Biodiversity on the Edge

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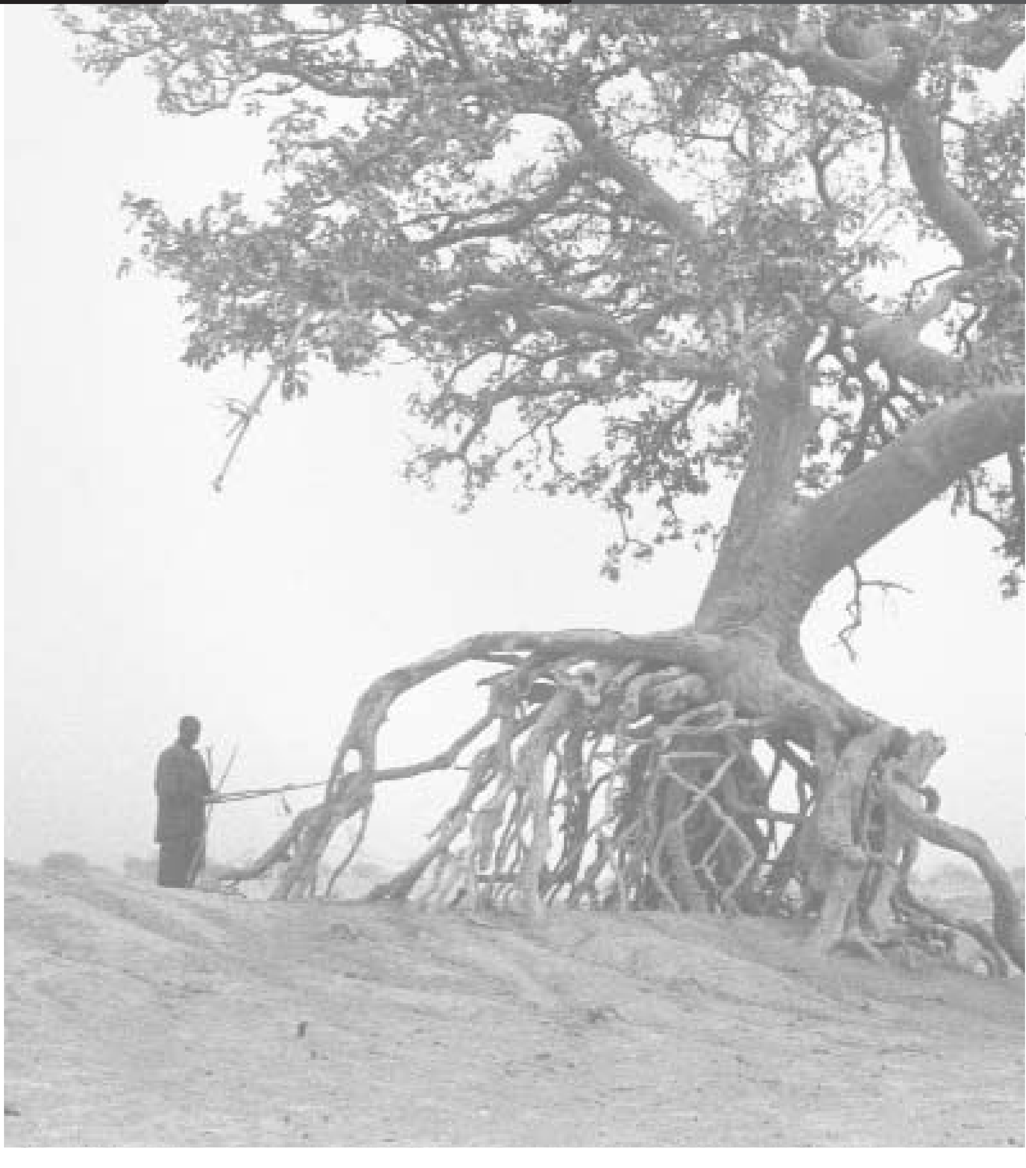


Environment on the Edge

We have been, as biologists, interested in discovering and exploring this planet for 200 years, documenting and describing species, from coral reefs and the depths of the oceans to forests all over the world. In that process we have described, catalogued and collected many of the species that make up the biological diversity of this planet. We have been fascinated by these species for scientific reasons, especially in order to understand the very complex interactions that exist between them, and to understand how many of these groups have co-evolved over millions of years.

