



Background Paper of the Task Force on Environmental Sustainability

April 18, 2003

Comments are welcome and should be directed to:

Robin Sears
(email: rrs26@columbia.edu)

Note to the reader

The Background Paper provides a preliminary overview of existing knowledge and scopes out the questions addressed by this Task Force. The analysis, conclusions and recommendations contained herein should be considered as very preliminary as they are likely to evolve as the Task Force works toward its final report at the end of 2004. Comments and suggestions are welcome. Please cite this paper as "Background Paper of the Millennium Project Task Force on Environmental Sustainability".

Disclaimer

This publication does not necessarily reflect the views of the United Nations Development Programme (UNDP), its Executive Board or its Member States.

Important note:

This Background Paper only deals with a subset of the questions the Task Force on Environmental Sustainability is working on. The Interim Report to be published at the end of 2003 will address a broader range of issues in addition to management of ecosystem services and biodiversity. These include long-term climate change, water and air pollution.

1 Nature at the Center: A case for action

1.1 The importance of biodiversity and ecosystem services

Protection and sustainable management of ecosystems, their biologically diverse components, and the services they provide the human population, are central to alleviating many of the world's most pressing concerns and addressing most of the Millennium Development Goals (MDGs).

While the intrinsic value of species, ecosystems and ecosystem services may be difficult to calculate with precision it is important to focus on their present and future economic and social benefits because such considerations strongly motivate decisions. No doubt intrinsic values of nature also play an important role in human well-being and in decision making processes. However, the Task Force firmly believes that the primary guide for current and future decisions should be the public and private human benefits derived from biodiversity (ecosystems, species, and genes) and its services discounted into the future.

A considerable body of scientific data points to environmental degradation, the erosion of genetic diversity, the loss of species, the degradation of ecosystems, and the decline of ecosystem services, as a direct cause of many of the most pressing issues we face today, including poverty, declining human health, hunger, undrinkable water, emerging diseases, rural-urban migration, and civil strife. In the face of this evidence, we often find ourselves dealing only with the "symptoms" of a larger environmentally induced "disease," and neglecting the underlying causes of the loss of biodiversity and its declining services to humans that collaterally affect all aspects of our lives.

We recognize the fundamental importance of addressing hunger, water availability, disease, civil unrest and the other MDGs. However, a root cause of these unmet human needs is the increasing degradation of the biological systems upon which all life, including the human population, depends. The Task Force on Environmental Sustainability, therefore, seeks to identify appropriate policy measures that will reverse this degradation and instead ensure more productive management of ecosystems as a basis for enabling the other MDGs to be met. This will require that the sustainable management of ecosystems, their constituent species, and their essential services contribute directly to development planning in sectors such as agriculture, water, forestry, fisheries, energy, transportation, health, and industrial production.

1.2 The world after the Millennium Declaration and WSSD/WEHAB

Out of the Rio Conference of 1992 came a deep, international consensus and commitment to act in ways that would lead to sustainable path of development. Rio marked the beginning of the transition towards a more coherent international environmental order represented by a new generation of multilateral environmental agreements. Undoubtedly, the Rio Conference was a landmark to advance international negotiations regarding long-standing controversial issues related to the conservation and sustainable use of the Earth's ecosystems and the species they contain. The Convention on Biological Diversity (CBD), which now has 187 parties, is a key international

agreement reflecting this commitment. The full scope of agreements on biodiversity and ecosystem services extends beyond the CBD, though, and includes the following, on which the Task Force will base its work:

- Convention to Combat Desertification
- Convention on Wetlands of International Importance
- Framework Convention on Climate Change
- Regional Seas Conventions
- Statement of Principles for the Sustainable Forest Management (SFM)

The CBD established three linked objectives:

- The conservation of biological diversity
- The sustainable use of its components
- The fair and equitable sharing of the benefits arising from commercial and other uses of genetic resources.

Some of the specific provisions made in the CBD include:

- Develop national strategies, plans or programs for the conservation and sustainable use of biological diversity.
- Respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities relevant for conservation and sustainable use of biological diversity.
- Establish and maintain programs for scientific and technical education, training, and research.
- Facilitate access to genetic resources by other parties on mutually agreed terms.
- Facilitate exchange of information, including results of technical, scientific and socio-economic research.
- Provide financial and other support for implementing the Convention.

These provisions constitute a subset of the aims embodied in the CBD, but, in conjunction with the three main objectives and the provisions of other conventions on the environment, they provide a definition of the overarching goal of environmental sustainability. In this way, they constitute a direct means of measuring the progress we have made toward achieving the sustainable use of our natural environment, even though the CBD and most other conventions leave the establishment of specific goals and targets to each government.

At the Millennium Summit in 2000 it was fully recognized that economic and social development and poverty eradication are the first and overriding priorities for achieving the conservation and sustainable use of natural diversity. The Millennium Declaration led to the 8 MDGs that provide the framework for a new international commitment to address poverty eradication.

The most relevant goal for this Task Force is Goal 7, “Ensure environmental sustainability” and in particular Target 9, “Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources”. Both clearly establish the links between livelihood development and the conservation and sustainable use of biodiversity. The MDGs were reaffirmed at the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg. In addition, the UN Secretary General proposed WEHAB (Water, Energy, Health, Agriculture, and Biodiversity) as a conceptual and organizational framework for the WSSD process. It reaffirmed the centrality of biodiversity and ecosystem services to the future of water, energy, health and agriculture. Taken together the 8 MDGs acknowledge that environmental sustainability has the potential to offer opportunities and innovative choices for achieving food security, health improvements, income generation, reduce vulnerability and enhance the provision of ecosystem services, essential for productive activities.

Specifically, countries present at WSSD agreed to pursue a more efficient and coherent implementation of the three objectives of the CBD and to achieve by 2010 a significant reduction in the current rate of loss of biological diversity. Reaching this target will require lasting changes in the use of environmental resources, and the provision of new and additional financial and technical resources to developing countries that may not have the capacity to implement sustainable use patterns without outside assistance.

The task ahead is to enable countries to meet their commitments made at the Millennium Summit, the WSSD, and several other international conferences. However, the world is currently lacking a clear operational understanding of how the goals on environmental sustainability can be achieved. To date no robust framework of implementation exists that addresses the challenge of protecting and managing gene, species, and ecosystem diversity, as well as ecosystem services, in order to support sustainable development as promoted by the CBD. Such a framework for action will need to address the problem at the global, regional and national scales, while concomitantly allowing for local specificity in the implementation of recommendations, as well as providing the means by which to measure progress.

1.3 Key areas of environmental degradation

Key aspects of environmental degradation can be divided into general threats that affect all species and ecosystems, and their related services globally, and those threats that affect specific species or types of ecosystems, or all ecosystems in particular parts of the world.

