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Turning science into policy: challenges and experiences from the science–policy interface

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This paper discusses key issues in the science–policy interface. It stresses the importance of linking the conservation and sustainable use of biodiversity to the Millennium Development Goals and to issues of immediate concern to policy-makers such as the economy, security and human health. It briefly discusses the process of decision-making and how the scientific and policy communities have successfully worked together on global environmental issues such as stratospheric ozone depletion and climate change, and the critical role of international assessments in providing the scientific basis for informed policy at the national and international level. The paper also discusses the drivers of global environmental change, the importance of constructing plausible futures, indicators of change, the biodiversity 2010 target and how environmental issues such as loss of biodiversity, stratospheric ozone depletion, land degradation, water pollution and climate change cannot be addressed in isolation because they are strongly interconnected and there are synergies and trade-offs among the policies, practices and technologies that are used to address these issues individually.

Keywords: biodiversity; climate change; ozone; assessments; plausible futures; indicators

I would like to share the experiences I gained of how science was turned into policy during my times as the chair or former chair of the international assessments of stratospheric ozone depletion, climate change and biodiversity, and that were further informed by my work in the World Bank and as a former adviser in the Clinton–Gore administration.[1]

We need to recognize that, at least in the present day, politicians are rarely elected for protecting the environment, but rather for what they do to improve the economy, human security and human health. Therefore, if we are to successfully promote the importance of conserving biodiversity to decision-makers and the wider public, which we have failed to do so far, we need to link biodiversity loss to the issues of most concern to current decision-makers, i.e. the economy, security and human health. We also need to link the implications of biodiversity loss to the Millennium Development Goals (MDGs; which include reducing poverty and hunger) because all countries have endorsed them. There is an urgent need to demonstrate that there is no dichotomy between economic growth and environmental protection—indeed, we need to demonstrate that environmental degradation undermines sustainable economic growth. Simply put, we need to appeal to the self-interest of politicians and the general public because human self-interest underpins most decisions.

Prior to the World Summit on Sustainable Development in 2002, the United Nations Secretary-General, Kofi Annan, identified five key development challenges: water, energy, health, agriculture and biodiversity. The challenges include providing the 1.3 billion people that do not have clean water with clean water, the 2 billion people that do not have sanitation with proper sanitation, the 2 billion people that live without any modern energy with energy services (including electricity) and the 800 million people that are malnourished with affordable, nutritious food. Furthermore, we need to reduce the threats to human health, many of which are linked to environmental conditions. The World Health Organization has estimated that 20% of the global burden of disease is linked to environmental conditions, which is comparable to that attributed to nutritional insecurity. Those exposed to dangerous levels of outdoor air pollution number 1.4 billion, 2 billion people are exposed to dangerous levels of indoor air pollution, and about 2 billion people are exposed to vector-borne diseases (e.g. malaria and dengue) and water-borne diseases (e.g. cholera). We have to ask ourselves: how do we address these development challenges, many of which are drivers of biodiversity loss, while at the same time meeting the challenge of sustaining the full diversity of populations, species and ecosystems that make up the planet's biodiversity?

If we are serious about meeting the challenges of providing improved access to clean water and sanitation, clean energy, nutritious food, improving human health, while maintaining biodiversity, we cannot simply talk about monitoring birds and butterflies to most policy-makers—it has little or no chance of working. We have to link the conservation and sustainable use of biodiversity to the development issues that policy-makers and the majority of the general public care about. This can be done by linking ecosystem services, i.e. the provisioning, regulating, supporting and cultural services to key development issues (table 1). One ecosystem service of growing

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One contribution of 19 to a Discussion Meeting Issue 'Beyond extinction rates: monitoring wild nature for the 2010 target'.

Table 1. Ecosystem services, that is, the goods and benefits derived from ecosystems that further human well-being, can be subdivided into four categories.

provisioning	regulating	cultural	supporting
goods produced by ecosystems	benefits obtained from ecosystems	non-material benefits obtained from ecosystems	services maintaining the conditions of life on Earth
fresh water	climate control	spiritual	soil formation and retention
food	disease control	recreational	nutrient cycling
fibres	flood control	aesthetic	carbon sequestration
fuel wood	fire control	inspirational	nitrogen sequestration
biochemicals	detoxification	educational	phosphorus sequestration
genetic resources		communal	pollination
		symbolic	pest control

importance is carbon storage, because it is linked to the one global environmental issue that is currently at the centre of attention in all parts of the world, i.e. human-induced climate change.