But it is also important to remember that this biodiversity, this planet and life on Earth, has been the backdrop to human evolution. We see this all around the world and going back through the ages. For example, there are pre-Colombian paintings from the Amazon that are several thousand years old and remind us that humans were interacting with nature in many ways, as hunter-gatherers and through the process of crop domestication. Recent work shows that we were already starting to see early domestication of certain crops in the Middle East as far back as 20,000 years ago.

But what is clear is that over the decades, as human population density has increased and practices changed, the footprint we humans have made on the environment continues to become greater and greater, to the point where we have settled, built cities and seen the impact of our activities spreading all over the globe. We see far-flung effects such as invasive species or, in some areas, the process of deforestation driven by overseas markets. The environmental impact of activities in the United Kingdom, for example, is now felt as far away as Indonesia. These changes have been expanding very rapidly.

These are just some findings from a recent project, the Millennium Ecosystem Assessment. Since 1960 the human population has doubled from 3 billion to 6 billion. The size of the global economy has increased sixfold. Food production has increased by 2.5 times, the demand for water for human consumption has doubled and the amount of water that is impounded by dams has quadrupled. The flow of chemicals such as phosphorus used in fertilizers has tripled, and all this in a matter of 40 years. These activities are clearly having an impact.

During that time we have made important scientific advances: for example, describing some 1.75 million species and setting aside protected areas – about 11 per cent of the world's terrestrial ecosystems are protected. We have seen increases in human health and longevity, decreases in child mortality, incredible increases in agricultural productivity, increased awareness of environmental issues among people all over the world, and development of multilateral agreements relating to the environment. Some of the best known, such as the Convention on Biological Diversity, resulted from the 1992 Earth Summit in Brazil.

The fact is, despite all this progress and achievement, we know that biodiversity is declining in many areas of the world, and that many people are still living in poverty – more than a billion people live below minimal thresholds. Most importantly, we see that there are still inequities in the distribution of the benefits of biodiversity among people and among countries, and that many of these inequities seem to be getting worse. You may have seen the striking figures – that the total assets of the three richest men in the world are greater than the total size of the economies of the 50 least-developed nations worldwide. The paradox is that many of the richest countries in terms of biological diversity are the least developed economically. Much of the capacity and information about that biodiversity is in a few countries like the United Kingdom, the United States and others, and most of the biodiversity is in countries where the scientific and technical capacity is still developing.

How can we bring the best of our science to inform policy and benefit society? I will address this question primarily from a biological perspective, covering three topics: first, the current status and frontiers of our understanding of biodiversity; second, focusing on conservation, threats, status and trends; and finally, what this means for human well-being.

How much do we know?

As biologists we ask a whole range of questions about biological diversity, including:

- What is this species? (taxonomy)
- How are species related to each other? (phylogenetics)
- Where are they found? (biogeography)
- How do they interact? (ecology)
- How did they come to be? (evolution, paleontology)
- How are they used by people? (ethnobiology)
- What is the impact of people? (conservation biology)

As an example of how little we still know, last year a scientist in a deep-sea submersible took a photograph of a giant squid more than ten feet long. It had never been collected, and this was the first time it had been seen, although it is a very large animal. Likewise, only last year, a scientist at the Smithsonian described a new species of whale.

But it is not only the large creatures. The frontier of our understanding is very often in the small organisms. When Betsy Arnold and Helen Herre at the Smithsonian began to examine leaves of cocoa trees in the Isthmus of Panama, and took cultures of the fungi that grow inside the leaves, they found 600 species of endophytic fungi growing inside the leaves of one species of tree. Given these kinds of numbers, our understanding of how things operate and what is out there is really just incipient. Furthermore, they have found that the presence of certain endophytic fungi confers resistance to some kinds of disease. Another extreme in this area is the current tally of the number of different micro-organisms found inside the mouths of human beings – more than 600 to date.