1.3.1 General threats

General threats either directly affect the long-term viability of all species, or the functioning of all ecosystems, thereby threatening the species they contain and impairing the availability of ecosystem services they provide. One of the most important general threats is climate change. The scientific community has reached a broad consensus that climate change is now an issue of major concern (Houghton et al., 2001). While we may see this as a “long-term” problem, the first terrestrial evidence of its current effects on the distribution of species is beginning to emerge (Root et al., 2003). The effects on marine ecosystems may be even greater (Hoegh-Guldberg, 1999). No doubt all countries will be affected by climate change, but developing countries and particularly small island developing states are most vulnerable as these changes affect weather patterns, water distribution, disease incidences and fisheries in ways that stress those human populations least able to protect themselves from flooding, soil erosion, emerging epidemics, water shortages, crop failures, and coral bleaching.

A second important general threat to species and ecosystems is the loss of species diversity and genetic diversity within species. In terms of species diversity, from 1996 to 2002, the number of threatened species rose in every category of vertebrate, from mammals to fishes (IUCN, 2002). Even more troubling is the percentage of newly assessed species that fell into the threatened category. Even when one accounts for data collection bias (i.e. species are more likely to be assessed in areas that are degraded and under severe threat), the evidence demonstrates that threats to species are accelerating.

Experimentally, at least, it has been shown that the long-term stability of ecosystem functioning is directly tied to the redundancy of representatives within each of an ecosystem’s functional groups of species, and hence to species diversity itself (Naeem and Li, 1997; Naeem, 1998). It follows then, that a decline in species diversity (i.e. in the number of representatives within each of an ecosystem’s functional groups) would necessarily present a general threat to the stability and reliability of ecosystems and the services they provide humans.

We are only beginning to assess the loss of diversity within species of plants and animals whose populations have been severely reduced, but the potential impacts of this loss are enormous. They affect countries across the globe regardless of their income levels. For example, suffering severe and prolonged population decline due to land development and habitat destruction, the Florida panther began to exhibit signs of inbreeding depression (Roelke et al., 1993). Only after the introduction of panthers from a geographically distant population in Texas did the problems abate, but they did so at a cost to the specific genetic adaptations of the Florida panther that is now increasingly a hybrid of the Florida panther and Texas cougar. Similar consequences are emerging in vertebrates in Asia (e.g. Sumatran and Javan Rhinos), Africa (e.g. Mountain Gorillas) and South America (e.g. Lion Tamarins), all due to loss of habitat, declining population size, and inbreeding. Though we are just at the leading edge of problems associated with a decline in naturally occurring genetic diversity, this general threat to the viability of populations and species of animals will be significant if current conditions persist or erode further (e.g. Landweber and Dobson, 1999).

In plants, we see the effect of the loss of genetic diversity most readily in wild and domestic varieties of many of our agricultural crop species, whose genetic variants dwindle as lands containing unique wild strains are converted and local domestic varieties of common crops are out-competed by highly productive genetically uniform commercial varieties. With 75% of the world's food energy intake narrowed to nine plant species (FAO 1998), and ever fewer varieties of each remaining, there is a danger that these species may be less able to resist large-scale plant diseases (e.g. wheat rust) with serious repercussions for world food security.

A reduction in the number of varieties in use does not necessarily imply a reduction in genetic diversity, as there is no clear mapping from a reduction in the number of varieties to a loss of genetic material: indeed, some new varieties may be crosses that bring new genetic material into the commercial population even in the face of a drop in a count of varieties (Smale 1997, 1998 a and b). Over the twentieth century the dominance of commercial bread wheats by a small number of varieties decreased. Additionally, some of the land races no longer cultivated are still maintained in seed banks, and indeed have contributed genetic material to currently-used varieties. Modern plant breeders aim for polygenic resistance to pathogens, which is intrinsically more durable and stable than the monogenic resistance that characterized early plant breeding. The loss of diversity associated with the introduction of the most resistant genotypes does, however, carry with it the potential for loss of resiliency at the level of the system as a whole.

The U.S. National Research Council, looking into this issue in 1993, concluded that the pattern is complex: various components of genetic vulnerability are going up, and others down, simultaneously in different parts of the world and for different crops. Overall, the committee concludes (National Research Council 1993, p. 80): "For major crops in developed countries, varietal turnover and the number of varieties planted have increased since 1972, indicating that the overall level of genetic vulnerability may have decreased. The genetic basis of elite germplasm, however, was found to be shallow because of extensively shared ancestry and limited use of exotic germplasm."

On balance, while modern crop varieties tend to be more resistant to traditional wheat diseases, the evidence is less clear on overall system resilience. Due to the gravity of the possible consequences of reduced resilience, a better understanding of crops' resistance to a diverse range of diseases and pathogens is of utmost importance. This analysis should be carried out with a particular focus on improved crop varieties adapted for tropical countries.

1.3.2 Specific ecosystems under threat

Some of our most important types of ecosystems that are now under threat through destruction, over use, and pollution include agroecosystems, forests, and fisheries.

- **Agroecosystems** have been heavily degraded. Some 40 percent of agricultural land has been strongly or very strongly degraded in the past 50 years by erosion, salinization, compaction, nutrient depletion, biological degradation, or pollution (MA 2002, p.7). In addition, as agricultural lands become more and more distant from natural habitats, many of the ecosystem services provided by invertebrate and vertebrate fauna (i.e., pollination, seed dispersal, and pest control) become less effective (e.g. Kremens et al 2002). This puts additional strains on an already stressed system.
- **Forests** are a key provider of ecosystem services including climate and soil stabilization, timber and non-timber forest products, water purification and retention, and habitat to support a host invertebrate and vertebrate species which themselves provide additional services (e.g. Mahli, et al., 2002). These forests are threatened by continuing over harvesting of timber, land conversion for agriculture, increasing commercialization of bushmeat and medicinal plants, and general degradation through over use by a growing human population. This is particularly true of most tropical forests. In the first five years after the Rio Conference (1992-1997), 8.1 million hectares of moist tropical forest per year were cleared or severely degraded (Achard et al 2002). While the data for the following five years have yet to be as accurately corroborated, there is no indication that these trends have declined. If anything, these trends and their collateral damages have increased (Laurance, 2000) and are worsened by a lack of effective local or national government control. For example, in Indonesia, it has been estimated that some 80% of the timber extraction on the large islands of Sumatra and Borneo is illegal (Bonner, 2002).
- **Global fisheries and marine ecosystems including coastal habitats** are being degraded at alarming rates. For example, fully 58% of the world's coral reefs were assessed as threatened five years ago (Bryant et al 1998), and that number is likely to be considerably higher as the negative effects of climate (Goreau et al 2000), destructive fishing (Polunin and Roberts 1996), terrestrial runoff, pollution, and eutrophication (Pimentel et al 1995) continue to destroy productive coral reef ecosystems, mangrove forests, and other coastal habitats. Beyond the over exploitation of most marine fisheries (e.g. MacManus 1997; Schiermeier, 2002), where yields and stocks have significantly declined in areas whose human populations critically depend on them for much of their protein, the degradation of coral reef and mangrove nurseries are increasingly foreclosing on the natural ability of fish species to recover. This has led to a call for integrated coastal management plans that reduce marine harvesting to sustainable levels, end illegal and destructive fishing, and protect critical coastal habitats (Courtney and White, 2000).
- **Fresh water ecosystems** are even more vulnerable to degradation and destruction from terrestrial runoff and silting, increasing use of organic and inorganic fertilizers, chemical pollution, and invasive plants and animals. Most rivers, streams, lakes and ponds in all but the remotest areas are now directly affected by human activities, resulting in local extirpations of species of fish and amphibians and considerable stress on the species that remain.
- **Dryland habitats** suffer from increasing desertification, over-grazing, over-irrigation or dropping water tables, and invasive plants. As a result, human populations in dryland areas, which often live at the margin of existence, have experienced famine, water related diseases, and high infant mortality.
- **Islands** have been particularly vulnerable to invasive plants, animals, and pathogens, evidenced for example by Polynesia, because they have been visited by numerous human colonizers over the centuries who act as conduits for invasive species and because the

