Likewise, simple shifts in socioeconomic–political systems—instituting high-occupancy vehicle lanes to reduce carbon emissions, for example, or demanding high-seas ballast water exchange for cargo ships to reduce species introductions—would do a great deal.

Although population growth has slowed or is slowing in many developed countries, it remains high in many developing regions. Much is known about how to hasten the transition to a stable and then declining world population. Education and employment—for women especially—along with access to contraception and safe abortions are the most important components (59). Less is known about how to prevent overconsumption of natural resources (22). Mass media are a powerful tool for raising environmental awareness and influencing attitudes toward consumption, as demonstrated by Al Gore and his documentary film *An Inconvenient Truth*. To this end, we should exploit the media to the fullest possible extent. Although more environmentally benign technologies will also help, the battle will not be won without a transformative collective decision by consumers that less can be more. For example, although an 80% shift from beef and pork to farmed fish and poultry could enable displacement of up to 22% of U.S. gasoline consumption with low-impact, high-diversity biofuel (D. Tilman, personal communication), such a shift will not happen without hundreds of millions of conscious decisions that a sustainable economy is worth more than the taste of bacon cheeseburgers.

Into Perpetuity via Endowments for Conserved Areas. As many conservation biologists have noted, formally protected areas are not realizing their full potential, being too few, too small, too far apart, too expensive to establish and maintain, and/or too poorly administered (60, 61). These pitfalls notwithstanding, nature parks and other conservation areas are central to the future of biodiversity (62).

The outstanding national parks of North America and Australia demonstrate that well fed voter/taxpayers, whatever their environmental shortcomings, are at least willing and able to support biological preserves; people in poorer countries, the argument goes, cannot necessarily afford that luxury. Of the various forms of revenue used to support protected areas in poor countries, conservation trust funds—specifically, endowment funds intended to last in perpetuity—are the most promising. Unlike taxes, user fees, and debt swaps, endowments provide sustained funding and are relatively resilient to political whims and fluctuations in the demand for ecotourism (63). As of 2000, conservation trust funds had been established in more than 40 countries, and nine developing nations boasted endowments of US$10 million or more (63).

Spergel (63) argues that conservation trust funds should be additional to existing government funding, but this may not always be the case. Consider the following initiative being considered in Costa Rica. It is called Paz Con la Naturaleza—Peace with Nature—and it aims, among other things, to generate $500 million to endow the country's entire conserved-area system. Crucially, this would relieve Costa Rican taxpayers of the burden of financing conservation. Under the plan, $100 million would be spent to consolidate the existing national park system—25% of the country—into 11 large conservation areas (ref. 64 and D. H. Janzen, personal communication). The remaining $400 million would be invested outside the country in a university-like endowment; $20 million of annual revenue from that endowment would be divided among the conservation areas and used to cover operating costs, with any remaining income plowed back into the fund for growth. Although the financing would operate at a national and international scale, the plan calls for decentralized local administration of the individual conservation areas. This plan, with an endowment as its centerpiece, simultaneously redresses most of the frequently cited shortcomings of conservation areas: it aims to make them bigger, closer together, better administered, and essentially free to their users (aside from the opportunity cost of the land use).

It is an ambitious goal, to be sure. The price tag is steep by traditional conservation standards, but with many U.S. research universities boasting endowments in the multiple billions of dollars, $500 million to conserve 25% of a nation and 4% of global biodiversity forever—creating the world's first explicitly green country in the process—seems like a bargain. It remains to be seen whether the plan can be implemented in small, stable, "green" Costa Rica, much less anywhere else; we will not know until money is pledged. In any event, perpetual endowment funds have tremendous potential in conservation (e.g., as a source of revenue for restoration and other projects: refs. 63 and 65) and will generally increase the "localization" and longevity of conservation initiatives by tying funds to long-term programs in particular areas.

Into Human-Modified Landscapes, as Best It Can. Unbroken tracts of conserved wild area, if they exist, will always be the greatest reservoirs of biodiversity and the most interesting places to visit. But under certain conditions, human-dominated pastoral and agricultural landscapes can also harbor an appreciable amount of biodiversity (66–68). Simple and inexpensive management techniques, such as maintaining living hedges around agricultural plots (69) and preserving remnant trees in pasture (70), can often buttress the biodiversity of these areas.

