POLICY FORUM: ENVIRONMENT

Can We Defy Nature's End?

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In the catalog of global environmental insults, extinctions stand out as irreversible. Current rates are high and accelerating (*1*). After a recent conference (*2*), we concluded that preventing extinctions is practical, but requires innovative measures. Enforceable protection of remaining natural ecosystems is an overarching recommendation. Our deliberations regarding the implementation of this led us to attempt to answer a number of questions. The answers outlined here represent, if not consensus, then the opinion of the majority. Supplementary material summarizes unresolved debates (*3*).

Is Saving Remaining Biodiversity Still Possible?

Globally, the harm we inflict on biodiversity often stems from impacts on vulnerable, biodiverse areas that contribute relatively little to overhall human well-being and often diminish it. For example, tropical humid forests house two-thirds of terrestrial species (*4*). Within half a century, tropical forests have shrunk by half, a loss of 9 million km^2 (*5*), with several times more forest damaged than cleared each year (*6*). Yet clearing tropical forests has created only ~2 million km^2 of the planet's 15 million km^2 of croplands (*7*). The poor soils underlying many tropical forests soon degrade and are abandoned or contribute only marginally to the global livestock production (*7*, *8*). About 10% of these cleared forests are on steep mountain slopes where high rainfall has predictably tragic consequences to those who settle there (*8*).

The Amazon, the Congo, and rivers in Southeast Asia hold almost half the world's freshwater fish species. Their fates depend on the surrounding forest watersheds. Elsewhere, most accessible rivers are dammed and channeled (*9*), causing their faunas to be more threatened than terrestrial ones (*10*). Diversion of water for irrigation threatens ecosystems, such as the Mesa Central (Mexico) and the Aral Sea and its rivers (Central Asia). Irrigation projects are often economic disasters (*11*, *12*), as salt accumulation quickly destroys soil fertility (*13*).

Fishing contributes only 5% of the global protein supply, yet is the major threat to the oceans' biodiversity. The multitude of fish species caught on coral reefs constitutes only a small, though poorly known, fraction of the total catch, but fisheries severely damage these most diverse marine ecosystems. Most major fish stocks are overfished (*14*); thus, mismanagement diminishes our welfare and biodiversity simultaneously. Conversely, protected areas enhance biodiversity and fish stocks (*15*). It is at regional and local scales that human actions and biodiversity collide. On land, 25 areas, called hotspots, contain concentrations of endemic species that are disproportionately vulnerable to extinction after regional habitat destruction (*16*). These areas retain <10% of their original habitat and have unusually high human population densities (*17*). Locally, those who destroy biodiversity do so because they are displaced, marginalized, and perceive no alternative. Others do so for short-term profit (*3*).

Is Protecting Biodiversity Economically Possible?

Although a global reserve network covering ~15% of each continent might cost ~$30 billion annually (*18*), reserves in tropical wilderness areas and hotspots need only cost a fraction of this. Tropical wilderness forests, predominantly the relatively intact blocks of the Amazon, Congo, and New Guinea are remote and sparsely populated. Land values are low and sometimes equivalent to buying out logging leases. Recent conservation concessions suggest ~$10/ha for acquisition and management (*3*). Securing an additional ~2 million km^2 and adequately managing the ~2 million km^2 already protected for biodiversity and indigenous peoples requires a one-time investment of ~$4 billion. Land prices for the densely populated hotspots are much higher. Of the 1.2 million km^2 of unprotected land, some will remain intact without immediate intervention, some is already too fragmented, and perhaps one-third constitutes the highest priority. A study of the South Africa fynbos hotspot (*3*) suggests a one-time cost of ~$1 billion, and so by extrapolation, ~$25 billion for the protection and adequate management of all hotspots. Additional marine reserves would likely require ~$2.5 billion (*3*).

These sums, although large, undercut arguments that saving biodiversity is unaffordable. They are of the same order of magnitude as the individual wealth of the world's richest citizens—and 1/1000th the value of the ecosystem services that biodiversity provides annually (*19*). This suggests a strategy of leveraging funding from governments and international agencies through private sector involvement.

Will Protecting Areas Work?

The pressures to destroy ecosystems are often external (*20*). For example, the World Bank and the International Monetary Fund have indirectly encouraged governments to deplete their natural resources to pay off debt (*21*). Even when available, some countries may view foreign purchase of conservation concessions as imperialism in a 21st-century guise. Almost all the hotspots were European colonies; one is still French territory (*3*). Some countries have unstable government, and others are at war.

Some countries have welcomed pre-emptive purchasing of logging rights and other conservation actions, recognizing the advantages of protecting forests and receiving funds to do so. Unfortunately, cutting forests and otherwise depleting resources is too often a way to personal aggrandizement among some government officials (*22*). How good is even a well-intentioned government's guarantee of a forest's security when its peoples need wood for cooking or land for farms? Will the government return the concession fees to those whose livelihoods are affected?