endemic species of these islands are usually highly specialized, immunologically naive, and susceptible to predation. Deforestation, erosion, and runoff have often devastated the terrestrial landscape and the coral reefs and fisheries that contribute substantially to the well-being of the human populations on these islands.

1.3.3 Specific ecosystem services under threat

As a result of general and specific threats to ecosystems, a number of ecosystem services are increasingly under stress. Among the most important of these for human needs are (cf. Daily, 1997):

- Stabilization of climate and weather
- Purification of water and air
- Mitigation of droughts and floods
- Generation, preservation, and fertility of soils
- Detoxification and decomposition of wastes
- Pollination of crops and natural vegetation
- Dispersal of seeds for vegetation regeneration
- Control of agricultural pests
- Prevention of riverbank, lakeside, and coastal shoreline erosion
- Production of food and other natural products.
- Protection against emerging diseases

Many of these services are entwined in complex networks of interactions that we usually only recognize from their outcomes. For example, crop failures can be the result of rising temperatures, strong El Niño-Southern Oscillation (ENSO) influences, violent weather combined with flooding due to inappropriate land clearing, a decline in soil fertility, and/or an unraveling of invertebrate and vertebrate communities that pollinate, disperse seeds, and control pests. The emergence of new diseases in the human population may result from a removal of mammalian hosts and their predators, a disruption to an ecosystem greatly increasing the incidence of vectors or intermediate hosts, and changes in the distribution of water due to changes in climate and weather patterns. Understanding these complexities will be critical to the argument for sustainably managing biodiversity, as well as for the management itself.

Declining biodiversity and impaired ecosystem services can also have adverse cultural and social impacts, such as posing a threat to the traditional use and knowledge of wild species for medicine, food and crafts.

1.3.4 Impact of environmental degradation on the MDGs

At least six of the eight MDGs, including MDG7 upon which this Task Force is based, have strong direct links with biodiversity and ecosystem services:

- **Eradication of Extreme Poverty and Hunger (MDG 1)** is directly dependent on a number of the ecosystem services listed above and intimately tied to agricultural productivity and yield of fisheries, which provide the livelihoods of the rural poor. Reduced soil fertility, and limited access to clean water are important examples of the decline in ecosystem services upon which those livelihoods depend. Of particular importance to many low-income countries where seafood constitutes an important source of protein is the state of the global fisheries. The causal relationship between poverty and environmental degradation runs in both directions. Poverty can force people to deplete environmental resources around them, thereby destroying the ecosystem services upon which their incomes rely. Conversely, persistent environmental degradation can contribute to poverty – particularly among subsistence farmers and fishermen. Sometimes the impact of environmental degradation on income levels may take a long time to materialize, as

evidenced by the destruction of the Aral Sea in Central Asia, which is now causing widespread economic hardship to the local population after excess extraction of water from the rivers feeding the sea permitted dramatically increased production levels of cotton and cereals for decades.

- **Reducing Child Mortality (MDG 4)**, while clearly related to maternal nutrition, prenatal intervention, and peri- and post-natal care, will also be directly tied to the control of endemic and emerging diseases, which in turn is naturally linked to an intact ecosystem's ability to mediate climate change, mitigate water quality and distribution, and provide alternative hosts for existing and emerging disease vectors. Degraded ecosystems, with a considerable amount of standing water and little natural control of invertebrate populations, will be ripe for high incidences of water- and insect-borne diseases (e.g. malaria, dengue, diarrheal diseases) that will inevitably take the lives of infants ill-prepared to withstand their symptoms.
- **Improving Maternal Health (MDG 5)** is related to environmental sustainability in two main ways. First, as natural resources are depleted, women, who in many cultures are principally responsible for collecting firewood, drinking water, and various non-timber forest products, must venture farther from home and traverse ever rougher conditions. The physical stresses associated with collecting these resources cannot help but diminish the health of mothers. Second, as is the case of all of the members of a family and a community, environmental degradation, and its consequent negative effects on food availability, water quality, and the incidence of disease, affect maternal health. Because gestation and lactation are physiologically stressful under the best of conditions, the negative effects of environmental degradation are disproportionately visited on mothers.
- **Combating HIV/AIDS, TB, Malaria and Other Diseases (MDG 6)** has a strong connection to the state of the natural environment. The relationship between ecosystem management and human health is complex and requires careful consideration, but environmental degradation often leads to local economic disruption, population dislocation, rural to urban migration, and the crowding of urban areas. These contribute to the spread of communicable diseases like HIV/AIDS and tuberculosis. Furthermore, increases in water-borne and insect-borne disease incidence and distribution are related to land conversion, environmental degradation, ecological disruption, and declining water quality. However, the destruction of natural habitats has also led to significant improvements in public health, such as the eradication of malaria in Southern France, Sardinia, southern USA, Singapore, Israel, and parts of Algeria through large-scale drainage of wetlands. On the other hand, the long-term effects of these environmental changes are unknown (e.g. to local water tables, bird populations that control pests), nor is it likely that these measures would succeed on a large scale in tropical landscapes.
- **Developing a Global Partnership for Development (MDG 8)** must include a worldwide effort to maintain ecosystem services and protect species and genetic diversity. This is particularly important since the benefits of ecosystem services, such as climate stabilization and water retention, are shared internationally, while the costs often accrue locally. It is also important to advances in science and biomedicine, which have borrowed heavily from the anatomy, physiology, and genetics of naturally occurring species. This dynamic must be addressed through the global trade system and an equitable sharing of costs and benefits.