The challenge, therefore, is to manage our ever-changing planet in a sustainable manner in the face of rapid demographic changes, economic growth, technological innovations, socio-political conditions and changing behavioural patterns. This will require a realization by politicians and civil society that many of the environmental issues that we are dealing with are issues of the global commons or issues of global concern. Successfully addressing issues of the global commons, such as stratospheric ozone depletion, climate change, persistent organic pollutants and open ocean pollution, requires coordinated global action. While stratospheric ozone depletion is fundamentally a solved problem with both developed and developing countries agreeing to eliminate the production and use of ozone-depleting substances, the other three issues are far from being addressed in a meaningful manner, and require political will and the involvement of a range of stakeholders, including governments (national and local), the private sector, non-governmental organizations (NGOs), foundations and the academic community. Unresolved issues of global concern include land degradation, water scarcity and degradation of water quality and biodiversity loss. While these are also issues of the global commons at one level, most actions will have to be taken at the local level and are not dependent upon coordinated global action. Therefore, different social and political structures are needed to deal with global commons issues such as climate change versus issues of global concern such as biodiversity loss.

What makes addressing these environmental issues even more challenging is that we cannot deal with climate change or biodiversity loss or any of these issues in isolation because they are all coupled to each other (Watson *et al*. 1998; STAP 2004). For example, climate change affects other issues such as ozone depletion, air and water quality, land degradation, forests and biodiversity; but in turn, changes in these issues will impact on climate change. Likewise, biodiversity is affected by climate change, ozone depletion, land degradation, persistent organic pollutants, air pollution and pollution of fresh and marine waters; but again changes in biodiversity will, in turn, affect climate, stratospheric ozone and land degradation. While climate change primarily affects the other environmental issues, biodiversity is primarily affected by changes in the other environmental issues. Therefore, we should not address these issues in isolation. We need to understand and analyse all of the interacting drivers and stresses, and identify policies and practices that can simultaneously address more than one issue at a time. We need to develop integrated models to understand these interactions, complemented by comprehensive satellite and ground-based observational systems, including direct observations of species and ecosystems. An integrated modelling and observational research programme can provide the information that is essential for informed policy-formulation.

Consequently, it is critical to identify synergies and trade-offs in addressing the major environmental issues, and to identify the synergies and trade-offs between environmental issues and national sustainable development goals. Most countries in the world will not act to protect the environment unless it is also consistent with achieving their national sustainable development goals. Furthermore, it is absolutely critical to involve local communities, NGOs and the private and public sector in both policy and project formulation and implementation. Scientific analyses and management actions to address conservation of biodiversity will have to be performed at a multitude of spatial scales, including the landscape level, to assist communities to adapt to the effects of global climate change. Small isolated reserves (protected areas) will not be sufficient to effectively protect biodiversity in the face of a changing climate given that the boundaries of climatic zones could move polewards several hundred kilometres and upwards in elevation by several hundred metres (IPCC 2001*b*, 2002; CBD 2003).

The underlying drivers of environmental change tend to be similar for most environmental issues, whether the environmental issue is land degradation, biodiversity loss or climate change (Millennium Ecosystem Assessment 2003). The main drivers are changes in: (i) the economic system (e.g. economic growth, purchasing power parity, globalization, trade liberalization, privatization, structural adjustment policies and subsidy regimes); (ii) demography (population size, the rural to urban migration, family size, age structure and gender status); (iii) science and technology (e.g. public and private sector funding for research, technological advances in biotechnology and information/communications and technology transfer); (iv) socio-political systems (e.g. multilateralism, regionalization, security, balance of power and migration); and (v) individual and community behaviour. Many people point out that we need to limit population growth, which is a fair point, but we need to recognize that in the next 50 years, while the world population is projected to increase from about 6.3 billion people to between 8 and 9 billion people, at the same time, world gross domestic product is projected to increase from about 33 trillion US dollars to 140 trillion US dollars, a factor of more than four (World Bank 2004). Therefore, the major stress on environmental systems will probably be through the increased demand for goods and services (e.g. biological resources and energy) because of economic growth, not population growth. Further important causes of environmental change are market imperfections such as: (i) perverse energy, water, agricultural and transportation subsidies; (ii) the lack of recognition of the value of natural resources; (iii) the failure to appropriate the global value of natural resources down to the local level; (iv) the failure to internalize the social costs of environmental degradation into the market price of a resource; (v) the failure to invest in research and development of future technologies; and (vi) limited technology transfer to, and the inefficient use of, technologies in developing countries.