We have new tools to describe and understand what is around us. The National History Museum in London is talking about DNA bar-coding to use molecular techniques to unveil some of this diversity and to find new, cryptic species. You may have read some papers we have produced in the United States. Paula Hebert and colleagues at the Smithsonian have been using DNA bar-coding with groups of birds in North America. Four new species of birds have been found this way, as have cryptic species of butterflies in Costa Rica, and other organisms.

These new technologies are helping us to unveil biological diversity and also helping in the process of constructing the tree of life. Hundreds of scientists around the world are involved in this, trying to form a tree where every branch is a different species, and where we can see where different kinds of related organisms are found on the tree, encompassing all 1.75 million known species. It is not all about knowing about the species and their interactions, about how these things are operating in nature; a lot of this fundamental understanding is essential for scientific curiosity as well as for conservation and sustainable use.

At the other extreme of technology, we have important advances in remote sensing that allow us to monitor different ecosystems, and by combining observations we can start gaining a better understanding of the distribution of biological diversity. Maps from the UNEP World Conservation Monitoring Centre show different patterns of species richness, such as the diversity of families of flowering plants and their highest concentrations. Not surprisingly, the areas of tropical forests in Southeast Asia and Central America as well as the Andes are some of the most diverse. The pattern changes from one group to another. Different pictures emerge for terrestrial vertebrates and for freshwater fish. The maps are updated all the time and are important for synthesizing our knowledge and setting priorities for conservation.

How are things changing?

But how we can conserve the diversity, and what are the main threats? If you look at a map of terrestrial wilderness areas, which are relatively intact ecosystems, they are found in the Amazon rainforest, the African deserts, and tundra in Asia, North America and other places. If you then compare this map with one of human population, you can clearly see that the highest and densest settlements of populations are where the biggest impacts on, and transformations of, the ecosystems have happened.

The Millennium Ecosystem Assessment study has found that in 2000, 25 per cent of the Earth's terrestrial surface was under cultivation, a substantial figure. Most change has happened in the last 40 to 50 years, and looking ahead we can see that in some areas the agricultural frontier is likely to expand, for example in South America, and in others it will most likely contract, as in parts of Europe and North America.

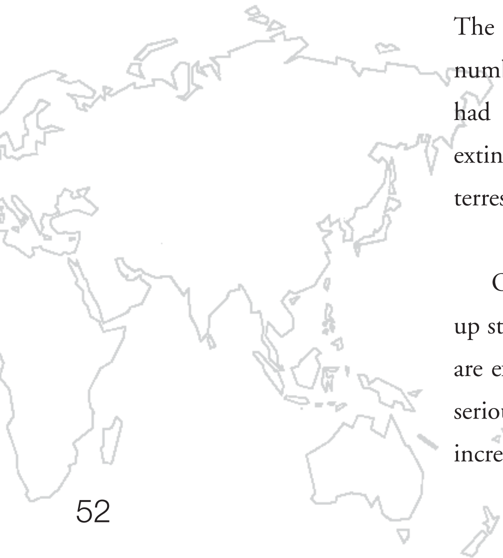
A global analysis has looked at how biomes have been affected in terms of percentage loss, taking the loss before 1950, the loss between 1950 and 1990, and projections for the future using Millennium Ecosystem Assessment scenarios. Six kinds of biomes have lost close to 50 per cent of their original area: Mediterranean forests, temperate broadleaf forests, tropical forests, grasslands, savannahs and coniferous forests. Change in some of these biomes has been more rapid in the last 40 years, primarily in the savannah ecosystems, coniferous forests and tropical dry forests. The projection for many of these ecosystems or biomes is that the total area will change more, except in temperate forests, where we expect to see a net gain in total area due to soil regeneration and reforestation. But some of the areas will lose an important part of their total surface area, depending on the scenarios and models used. For some tropical forests we estimate that 20 to 25 per cent might be lost over the next 50 years.

It is not only the terrestrial systems that are suffering. Data for marine fisheries are expanding, and a reconstruction from the Millennium Ecosystem Assessment provides a model of how fishing pressure has changed over 50 years. It shows that the fishing industry has expanded to the point where there is no corner of the oceans that is not under some pressure at this time.