1.4 Incomplete understanding of the environment and the nature of successful interventions

Despite the wealth of knowledge available today, our systematic identification and mapping of biodiversity and our understanding of ecosystem functioning, as well as our ability to measure, predict, and assess the impact of change in these natural systems remains insufficient. The over-

arching question that needs to be answered is how environmental concerns can be better integrated into development. Specifically, we need to:

- Develop appropriate indicators to “measure” and map biodiversity, at the ecosystem, species, and genetic levels, and to monitor the functioning of ecosystems. Since no widely-agreed measure of diversity exists, a species inventory is the most practical means to map biodiversity.
- Establish a clear set of baselines from which to measure trends.
- Gain a greater understanding of the functioning of complex ecosystems and their response to exogenous shocks (e.g. climate change, species range shifts and extinction). In particular, we need to better understand what thresholds, regime shifts, or irreversible changes may result from environmental change.
- Assess the impact of declining levels of genetic diversity on the populations experiencing these declines, and model future challenges to population and species survival in wildlife and important crops as genetic diversity erodes over time.
- Model detailed scenarios of environmental dynamics to assess the likely changes in our natural environment, as well as the impact of those changes on the human population.
- Improve our understanding of the links between biodiversity/ecosystem change and human well-being.
- Better understand how policy, institutional, and technological interventions can improve the capacity of ecosystems to meet human needs without degrading those ecosystems.
- Communicate existing and newly gained scientific information in a manner that policy makers and the general public can understand in order to implement the needed actions.

This Task Force supports the intent of the Millennium Ecosystem Assessment (MA) to provide an integrated assessment of the consequences of ecosystem change for human well-being, as well as an analysis of the options available to enhance the conservation of ecosystems and their contributions to human needs. The MA is designed to meet some of the assessment needs of the Convention on Biological Diversity, the Convention to Combat Desertification, and the Ramsar Convention on Wetlands, as well as needs of other users in the private sector and civil society. Other efforts are under way to better understand the distribution, functions and services of ecosystems and their constituent species. We will also engage these initiatives to gather as much current knowledge about gene, species and ecosystem diversity and management, as possible.

Hence, this Task Force sees its role as complementary, building on the work of the MA and using its scientific data, as well as those gathered by other initiatives, as the basis for developing an explicit Action Plan for achieving the MDG target on environmental sustainability.

1.5 The economic value of biodiversity and ecosystem services

The Task Force recognizes the importance of economic valuations of biodiversity and ecosystem services to better inform policy recommendations. An analysis of economic *benefits* should provide regionally disaggregated answers to several questions, including the following:

1. What is the annualized economic value of ecosystem services and biodiversity?
2. How is this value affected by different types of environmental degradation?
3. What are the private and public benefits from consuming biodiversity and ecosystem services beyond the carrying capacity of the ecosystems that provide them? What are the benefits derived from human activities such as agriculture that lead to a reduction in biodiversity?

Closely related to the *benefit* analysis is an estimate of *costs* related to sustainably managing biodiversity and maintaining ecosystem services. It must address:

1. How high are the public and private costs associated with the preservation of biodiversity and maintenance or restoration ecosystem services?
2. What share of these costs can be recuperated through the removal of adverse economic incentives (such as subsidies encouraging an overcapacity in global fishing fleets) by (a) reducing public expenditures and (b) decreasing the environmental burden of associated human practices.
3. How are the costs and benefits of environmental management distributed?

A comprehensive investigation of these questions is complicated by a number of factors. First, many ecosystem service flows that underlie the economic calculus tend to be difficult to estimate in terms of magnitude and sometimes even in direction. Second, products and services provided by ecosystems and the economic benefits derived from them vary tremendously from one ecosystem to the next. As a result, we lack a sound understanding of the depth and dynamics of associated economic markets, which makes it difficult to interpret results obtained at the margin. Third, economic benefits of biodiversity and ecosystem services cannot always be fully quantified and expressed in monetary terms. Contingent valuation techniques developed to overcome this difficulty continue to suffer from a number of theoretical and practical shortcomings. Fourth, on the costing side, some uncertainty remains on the types of interventions required to maintain ecosystem services and restore biodiversity, which complicates any detailed analysis of costs. Last, we do not fully understand the impact that the removal of environmentally perverse incentive schemes will have on biodiversity at the ecosystem, species, or gene levels.

Nevertheless, a large number of economic studies have attempted to answer one or more of these essential questions. One strand of the literature, largely based on Costanza et al. (1997), bases its analysis on replacement costs for ecosystem services. A consensus has now emerged that this approach is deeply flawed and that its results tend to overestimate the true benefits of ecosystem services and biodiversity¹.

From a policy standpoint marginal costs and benefits matter most. A wealth of studies follow this approach to develop alternative estimates of the economic value of biodiversity and ecosystem services.² The Task Force will need to review this research carefully in order to extract lessons that can be learned from it.

A sizeable literature exists on the costs of improved environmental protection and management. Many studies focus on the capital outlays required to secure adequate habitat cover, including opportunity costs, and the funds required to manage these areas on an annual basis. A particular focus has been given to hotspots. Pimm et al (2001) calculate that the 25 terrestrial hotspots (Myers et al., 2000) will require a one-time investment of about \$25 billion to secure and manage sustainably. An additional \$2.5 billion are estimated for marine reserves. The supplementary materials to Pimm et al (2001), present sharply divergent opinions as to the real cost of securing and sustainably managing adequate terrestrial and marine areas. More recently, Balmford et al (2002) put the cost of managing biodiversity in a sustainable way at \$45 billion per year. This includes the amortized cost over a 30 year period of securing large protected contiguous areas of land (15% of total surface area) and marine (30% of area) based environments, and the annual expenses of

¹ For example, Costanza et al. conclude that the return on typical environmental investment will range from 100 to 1000. However, we are not aware of any well-documented cases where such returns have actually been achieved. More realistically, it seems that the savings of \$ 8 billion from a \$1.5 billion investment in New York City's watershed (i.e. a multiple of 5.3) is at the very top of the range of returns that can reasonably be expected.

² Walter Reid has suggested Pagiola and Bishop (eds.) 2002 "Selling Forest Environmental Services", Earthscan.

managing these areas worldwide. While the sum may appear staggering it only represents about 20 cents of every U.S. \$100 of GDP of the wealthiest countries. It is also, by comparison, more than an order of magnitude smaller than the savings that would be generated by phasing out agricultural, transportation and energy subsidies that all contribute to biodiversity loss and ecosystem degradation (Myers and Kent, 2001). For example, agricultural subsidies in the wealthiest nations have now cumulatively reached nearly U.S. \$ 1 billion per day (Browne 2002).

These studies, however, suffer from major methodological shortcomings, such as the reliance on a small number of marginal cost estimates derived from small-scale analyses, which are then effectively applied as average costs for the system as a whole. It is therefore unlikely that the resulting cost estimates are robust. More fundamentally, the cited studies have come under attack for focusing on biodiversity hotspots, the definition of which may merely reflect sampling bias (see for example Meegaskumbura et al., 2002), whereas the majority of biodiversity is found elsewhere. In addition, projected climate change will likely make it impossible to maintain some of the hotspots over the coming decades, and shifts in species ranges associated with those climate changes may very well shift the geographical limits of species concentrations. This unpalatable but likely scenario will need to be incorporated into any future economic analysis.