There are many compelling reasons to conserve countryside biodiversity. One is that most human-dominated landscapes will not revert to wildness anytime soon; enabling wild populations to persist in these areas is the best plausible outcome for biodiversity. Another is that habitat types vary in their tolerance of human activity. Whereas tropical forests are quite sensitive to burning, wood chopping, and hunting, tropical savannas are relatively resilient to anthropogenic disturbance. In many parts of Africa, much or most wildlife occurs outside of nationally protected areas (68), and wildlife can coexist alongside limited livestock populations (71). That people also share this space does not necessarily diminish its conservation value. Moreover, maintaining nonconserved areas in biodiversity-friendly ways aids migration and dispersal between protected areas, a process that will become even more important as climate change rearranges species' distributions (48, 72). Finally, maximizing biodiversity in areas where humans are active in their daily lives increases the frequency of interactions between human and nonhuman organisms, which enhances the potential for ecosystem-service delivery and bioliteracy development (see *Onto the Cultural Radar Screen*). Economic incentives (or legal strictures) can be developed to encourage (or require) biodiversity-friendly use of privately held lands (73, 74).

Biodiversity maximization in human-dominated landscapes does not in any respect reduce the need for large conserved wildlands. How to allocate conservation resources among these two different frameworks is a local problem, and answers will vary depending on such factors as the habitat types involved, local land-use history, the state of the region's government and protected-area system, and the availability and price of land for purchase. As in most other respects, Britain is different from Kenya is different from Amazonia. The challenges in planning for conservation in human-dominated landscapes are perhaps most pronounced in fragmented tropical forest–pasture–field mosaics, because tropical-forest biodiversity is so great and the alternate landscape states are so dramatically different from the baseline. One uncertainty is whether the apparently high conservation value of these mosaics (e.g., refs. 66 and 75) will be sustained over centuries, or whether it will ultimately succumb to the "extinction debt" (76, 77). A related concern is that the diversity of interspecific interactions in human-dominated landscapes will decline more quickly and less perceptibly than the diversity of populations or species and that this will eventually lead to additional population and species loss. A 300-year-old canopy tree species in a Brazilian pasture may serve as a roost for a diversity of birds, epiphytes, and other organisms. But if its pollinator or seed disperser has been lost or will not venture into the pasture (78), or if its seeds will not germinate in a pasture, or if its seedling crop will be devastated by pasture-tolerant seedling predators, then it is among the living dead (76): it will not replace itself, and, when it goes, so go the other species that used it.

Toward a (Protected) Role Within the Global Economy. Ecotourism has long been one of the most potent forces favoring conservation and will continue to be so. Ecotourists are consumers of services that nature provides (beauty, adventure, life lists, etc.), and they obligingly pay for these services in many ways (paying for park entry fees, rooms at hotels, vehicle repairs at the local mechanic, etc.).

But ecotourism is exceptional in these respects. The biosphere provides a steady stream of other direct and indirect benefits to humanity for which nobody pays. The last decade has seen "ecosystem services" transformed from an abstract academic concept (79) into an applied research program and a powerful policy tool (51, 80). These services include, but are not limited to, providing raw materials, natural water filtration, carbon sequestration and storage in forests, flood and erosion mitigation by plant communities, and pollination of crops by wild animals (80). Ecosystems, in addition to being reservoirs of biological diversity and an integral part of our planetary and cultural heritage, are capital assets.

The global economy does not in any serious way account for the value of ecosystem services. The perversity of this situation is obvious. The costs, both in the traditional economic sense and in terms of human health and well being, of losing these services would be immense: many economic institutions would either collapse outright or require technological surrogates vastly more expensive than simply conserving the relevant ecosystems. The archetypal example of an ecosystem service in action is the conservation of the Catskill watershed, which has (thus far) spared the city of New York the $8 billion cost of building a water-filtration plant. Elsewhere, there are indications that mangroves and other coastal vegetation might have protected some coastal villages from the devastating Asian tsunami of 2004 (81). Recent population crashes of honey bees (*Apis mellifera*) have threatened an approximately $15 billion crop-pollinating industry in the United States, highlighting the importance of conserving diverse native-bee communities (82, 83). These case studies are small components of a total-biosphere value that is, effectively, infinite (84).