We know that ecosystems are changing rapidly, and that in every area species are changing. A yellow-eared parrot, an endangered species from the Andes once thought to be extinct, has been rediscovered in the forests of central Colombia. Like the parrot, thousands of species of animals and plants are endangered all over the world. The best approximation we have is the IUCN *Red List*, which gives different kinds of data: taxonomic groups, the numbers of described species, those assessed, those threatened and the percentage of species assessed actually under threat. Our current knowledge is limited, as only 38,000 species have been assessed, mostly birds and mammals, with a small percentage of fish. Of those that have been assessed, those threatened under IUCN criteria include 23 per cent of mammals, 12 per cent of birds, 32 per cent of amphibians, 61 per cent of reptiles, 46 per cent of fish, 57 per cent of invertebrates and 70 per cent of plants. These are very high percentages, although one should bear in mind that many study groups have focused on species known to be endangered. We all recognize that there is a problem, and that we need to do something about it.

The current tally of extinct species documented worldwide is 784, and this is a reliable figure. Around 60 species have become extinct in the wild but have been saved in botanic gardens and zoos. The data show that the extinctions have not been random. IUCN analyses have found that high numbers of the extinctions have occurred in oceanic islands, many of which historically we know have had very small populations of endemic species prone to extinction. In addition, many species extinctions appear to have taken place in parts of North America, where aquatic, freshwater and terrestrial ecosystems have been transformed, but also have better data.

Over the last 500 years, the number of documented extinctions has, not surprisingly, been going up steadily, and many extinctions have happened in the last 150 years. The main causes of extinction are exploitation of the species, habitat degradation and invasive species. The latter is an increasingly serious problem for many groups of plants and animals, one that will get worse as commercial trade increases.



We all recognize that extinction happens, and the figures I have quoted are recent, for the last 1,000 years. From fossil records we know that there were hundreds of thousands of species that became extinct. But how do you distinguish between a natural extinction and one that is human induced? And is the rate different? The fossil record for marine groups shows that 95 to 98 per cent of all marine species have already become extinct. The question is, what is the background rate of extinction?

We know, of course, that there have been massive episodes of extinction – classic extinctions such as the Cretaceous/Tertiary boundary. If we look at extinction rates based on fossil records both for marine species and Pleistocene mammals, the background rate of extinction seems to be one species for every million species per year. But over the last century the estimated rate of extinction for mammals, birds and amphibians is about ten species per million species per year – ten times higher. Models may differ, but projections for certain groups suggest the rate of extinction in the next 50 to 100 years is likely to increase substantially. It varies within taxonomic groups, but all in all there is consensus in the scientific community, and it is recognized by the Millennium Ecosystem Assessment, that the rate of extinction now seems to be significantly higher than the background rate.

Another example I want to cite is the black-footed ferret. These animals used to be widespread on the prairies throughout North America, from the plains of northern Mexico to southern Canada. In the Natural History Museum of the Smithsonian Institution, where I work, we have several hundred specimens. We have found the historical collections extremely useful in these days of modern technology, using DNA analysis to reconstruct the genetic diversity of populations of black-footed ferrets. We have skulls collected as far back as 200 years ago, and we can gather DNA samples and look at the genetic variability within and between populations. We can also document the genetic bottleneck that has happened for this species. As the unpublished work of Samantha Wiseley, a postdoctoral fellow at the Smithsonian National Zoo, has shown, the genetic diversity for black-footed ferrets 150 years ago was substantially higher. The black-footed ferret is a success story in terms of conservation: the population was reduced to only a few individuals, but a captive breeding programme in zoos around the world has brought the population back to more than 1,000 today.

This shows how we need and use historical data for the planning and management of species *in situ* and *ex situ*. Protected areas are an important measure for conservation. Data from UNEP-WCMC, IUCN and other partners show that the total area set aside for protection of terrestrial ecosystems has increased exponentially, currently to 11 per cent. This is good news for terrestrial ecosystems, but the bad news is that for marine and coastal ecosystems it is less than 1 per cent at this time. This bias was one of the elements under discussion at the World Parks Congress of IUCN and the Convention on Biological Diversity. There are many areas where basic science will be important for conservation. Maps identifying critical areas to establish protected areas for conservation; basic research in reproductive biology and restoration ecology; understanding the impact of invasive species and their introductions and interactions; the impact of sustainable harvesting – these are all areas that need a lot of work.