Again, a large literature exists on the costs of sustainably managing (including protecting) biodiversity as well as maintaining ecosystem services, which the Task Force will need to review in detail. Given the sheer complexity of the distribution of biodiversity and ecosystem services, it is likely that the work of the group will need to proceed by focusing on the analysis of select types of ecosystems and services required to satisfy a particular human need, such as food production, while recognizing the importance of biodiversity for numerous aspects of human welfare. Evaluation efforts underway by OECD, CIFOR, the MA, and others will significantly assist in the process of refining the economic analysis.

2 The key drivers of environmental degradation

2.1 Overview

Understanding the factors that cause ecosystems to degrade and species and genetic diversity to decline are necessary for developing interventions that seek to mitigate the negative consequences of environmental change. This Task Force draws from the MA a framework for its analysis of key drivers of environmental degradation.

Some factors *directly* affect biodiversity and ecosystems either through natural processes (e.g. volcanic eruptions or changes in the sun's energy) or through human actions, which will be outlined below. *Indirect* drivers of change such as biophysical, demographic, economic, socio-political, technological, and cultural and religious forces in turn affect these *direct* drivers.

For any given decision-maker, some of these drivers will be exogenous, meaning that the individual's decisions will not affect them, while others are endogenous, meaning that decisions can directly affect the driver.

While it is important to separate the analysis into individual drivers, one must not lose sight of the complexity of human relations with environmental systems, which interact simultaneously with a large number of direct and indirect drivers. A robust analysis of such interactions must follow a systems approach to reflect the dynamic complexity of ecosystems and the changing nature of people's perceptions, needs and aspirations.

2.2 Direct drivers

Direct drivers of environmental degradation cover a broad range of human and natural impacts. Among the most important are:

- Land use change (e.g. through urbanization, road construction, energy and mining activities, deforestation, agriculture, illicit crops and fire incidents)
- Modification of river flow
- Input of irrigation or fertilizers
- Discharge of pollutants
- Overharvest of crops, wildlife, or fisheries
- Introduction of new, non-native or invasive species.

All of these have a direct impact on the health of ecosystems and the species they support; the size of populations of different species; the range of genetic diversity found within and among those populations; and the short and long term probability of their survival.

2.3 Indirect drivers

2.3.1 Demographic change

A key indirect driver of environmental change is human population size, growth, distribution, and resource consumption. Population numbers drive demand for all ecosystem goods and services – particularly food, shelter and energy. The UN Population Division's median forecast estimates a population increase of 2.9 billion people by 2050. Demographic estimates suggest that 95% of future population increase will be concentrated in developing countries, particularly in the tropics. Since 90% of food is produced in the country of consumption, tropical and subtropical ecosystems

will be forced to provide disproportionately more food, in addition to the services they already provide, than temperate systems.

Population growth also decreases per-capita availability of finite renewable resources such as drinking water as well as non-renewable resources including fossil fuels. Additionally, significant population increases, and the land cover transformations they engender, reduce the size of natural habitats, which can further reduce the per-capita availability of ecosystem services. This downward spiral can be profound, as specific examples of high population growth (e.g. coastal Madagascar; Kakamega Forest, Kenya) have demonstrated. While demographic drivers are exogenous to decision makers at any point in time, they can become endogenous over the medium to long term, and managed through appropriate planning measures.

It is important to note here that environmental degradation and the depletion of non-renewable resources are driven not only by population numbers, but by per capita consumption levels and patterns as well (see next section).

2.3.2 Economic drivers

Economic well-being and the increase in international trade have a strong yet often ambiguous impact on the demand for ecosystem services. Rising incomes tend to raise the level of consumption of ecosystem goods and services, but they also increase people's ability as well as willingness to mitigate adverse environmental change. While the overall *level* of consumption is important, consumption *patterns* can have a strong impact on the environment after controlling for income. Increasing incomes also tend to lower fertility rates and population growth, which slows the rate at which consumption levels increase. Conversely, poverty can have a negative impact on fragile ecosystems, as populations with low incomes are often forced to deplete environmental resources and do not have the ability to invest in their regeneration. As a result, poverty is an important driver of environmental change in low-income countries. Reductions in poverty and in inequality can sometimes help to alleviate pressures on ecosystems, but the effect can also be the reverse. The link between income level and environmental impact is highly context-specific and often depends on the surrounding ecosystems and the type of ecosystem service examined.

The net effect of economic growth on biodiversity and ecosystems can thus be difficult to predict. Historically, energy demand has increased steadily with per capita income while local pollution has initially increased and then fallen once a certain threshold income level has been achieved. It is, therefore, the combined rate of growth of GDP, trade and capital flows and their destination, and income inequality that is crucial to understanding the direction and extent of impacts on land use patterns, resource extraction, water diversion and pollution, biodiversity loss, and overall ecosystem degradation.

Developing countries that teeter on the edge of profound poverty urgently need economic development. The challenge before us is how to develop policies that allow for rapid economic development without the consequent extreme environmental degradation that often accompanies such growth. This is imperative because the imbedded costs of near-term crop failures, disease, water shortages and the like will surely drive down the value of economic development in very real, day-to-day ways.

2.3.3 Scientific and technological drivers

Science and technology affect the environment in two distinct ways. First, changes in technology have a direct impact on people's demand for ecosystem services and can adversely affect their ability to access those services as ecosystems are altered by area contraction, fragmentation, species loss, and pollution. Second, scientific understanding and technology can help humans mitigate

stress on ecosystems and environmental services by creating ecosystem-friendly alternatives and efficiencies.

The environmental expertise of political decision makers in many countries is very limited, helping to explain why important environmental considerations tend to be neglected in policy making. As argued in Section 1.4, the scientific knowledge and organization of knowledge of key aspects of biodiversity are limited. The situation can be grave in developing countries where technical expertise available locally may be profoundly inadequate. As a result, the monitoring of key environmental resources tends to be rare and of poor quality for the most part.

In addition, the general public often does not understand the direct connections between human health, economic well-being, and the natural systems that surround them. Therefore, few incentives are in place to protect biodiversity and ecosystems or to demand that political leaders do so. This applies particularly to farmers, operators of aquaculture systems, energy producers, and factory owners whose activities can cause significant harm to their local environments, and by extension to their workforce and themselves.

There is a severe, profound difference in the access to technological and scientific innovations between the developed and developing countries. Conversely, the developing countries contain a much greater proportion of biodiversity than the developed countries. Access to this information is paramount in developing countries if they are to efficiently draw on the benefits from their ecosystems without degrading those systems beyond their ability to function properly and provide the benefits upon which we all depend. In addition, tools need to be developed that allow developing countries to assess the health of local ecosystems and the short-term impacts that population, economic, and policy changes are having on that health.