The idea that economic growth is independent of environmental health, and that humanity can therefore indefinitely expand its physical economy, is a dangerous delusion. The problem is that although we know that individual ecosystem services are valuable, we rarely know precisely how valuable. And although quantitatively estimating the dollar value of individual services can be an eye-opening exercise, the effort required makes doing so prohibitive for every ecosystem (to say nothing of the futility of trying to add up to infinity). The challenges, then, are to provoke society to acknowledge ecosystem-service values (even though approximate or only qualitative) and to maintain service provision by protecting service sources.

In addition to the individual efforts of a growing number of academics and practitioners, innovative programs are emerging to tackle these twin challenges at large scales. The Natural Capital Project is an international collaboration involving Stanford University, The Nature Conservancy, and World Wildlife Fund that aims to integrate ecosystem-service values into land-use and policy decisions (85). By developing new decision-support tools—including software to quantify and map the value of ecosystem services across landscapes and seascapes—and applying them in several demonstration sites across the world, the project hopes to promote more forward-thinking land-use decisions.

In some cases, protecting ecosystem services (or even engineering them) may not enhance biodiversity conservation (86, 87), but it may be useful for other anthropocentric reasons. We should be frank about that when pondering how to justify and finance our operations. We should also think about how increased valuation of ecosystem services might spill over into other sectors of the economy: If we rely on an ecosystem to do a job, are we putting a human being out of work, and might that person retaliate against the service-providing ecosystem?

Finally, we must recognize that, for whatever reason, demand for particular ecosystem services will wax and wane, but that the sources of the services must not be allowed to wax and wane in sync. As proponents and critics of market-based conservation approaches both point out, complete commodification of ecosystems is not the goal. Yes, ecosystem services have enormous value in traditional economic terms for their role in sustaining and enriching human life, and efforts to ascertain these values are important. No, ecosystems and their biodiversity cannot compete on the open market as service providers alone (88). To subject ecosystems to all of the same demands and risks that commodities and corporations face in capitalist economies would be to ensure their eventual diminution and demise.

Globalization intensifies this hazard. In a globalized, demodularized world, goods and services can often be imported and outsourced more cheaply than they can be obtained locally—and this includes goods and services provided by ecosystems. "Endemic" ecosystem services, which cannot be supplanted by goods and services from distant sources, will likely be the most effective allies to biodiversity in the future.

Into Ecologically Reclaimed and Restored Habitats. Experience has shown not only that science can inform more rapid, more effective restoration of local habitats (89), but also that contiguous ecosystems can be built from scattered pieces at large scales (90). This process has several names—restoration, rewilding, renaturalization—and provides a constructive, creative counterpoint to the stop-loss approach of traditional conservation. Thus, the future of biodiversity is not just what we can save of what is left, but also what we can create from what is left (see also ref. 91). As Young (92) put it, "The conservation mindset is one of loss on a relatively short time horizon, whereas the restoration mindset is one of long-term recovery."

Successes abound. The regeneration of tropical forest in Guanacaste Province, northwestern Costa Rica (90, 93), is particularly heartening for several reasons: it involves restoration of multiple habitat types; it is large-scale yet local and decentralized; and it was achieved by using a portfolio of innovative mechanisms and via broad collaboration among scientists, businesspeople, politicians, and the local community. The result has been the regeneration and conservation of 700 km^2 of tropical dry forest along with abutting chunks of rain and montane forest. In poverty-stricken Niger on the fringe of the Sahara, farmers have helped hold off desertification in many areas by nurturing saplings in their fields rather than removing them—and they have begun to reap benefits from this greening of the countryside (94). In the oceans, researchers have had some success transplanting live coral fragments onto degraded reefs (95). Likewise, efforts to rebuild damaged watersheds and wetlands have been a major focus of scientific restoration ecology (e.g., ref. 96), with important implications for the availability of potable water.