What does this mean for human well-being?

We cannot just approach this issue as environmentalists, saying these things are going extinct and we need to save them, if we do not also realize they are fundamental to the lives of people around the world. It is not fair to think people on the edge of poverty in developing countries, where livelihoods are endangered, are going to put biodiversity conservation on top of their priority list. We must recognize that biodiversity and human well-being are inextricably linked.

The Millennium Ecosystem Assessment's sub-global assessments have made this point clearly, such as in the villages in the Western Ghats in India. As it turns out, the population in India has increased dramatically in the last two decades, and demand for fuelwood in the Western Ghats has likewise increased. As people have moved into the forest and cut the trees, the canopy cover has decreased to the point where grass is moving in. As grass moves in, the cattle from the villages range further into the forests and reach areas where they come into contact with monkey ticks, which carry a disease that can be passed on to humans. As the cattle go further from the villages to forage, they are bringing the disease back to the population in the Western Ghats, and the incidence of this tick disease has increased as a result of deforestation.

In parts of Africa the lack of fuelwood and inability to boil water has an impact on livelihoods through disease. There are many ways in which we are dependent on biodiversity in our livelihoods, either directly for food or through ecosystem services that are often not measured – such as having access to clean water.

In the Millennium Ecosystem Assessment the main focus was trying to understand the ecosystems and how they affect livelihoods. These were grouped in four categories:

- provisioning services, like food and fibre;
- regulating services, such as climate regulation and water regulation;
- cultural services, including aesthetic and spiritual values;
- basic supporting services, like primary productivity.

We recognize that these services affect different dimensions of human well-being, from health to cultural security, economic security and equity. The presence of people is, in turn, driving factors like population growth, markets and political issues, and these in turn affect a series of proximal drivers like climate change, land-use change and others. We are trying to understand how the various drivers affect the ecosystems and services they provide, and to identify response options. The assessment over four years has tried to quantify some of these factors. When the different kinds of biomes and main kinds of drivers like habitat change, climate change, invasive species, overexploitation and pollution are compared, the main drivers for each biome can be identified. Not surprisingly, we find that for areas like islands the main driver is invasive species, whereas for tropical forests it tends to be habitat change.

Once we understand the main drivers of ecosystems, we can design different kinds of response options. The fact is that all these drivers are interrelated in complex ways, so we know climate change can affect the supply of freshwater, which in turn can affect the biodiversity present, which in turn can affect forest productivity. This complex web of interactions is what decision makers are confronting on a day-to-day basis. The different responses, and the findings of the Millennium Ecosystem Assessment recently released, are in five main categories:

- institutional responses;
- economic responses;
- social and behavioural responses;
- technological responses;
- knowledge responses.

The Millennium Ecosystem Assessment also developed a series of scenarios for looking ahead – we know what the historical changes have been, but we also want to know how things will change over the next 50 years. How are they going to affect the different services? There are four main future scenarios:

- global orchestration – better cooperation and coordination between countries;
- order from strength – becoming isolated and self-dependent;
- the adaptive mosaic – developing local management practices;
- the techno-garden scenario – having technology solve your problems.

Clearly there are some scenarios where we can make disastrous decisions, and others that would have better trade-offs in terms of ecosystem services. Issues related to adaptive mosaics, such as developing local sustainable management practices, can work very well. Technology, too, can be very helpful in some areas. But clearly this is an interconnected world, and building on order from strength seems to be an unreliable possibility for the future.

We have to recognize that biological diversity is essential for everything we do; for our livelihoods. We as humans rely on biodiversity, and we have a profound impact on it. The choices we have before us will fundamentally alter the future. It is in our hands to try to decide, based on the knowledge we have, what the best options are for moving forward. Biologists are committed to strengthening our knowledge base so that we understand the diversity and how it is responding to changes, and so that we can use basic scientific information to improve the lives of people around the world. We need to create awareness and make this an important issue, one that is discussed at all levels from village halls and city councils to the United Nations, everywhere from academia to the private sector. If we all pool together the information we have, and there is increasing awareness, then we can really look out for the future, because that future is in our own hands.

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