Of course, tools, models, technologies, and assessments require people with the knowledge and skills to use these instruments. This necessarily implies the need for a major effort in technology training and other capacity building. Additionally, it implies that those trained and empowered to conduct assessments and make future technological advancements must come from the countries in which those assessments and advances must be made. Without a concerted, organized effort to export appropriate technologies and requisite training to the local level around the world, it is difficult to see how technology and scientific advances will provide benefits to biodiversity conservation, ecosystem management, and the efficient use of ecosystem services.

2.3.4 Institutional and socio-political drivers

Institutional and socio-political drivers that affect biodiversity and ecosystem services include:

- **Externalities and other market failures**
In the absence of appropriate institutions, behavior resulting in environmental degradation is encouraged due to the “tragedy of the commons” and externalities that prevent people from incurring the full cost or capturing the full benefits resulting from their actions. For example a farmer who maintains a forested hillside that reduces the risk of downstream flooding may not be remunerated for this service. Conversely, if that farmer clear cuts the hillside and sells off the timber for a handsome price, it is unlikely that he or she will have to pay for the environmental damage of the consequent flooding, erosion, and dislocation. In the face of no reward for leaving a forest intact and considerable returns for clearing the same forest, environmental degradation will be greatly exacerbated.
- **Government policies promoting ecosystem degradation**
Certain policies and investments in infrastructure are known to promote the accelerated conversion of ecosystems. Road building into forested areas is a prime example of an aggressive promotion of land conversion and extensive resource use; government-supported

colonization and resettlement programs have similar effects. Other sector-specific policies, like subsidies for agricultural production and for energy consumption, or provisions of excessively cheap access to timber and fishery exploitation work in the same direction. Even policies that in some situations make good macroeconomic sense, like currency devaluation, export incentives or rural investment programs, can have strong negative side-effects on biodiversity and ecosystem services (Wood et al. 2000; Angelsen and Kaimowitz 1999).

- **Inadequate (economic) incentive structures and subsidies**

Myers and Kent (2001)³ have estimated that \$2.5 trillion is spent annually on subsidizing agriculture, energy, road transport, water and fisheries. They argue that \$1.9 trillion of this amount is spent in ways that are contrary to the principles of sustainable development. This funding for “anti-conservation” creates and sustains incentives that encourage environmental degradation. Subsidies for agriculture, fuels, electricity, fisheries, and related industries have long been argued to be an essential component of sustainability in many countries. However, in many cases, prices at the production level are very low compared to the price at the consumer level (up to factors of 10-20), which may in part be caused by an inefficient distribution chain. More important, particularly in the context of tropical cash crops and natural resources, may be the presence of a monopsony where few buyers (either governments or the large food companies) seek the products of many sellers (the farmers). As a result of both inefficient distribution chains and monopsony, the producers/farmers do not get a fair price for their product. While the inefficient distribution chain can be improved by infrastructure investments, monopsonies can only be addressed through some form of regulation. The latter is complicated by the highly international nature of global food markets.

- **Gender and other forms of discrimination**

Limiting women’s access to education and the work place, and thus alternatives to large families, most often result in high birth rates and substantial population growth. As populations grow there tends to be direct pressure placed on surrounding natural habitats in order to meet basic needs of food, water, and fuel. In this way gender discrimination can have a profound indirect impact on biodiversity conservation, ecosystem health, and ecosystem services. These, in turn, will have direct impacts on the health and well-being of women and their children. These same effects can be seen in groups that are discriminated against because of their ethnicity, language, or social class.

- **Weak institutional frameworks, political instability and civil strife**

The absence or malfunctioning of political institutions can act as an important driver of environmental degradation. As indicated earlier, considerable forest clearing has occurred in developing countries during periods when central and local governments have become weak or corrupt and police authority and civil order have eroded (Laurance 2000).

³ Some Task Force members have raised concerns about the reliability and robustness of Myers and Kent’s conclusions. The Task Force will need to come to a consensus as to whether base its analysis on this work.

3 A framework of action for achieving MDG 7

3.1 Why has progress towards maintaining biodiversity and ecosystem services been so unsatisfactory?

Historically, ecosystem-related problems have been approached on an issue-by-issue basis. Questions such as agricultural productivity, water pollution, and the protection of biodiversity have tended to be addressed separately without taking their interdependencies into consideration. As argued above, such an approach fails to appreciate the dynamic complexity of species and ecosystems and human interactions with them, where the system as a whole is more than the sum of its constituent parts. Moreover, it cannot be used to devise strategies that are robust in the face of uncertainty and surprise and capable of adaptation, both to the dynamic complexity of the underlying system and to the changes in people's perceptions, needs and aspirations.

In line with the findings of this analysis, policies aimed at environmental management and sustainability have failed to address the core problem. Progress made towards one objective, such as food production, has often resulted in unacceptable costs for other objectives such as biodiversity conservation or water quality.

A second shortcoming of current environmental policies resulting from the failure to adopt a systems approach is insufficient recognition of the need to tackle "externalities". Much environmental degradation derives from the fact that on-site cost and benefit assessments do not take into consideration off-site effects of environmental change. It can be argued that a similar problem exists with the inter-temporal allocation of the benefits of environmental services and resources. A successful framework of action needs to develop policy tools to address these specific challenges. Current economic policies disregard the value of biodiversity and the need to preserve its integrity. Different schools of thought agree that the economic system does not incorporate environmental costs correctly. Strictly economic analysis of environmental problems tends to focus on the systemic failure of markets in the allocation of resources. These failings appear to be caused by the absence of prices and effective ownership systems, combined with inequitable distribution of costs and benefits and the existence of incomplete markets for many natural resources and environmental services. Such market failures can be remedied if economic and social agents receive the right signals about production and consumption through public policies and appropriate regulations. Environmental policies and institutions are essential to deal with aspects that the market cannot rectify, such as the needs of future generations.

A lack of adequate and timely access to scientific and economic information and a general lack of political further contributes to impeding progress toward slowing current trends of environmental degradation and outright destruction.

Overall, we conclude that environmental and biodiversity issues have not been adequately integrated into mainstream thinking and policy-making. Options for add-on environmental policies that fail to adopt a systems approach have been exhausted in many regions. Effective action will require better integration of biodiversity considerations into decision-making about agriculture, trade, investment, research and development, infrastructure and finance.