Large animals are particularly extinction-prone, at both the population and species levels. They are also often particularly important to ecological dynamics. Returning megafaunal species to what remains of their historical ranges (97) can yield a number of overlapping benefits: the return of these charismatic species undoes population extinctions, makes habitats more interesting and exciting, and can restore ecological interactions with appealing system-wide consequences. The repatriation of wolves to Yellowstone National Park in 1995 not only titillated tourists but also revived a multispecies trophic interaction involving elk, beavers, and trees, which has rejuvenated the region's riparian ecosystems (98, 99).

These examples and others illustrate that ecological restoration has a critical role in determining where biodiversity goes from here; we hope for enormous and rapid expansion of such revival efforts, even if the ultimate ecological goals take centuries to achieve. The only caveat is that many projects branded as "restoration" may be only weakly beneficial or neutral for biodiversity (100). Tree plantations are not forests.

Into the Fabric of Local Communities. For various reasons, conservation programs in developing regions are likely to fail when they are imposed from the top down by outsiders/foreigners (101). That realization has spurred interest in (*i*) involving local communities in conservation planning and (*ii*) fostering their desire and capacity to help achieve conservation goals. In some ways, these can be seen as short- and long-term components of the same strategy. Earning local support for a conservation initiative is needed to get the ball rolling; building local capacity ensures that the ball keeps rolling once the outsiders leave.

Community involvement in conservation planning and protected-area establishment/maintenance can take a variety of forms (102, 103) and is the subject of a gargantuan literature. At its most straightforward, it involves dialogue and follow-up with local stakeholders to establish what kinds of compensation (broadly construed) would sweeten the prospect of restrictions on habitat use, but more nuanced and sophisticated schemes have also been used (104, 105).

Local capacity building can also operate at multiple scales. Education is clearly central to this goal, from providing on-the-ground biodiversity training in parataxonomy (106, 107) to training professional national park staffs to facilitating advanced degrees for local students via scholarships and other mechanisms (52). But even more basic contributions (local-language publications and extension efforts, computer and telecommunications access, etc.) can be extremely beneficial.

As conservationists increasingly realize, programs along these lines should attend every tropical conservation effort. Such programs are crucial—not only for the long-term success of the given conservation effort, but also for the augmentation and transmission of biodiversity knowledge. Efforts to "engage" local communities in conservation and land management can and have gone awry, and there are often important tradeoffs between conservation and development (88). None of this alters the fact that, without local acceptance of biodiversity and the rationale for its conservation, any gains will be ephemeral.

Onto the Cultural Radar Screen. For decades, conservationists have appealed to aesthetics as a principal reason to conserve wild areas and species. But beauty is in the eye of the beholder, and the 13-billion-plus beholding eyes of the world are drawn to many things that are hostile to biodiversity: large families, tractors, treasure, pavement, goats, and Cadillacs, to name a few. The processes of economic and infrastructural development help to divorce people from the natural world. Moreover, although outdoor recreation and ecotourism are still important parts of many lives in rich countries, biophilic impulses seem increasingly swamped by other stimuli. In the United States, the rise of electronic media has coincided with a 20-year downturn in National Park visitation, after 50 years of steady increase (108). Recent findings indicate that similar declines in contact with nature are common to developed nations worldwide (109).

Such trends will not be reversed and the biodiversity crisis will not be resolved until nature can rival virtual reality as a source of entertainment, intrigue, and inspiration. Janzen (110, 111) offers a compelling analogy: as books are uninteresting and useless to an illiterate person, so is biodiversity uninteresting and useless to a bioilliterate person. People keep what they use, and increasing biliteracy would enable more people to find uses for biodiversity. Demand for ecotourism and perceived "existence values" would increase and, with them, biodiversity-sustaining revenues. In a world of stingy appropriations for conservation, we have a wonderful academic literature on how to maximize returns on conservation investments (112). But we have spent comparatively little effort figuring out ways to create a world of biodiversity fanatics and conservation voters, where conservation resources would presumably flow more freely.