Protected areas may be respected in one country, ignored in another, even attract exploitation in a third. Although more money generally yields more protection, richly endowed parks may be severely threatened (Everglades National Park; USA) and significant accomplishments are possible in the most economically unlikely places (Odzala National Park; Democratic Republic of Congo).

Whereas overall assessments of what conservation actions work, what do not, and why they are long overdue, discussions of possible factors typically devolve into idiosyncratic case histories. Likely, there is no single answer to these multi-

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scaled problems. One process, however, emerges as a unanimous choice: to train and empower conservation professionals in each biodiversity-rich country.

Should Conservation Research and Management Be Centralized or Distributed?

At present, these capabilities are highly centralized in industrialized nations, while many key tropical areas have few conservation professionals. Our experiences point to the pressing need for more and better-trained people. Those at La Selva (Costa Rica), Comision Nacional Para el Conocimiento y Uso de la Biodiversidad (CONABIO), Mexico, the Humboldt Institute (Colombia), the Centre for Ecological Sciences of the Indian Institute of Science (India), and the International Centre for Living Aquatic Resources (ICLARM), Philippines have been in place long enough to assist in training a new generation. Budgets for effective centers are a few million dollars per year. Roughly half a billion dollars would support 25 centers for a decade, enough for each hotspot and wilderness forest without centers plus additional centers for marine and freshwater hotspots.

Should Efforts Concentrate on Protection or on Slowing Harm?

Most of us agree that immediate protection of ecosystems and training of in-country professionals is vital. Nonetheless, some effort should be allocated to actions to lighten the burden on future generations of conservation professionals (*3*). Others argue in favor of actions that stem the processes that harm biodiversity and encourage those that protect it, with priority given to actions yielding near-term results.

Economic subsidies that degrade the environment are a common problem across terrestrial, freshwater, and marine ecosystems (*23*, *24*). For instance, massive economic subsidies make unsustainable fishing practices possible (*25*, *26*). Biodiversity can be depleted if property rights give ownership to those whose "economic use" translates into short-term forest clear-cutting, transient crops or grazing, and longer-term land degradation.

The public is often unaware of the costs of environmentally damaging policies. Annually, subsidies for such policies cost $2 trillion globally (*24*). We recommend a focused analysis on those governmental policies that artificially alter market dynamics and that have the most detrimental impact on biodiversity. The overarching message is that sound economic and ecological strategies may often involve the same, and not conflicting, strategies. Alliances of the fiscally frugal and the environmentally concerned are a still unexplored possibility.

We recommend a major outreach to national and international institutions that make loans for actions that degrade biodiversity. Many of them could benefit from improved ecological standards that factor biodiversity protection into their decision-making. Obligations of parties to existing legal instruments (such as the United Nations Convention on Biological Diversity) should also be used to promote adequate incentives.

Biodiversity-rich countries often lack legal mechanisms to encourage conservation. Tax savings, transferable development rights, and mitigation credits would at least allow private, public or indigenous landowners to secure economic benefits. Globally, the wilderness forests, if lost, would greatly exacerbate increasing atmospheric CO_2. Their value as carbon sinks alone appears to be broadly similar to our estimates of what it would take to protect them (*27*). Capturing these values could save large areas through efforts designed to highlight their true value.

Do We Know Enough to Protect Biodiversity?

Most debate centers on identifying priority areas for conservation. Surely all remaining habitats across the species-rich tropics must be priorities, ones that do not depend on our knowing the scientific names for 1 of 10, or the geographical distributions of 1 of 100 species, or not having resolved complex issues of reserve selection (*28*). However, even modest scientific advances greatly improve the efficiency of our actions. Knowing which areas within hotspots are especially important could reduce costs considerably.

Paradoxically, we are not limited by lack of knowledge, but by our failure to synthesize and distribute what we know. Museums and herbaria are vast repositories of data on what species occurred where, while decades of remote-sensing imagery detail how fast the remains of species' ranges are shrinking. Although a few of us question the utility of these taxonomic repositories, the majority emphasize the urgent need for more, globally distributed taxonomy (*29*).

In contrast, there was broad consensus for a greatly expanded research effort into the links between biodiversity, ecosystems, their services, and people (*30*). Infectious diseases are entering human populations as our numbers increase and as we encroach upon tropical forests and other pathogen reservoirs. Global climate change will have major impacts on human health through changes in food production, access to fresh water, exposure to vector- and water-borne disease, sea-level rise and coastal flooding, and extreme weather events (*31*).

In conclusion, we share mixed senses of concern, urgency, and optimism. Concern, because humanity's numbers (and consumption) are increasing. Across several human generations, a transition to sustainable use of natural resources is essential, and we must protect biodiversity in the interim. The urgency is driven by the pending loss of a major portion of biological diversity in the first half of this century if we do not act immediately. Our optimism stems from the realization that greatly increasing the areas where biodiversity is protected is a clear and achievable goal, one potentially attainable by using funds raised in the private sector and leveraged through governments.

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