3.2 Key elements of a framework for action

While it is premature for the Task Force to map out a comprehensive framework for action, the following elements can be provisionally identified as key to a successful framework:

- Applying the best science worldwide to measure, map, monitor, and model biodiversity at the ecosystem, species and genetic level to better understand the extent and root causes of biodiversity loss and ecosystem degradation. The best science needs to be applied to improve our understanding of the human consequences of change in ecosystems and to develop interventions that enhance ecosystem management.
- Assessing in fine detail the costs and benefits of conserving biodiversity and maintaining ecosystem services, and the distribution of these costs and benefits.
- Understanding and incorporating local perceptions, needs and aspirations of the value and use of biodiversity and ecosystem services into planning and action frameworks.
- Building institutional and regulatory capacity to implement the sustainable management of natural resources.
- Creating locally specific and adaptive frameworks of action with strong buy-in from government, civil society and the expert community, which define appropriate adjustments to national and sub-national policies. A key challenge is to devise effective means by which these action frameworks can guide policies pursued at the local and national level towards ensuring a sustainable flow of benefits from ecosystem services and the protection of biodiversity. One element of such frameworks of action should be “biodiversity with people” programs that involve indigenous communities, peasants and other communities in the conservation and sustainable use of biodiversity and ecosystem services.
- Developing locally specific public finance policies, economic incentives and financing mechanisms for managing the consumption of ecosystem services.
- Improving public knowledge and awareness of the daily benefits to human health and well-being that are derived from healthy ecosystems and their species.
- Strengthening international environmental governance to reinforce cooperation among states and increase coherence among international environmental accords and regulations related to biodiversity and ecosystem management
- Improving regional cooperation to ensure coherence in managing transboundary ecosystems. A good example for this is the Mesoamerican Biological Corridor.

Other elements, the precise form they will take, and their interactions with those listed above will need to be developed in greater detail over the coming two years.

The following principles have been suggested to guide the Task Force’s work on devising a framework of action:

- While considerable uncertainties remain with respect to the scientific evidence, economic assessments and our understanding of how interventions can be tailored to better manage ecosystem services, the Task Force will need to develop its recommendations on the basis of what is currently known rather than what ideally should be known.
- In moving forward, the Task Force should identify and make interim recommendations that can feed into ongoing policy initiatives towards achieving the MDGs.
- Since the work of this Task Force touches directly on that of several other Millennium Project Task Forces, we will need to coordinate our work closely with them. To this end it is important to develop a “first cut” of the framework of action that will guide the future work of this Task Force.

4 Appendix

4.1 Definitions

Biodiversity, a shortened term for biological diversity, is defined in the CBD as the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. This variability is continuously distributed from large regional biomes to the individuals in local populations. Conventionally, biodiversity is measured at three levels: ecosystem, species, and gene. At each of these levels, we have witnessed considerable decline in variability.⁴

Ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (CBD).

*Ecosystem goods and services*⁵ as defined by the Millennium Ecosystem Assessment are the benefits people obtain from ecosystems. These include provisioning services such as food, clean water, shelter and biomass for energy generation; regulating services such as flood and disease control; cultural services such as spiritual, recreational and cultural benefits; and supporting services such as nutrient cycling and climate stability that maintain the conditions for life on earth.

Environmental sustainability refers to the ability of ecosystems to maintain themselves indefinitely and to provide their constituent species, including humans, with critical ecosystem goods and services. To use and manage ecosystems sustainably, humans must act in ways that do not impair the self-perpetuating maintenance and service functions of these systems.

4.2 Recommendations that may be integrated into the framework of action:

Out of a general, provisional set of elements of a framework for action, the Task Force has identified a preliminary set of initiatives that can and should be addressed through decisive policy actions. These are:

- Improve the measuring, mapping and monitoring of biodiversity

Improved measuring, mapping, and monitoring of biodiversity at all levels using greatly expanded instrumentation, remote sensing, bioinformatics, and intensive "ground truthing" in all parts of the world will provide an essential foundation for subsequent action, and assessment of progress. **A new Global Life Observatory should be launched in 2003 as a cooperative international scientific venture, to gather, digitize, and freely disseminate existing and new information on ecosystem, species, and gene diversity throughout the world.**

This effort would follow a similar successful effort to create a global Earth Observatory system for climate measurement, mapping and analysis. One aspect of the Global Life Observatory could be the implementation of the ALL Species Concept by preparing a comprehensive worldwide map of

⁴ There is some debate surrounding ecosystem diversity. Arguably, by creating human-modified ecosystems diversity at that level may have actually increased.

⁵ Throughout this document ecosystem goods will be subsumed under the term "ecosystem services".

all species over the next 25 years. This would involve mapping the ranges of the approximately 1.7 million species already named, as well as the discovery of the untold millions of other species yet to be identified. In this sense, the species identification and mapping effort would parallel, at the species level, the ongoing ecosystem work of the Millennium Ecosystem Assessment. A second worldwide effort to map genome diversity should also be launched. A third aspect of the work of the Global Life Observatory would be to undertake the task of harmonizing the plethora of global reporting initiatives related to biodiversity (e.g. the MA, UNEP's WCMC, UNEP's Global Environment Outlook, and IUCN's Species Information System (SIS)). This would include the development of an effective, globally acceptable environmental information system supported by a harmonized set of data, indicators and indices that could provide the basis for decision-making.

These complementary initiatives would form the foundation of the Global Life Observatory, which would build a dynamic, fully accessible, scientifically credible database that any locality, nation, region or international governance body could freely use to develop appropriate plans and actions to sustainably manage biological resources. These data would also form the basis for ecosystem, species and population modeling to analyze current conditions and develop future predictions of the impact of human activities on natural systems and the benefits they provide the human population.

- Build the national capacity to implement country-level biodiversity and ecosystem services management plans

Donor and low-income countries require a new international framework to support the preparation of country-scale biodiversity management plans that can serve as the basis of national policy as well as donor financing of the conservation of natural resources (as called for in Article 6(a) of the CBD). In addition, clear recommendations are needed with regard to how countries should fully integrate these biodiversity plans into their overall development plans and policy-making cycles. This will also require that the necessary technical and financial resources are available at the country level. The experience of the GEF may provide important guidance as planning and financing expands from specific project to program-scale support.

For many countries management plans have already been developed. However, to put these plans into practice, a major effort must be undertaken to build the capacity for in-country scientists and practitioners to collect the requisite data, perform the appropriate analyses, and implement environmental management strategies. This effort will require considerable cooperation and partnering between institutions of higher education and professional development in wealthy countries and their sister institutions in developing countries.

The implementation of country-level management plans will only be successful if they are able to reflect the local contexts in which they are to be implemented. Therefore, it is imperative that such plans be developed and executed by local scientists, practitioners and policy makers. This will only happen if a major effort is made to develop the cadres of professionals necessary for this task. For this reason, **an International Network for Environmental Training (INET) to build local capacity to manage local biodiversity should be established immediately.**

- Increase funding for biodiversity conservation and ecosystem management

The funding needed for biodiversity conservation and maintenance of ecosystem functioning (e.g. through the establishment of reserves) has been estimated to be on the order of U.S. \$45 billion per year worldwide, both from domestic and international sources, and covering capital investments, maintenance activities, and the opportunity costs of land set-asides. Currently, we spend worldwide approximately U.S. \$6.5 billion annually (Balmford et al., 2002) to cover these expenses. These

estimates need to be refined in detail, and this will be a key priority of the Task Force. However, whatever the final estimates, it is clear that an increase in funding for the sustainable management of biological resources will be required. The mechanisms for generating and disseminating the necessary funding in an efficient and transparent way, as well as for equitably sharing in the benefits generated by the discovery and sustainable management of biodiversity, must be developed. The Task Force will take on the challenge of developing a set of alternative mechanisms to underwrite the cost of managing ecosystem, species, and genetic diversity, but **a multi-lateral “fund” or “bank” will need to be created if we are to implement biological resource conservation at the scale that is needed to be sustainable and provide benefits to all populations.**