The earlier in the developmental process comes exposure to nature, the better the odds of inspiring devotion to biodiversity and its conservation. It is a rare conservationist who did not encounter nature as a child. Every one of us can go to elementary schools to show pictures of animals and plants and tell funny stories about ecology. The teachers will be happy to have us. More ambitious people might think about how to finance and institutionalize school field trips to natural areas. Those of us who work in the tropics can do these things there, too.

Clearly, we can also use other strategies. One method is to appropriate the very technologies that are currently enforcing the divide between people and biodiversity. Biodiversity is increasingly on the World Wide Web via projects such as the Encyclopedia of Life (www.eol.org) and Wikispecies (http://species.wikimedia.org). But we can do more. We can upload science and nature shorts to YouTube and contribute our knowledge to Wikipedia and its offshoots. We can post our lectures online (113). We can work to add ecological dimensions to online virtual-reality platforms and video games like Second Life, which currently has 10 million registered accounts. These are obvious ideas; many more are possible. There is hope here: Online sales have helped to revitalize classical music (114), which is like biodiversity in that its devotees have long been predicting and lamenting its demise.

Some have argued that the key to widespread biodiversity appreciation is the ability to know immediately what is what in nature. Janzen (110) believes that this requires a comprehensive library of DNA barcodes (115) along with a handheld, nanotechnological, field-portable sequencing device. We are hopeful about this dream, as well as any other means of achieving the same end.

Profound social transformations are not impossible or "unrealistic." Shifts happen. They have happened in our lifetimes. We all know these terms: segregation, Iron Curtain, apartheid. "Anthropogenic extinction" belongs on that list. More than anything else, the long-term future of biodiversity will be determined by our success or failure in helping to precipitate such an overhaul in popular perceptions of nature and what it means.

Concluding Thoughts

A substantial amount of biodiversity—enough to preserve many functional ecosystems and to satisfy the desire felt by many to coexist with our only known living companions in the universe—can be saved via the pluralistic deployment of the seven sets of actions that are discussed above and that have been discussed for years in countless other corners of academia.

The subheadings sound ambitious, but the actions they comprise are demonstrably doable. As with the atmospheric "stabilization wedges" of Pacala and Socolow (1), each of the strategies above has passed beyond the laboratory bench and demonstration phase, but none has yet been implemented on a large-enough scale or in conjunction with enough of the others. Part of the reason for this shortfall is that most of us in the academic community who are familiar with all of these ideas do not see implementing them as part of our job description.

Where Does Conservation Biology Go from Here? Academic ecological papers are often tinseled with one or two sentences about the applied significance of the science (116), which accomplishes little. The selective pressures of academia, as currently set up, promote this practice by insisting on work that is at once scientifically transformative and socially beneficial. Yet many of the most useful things that we can do for biodiversity—like talking to kindergartners—are not at the cutting edge of science. Thus, we are implicitly encouraged to deck our papers with references to the urgent biodiversity crisis while quietly opting out of the grittier work. (We do not excuse ourselves from this indictment.)

This phenomenon is the very definition of the Ivory Tower, but it need not apply here. It is up to us. We can maintain the status quo, which has not yet enabled us to stop or even slow biodiversity loss. Alternatively, we can go a few steps down from our cathedral by systematically rewarding (or even mandating) a certain tithe to society and incorporating it into our system for evaluating one another. Each institution seems free to make its own decision on this front. Major funding bodies, such as the U.S. National Science Foundation, rightly insist that applicants explain both the intellectual importance and the "broader impacts" of their science. However, we suspect that scientists face more accountability to the former than to the latter. Closer scrutiny of the delivery of societal benefits promised from previous grants would likely prompt an increase in tithing.

Where Does Humanity Go from Here? Where the human juggernaut goes from here will depend in many ways on where biodiversity goes. In this article we have tried to suggest one hopeful answer: from here, humanity goes to grips with biodiversity as a part of society that we accept, accommodate, need, use, pay for, puzzle over, admire, and enjoy. The alternative future is much uglier, but we still have time to reject it.

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