- Improve awareness among policy makers and the general public

All of the above pre-supposes that conserving nature is seen by the world community as something other than a luxury. As long as the conservation of natural systems is not seen as a central, critical concern, around which the solutions to many of the other problems we face deeply depend, the motivation to gather credible scientific information, develop politically and economically feasible management plans, and create finance mechanisms to take action will be limited. We need to re-frame the argument for nature conservation in a way that makes clear nature’s present value to all of us. We need to do this for the general public, as well as for those who make our policies. This will require a new and creative marketing and public relations strategy that makes our best scientific information available to policy makers and to the general public in a way that is understandable and compelling. Therefore **it is imperative that a worldwide Campaign for Public Awareness of the importance of biodiversity and ecosystem services to our daily lives be established for all sectors of society.**

- Consolidate international markets for global environmental services

Countries can play a proactive role in the multilateral negotiations associated with the UN Framework Convention on Climate Change with a view to consolidate suitable mechanisms for capturing the economic value of global environmental services. It is necessary to build the capacity to capitalize on the opportunities opened up by these new market mechanisms proposed by the Kyoto Protocol. The promotional and catalytic role of seed funding from multilateral and regional organizations will be critical in the early start-up and consolidation phases of these markets, until they acquire enough momentum to mobilize funds on their own. Payment for environmental services is thus a practical and viable tool for fulfilling conservation objectives for strategic areas. **Therefore it will be essential to build capacity to value environmental services and establish systems to capture economic value from resources that provide benefits (global, regional, national or local).**

5 Literature cited

- Angelsen, A., and Kaimowitz, D. 1999. Rethinking the causes of deforestation: Lessons from economic models. *World Bank Research Observer* 14: 73-98.
- Achard, F., Eva, H.D., Stibig, H-J., Mayaux, P., Gallego, J., Richards, T., and Malingreau, J-P. 2002. Determination of deforestation rates of the world's humid tropical forests. *Science* 297: 999-1002.
- Balmford, A., et al. 2002. Ecology – Economic reasons for conserving wild nature. *Science* 297: 950-953.
- Bonner, R. 2002. Indonesia's forests go under the ax for flooring. *New York Times*, September 13: A3.
- Browne, A. 2002. Summit calls for cut in farm subsidies. *The Times (London)*, August 28: Overseas news, 13.
- Bryant, D., Burke, L., McManus, J., and Spalding, M. 1998. *Reefs at Risk: A Map-Based Indicator of Potential Threats to the World's Coral Reefs*. Washington, DC: WRI and Cambridge:UNEP-WCMC.
- Costanza, R., et al. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.
- Courtney, C.A., and White, A.T. 2000. Integrated coastal management in the Philippines: Testing new paradigms. *Coastal Management* 28: 39-53.
- Daily, G.C. (Ed.) 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington, DC: Island Press.
- FAO. 1998. *The State of the World's Plant Genetic Resources for Food and Agriculture*. FAO
- Goreau, T., McClanahan, T., Hayes, R., and Strong, A. 2000. Conservation of coral reefs after the 1998 global bleaching event. *Conservation Biology* 14: 5-15.
- Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research* 50: 839-866.
- Houghton, J.T., Ding, Y., Griggs, D.J., Noguera, M., van der Linden, P.J., Dai, X., Maskell, K., and Johnson, C.A. (Eds.). 2001. *Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press.
- IUCN. 2002. 2002 IUCN Red List of Threatened Species. International Union for the Conservation of Nature and Natural Resources. www.redlist.org

- Kremen, C., Williams, N.M., and Thorp, R.W. 2002. Crop pollination from native bees at risk from agricultural intensification. *PNAS* 99: 16812-16816.
- Landweber, L. F. and Dobson, A. P. (Eds.) 1999. *Genetics and the Extinction of Species: DNA and the Conservation of Biodiversity*. Princeton, NJ: Princeton University Press.
- Laurance, W. F. 2000. Cut and run: the dramatic rise of transnational logging in the tropics. *TREE*, 15: 433-434.
- MA. 2002. People and Ecosystems: A Framework for Assessment and Action. *Second preliminary draft, Millennium Ecosystem Assessment*.
- McManus, J. 1997. Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia. *Coral Reefs* 16 Suppl: S121-S127.
- Malhi, Y., Meirl, P. and Brown, S. 2002. Forests, carbon and global climate. *Philosophical Transactions of the Royal Society of London Series A* 360: 1567-1591.
- Meegaskumbura, M., Bossuyt, F., Pethiyagoda, R., Manamendra-Arachchi, K., Bahir, M., Milinkovitch, M.C., and Schneider, C.J. 2002. Sri Lanka: An amphibian hotspot. *Science* 298: 379.
- Myers, N. and Kent, J. 2001. *Perverse Subsidies: How Tax Dollars Can Undercut Both the Environment and the Economy*. Washington, DC: Island Press.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., daFonseca, G.A.B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.
- Naeem, S., and Li, S. 1997. Biodiversity enhances ecosystem reliability. *Nature* 390: 507-509.
- Naeem, S. 1998. Species redundancy and ecosystem reliability. *Conservation Biology* 12: 39-45.
- National Research Council. 1993. *Agricultural Crop Issues and Policies: Managing Global Genetic Resources*. Washington, D.C.: National Academy Press.
- Pimental, D., Harvey, C., Resosudarno, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., and Blair, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science*, 267:1117-1123.
- Pimm, S.L., et al. 2001. Environment – Can we defy nature’s end? *Science* 293: 2207-2208.
- Polunin, N.V.C. and Roberts, C.M. (Eds.). 1996. *Reef Fisheries*. London: Chapman and Hall.
- Roelke, M.E., Martenson, J.S., and O’Brien, S.J. 1993. The consequences of demographic reduction and genetic depletion in the endangered Florida panther. *Current Biology* 3: 340-350.
- Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweig, C., and Pounds, J.A. 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421: 57-60.
- Schiermeier, Q. 2002. How many more fish in the sea? *Nature* 419: 662-665.

Smale, M. 1997. The Green Revolution and Wheat Genetic Diversity: Some Unfounded Assumptions. *World Development* 25: 1257-1269.

Smale, M., et al. 1998a. The contribution of genetic resources and diversity to wheat production in the Punjab of Pakistan. *American Journal of Agricultural Economics* 80(3): 482-93.

Smale, M (Ed). 1998b. Farmers, gene banks and crop breeding: Economic analyses of diversity in wheat, maize and rice. *Natural Resource Management and Policy Series*. Boston: Kluwer Academic.

Wood, C., Dipper, B., and Jones, C. 2000. Auditing the assessment of the environmental impacts of planning projects. *Journal of Environmental Planning and Management* 43: 23-47.