To influence decision-making we have to understand the underlying causes of environmental change and the process of decision-making. Although sound science is necessary for informed public policy and decision-making, it is not sufficient. We have to identify the problem, identify what the policy choices are, implement those policy choices and then monitor and evaluate the effects of those policy choices. Furthermore, we must recognize that decision-making processes are highly value-laden, combining political and technocratic elements, that they operate at a range of spatial scales from the village to the global level, and that, to have any chance of being effective, they must be transparent and participatory, involving all relevant stakeholders (Millennium Ecosystem Assessment 2003).

There is solid evidence that key decision-makers, including governments, the private sector and the general public, are influenced in their decisions by sound, solid scientific knowledge. Developing sound scientific knowledge requires national and internationally coordinated public and private sector research programmes, combining local indigenous knowledge with institutional knowledge where appropriate, and the free and open exchange of information. This knowledge then needs to be placed in an appropriate format for decision-making. Over the last 20 years or so the role of national and international scientific assessments has grown. I will now elaborate on how national and international scientific assessments can raise awareness and prompt informed action by all stakeholders, and how they have influenced policy decision-making on a range of contentious local, regional and even global scale environmental issues.

Scientific assessments that have influenced, to varying degrees, national and international decision-making have addressed issues including long-range acid deposition, stratospheric ozone depletion, climate change, loss of biodiversity and large dams.

For a scientific assessment to be useful, it has to have certain characteristics:

- it must be demand driven, and involve experts from all relevant stakeholder groups in the scoping, preparation, peer-review and outreach/communication;
- the process must be open, transparent, representative and legitimate;
- the process should incorporate institutional as well as local and indigenous knowledge whenever appropriate;
- the results and analyses need to be technically accurate;
- the results and analyses need to be policy-relevant but not policy prescriptive—providing options, not recommendations;
- plausible scenarios of the future should be relevant for policy-formulation over a range of spatial scales from local to regional and global;
- the conclusions must be evidence-based and not value-laden, i.e. they must be devoid of ideological concepts and value systems (however, it should be recognized that the assessment conclusions will be used within in a range of value systems);
- it must cover risk assessment, management and communication; and
- it must present different points of view, and whenever possible quantify the uncertainties involved.

In order for scientific assessments to impact the national government policy-making process, they need to involve and reach out to all key decision-makers within government. These include the finance, energy, transportation, agriculture and forestry ministries, not just the environment ministries, which are often one of the least powerful ministries. Obviously, we need to work with environmental ministries, but if we do not engage the finance, energy, transportation, agriculture and forestry ministries, we will not be able to promote our message. It is also important to involve the private sector, especially those parts that have a direct impact on the environment; for example, mining, oil and gas pipelines, roads, agriculture and forestry sectors. Involvement of NGOs, multilateral and international organizations, foundations and, of course, the international scientific community, is also absolutely critical. It is also important to involve consumers because their choices will determine the future demand for goods and services. Within each of these stakeholder groups, champions are needed who will argue that the issues that we care about, such as biodiversity, are critical to human security, health and economic and social well-being.

Let me first discuss the issue of stratospheric ozone depletion. The international ozone assessments, which began in 1981 on a non-governmental basis, were later conducted as part of an intergovernmental process, were peer-reviewed by experts, and provided the scientific and technical basis for the Vienna Convention to Protect the Ozone Layer and the Montreal Protocol (and its subsequent amendments and adjustments) on substances that deplete the ozone layer to eliminate the production and use of ozone-depleting chlorine- and bromine-containing chemicals (UNEP 1999). A key question is why were governments willing to take a series of 'hard' decisions to eliminate the consumption and production of ozone-depleting substances? The bottom line was that there was solid scientific evidence linking human activities to ozone depletion, which in turn resulted in increased levels of ultraviolet radiation at ground level leading to an increase in the incidence of melanoma and non-melanoma skin cancer in light-skinned people (UNEP 1999). Skin cancer is an issue that the general public care about, and they demanded that action should be taken to protect them. If an increased incidence of skin cancer had not been the primary impact of ozone depletion, we might still be arguing about whether or not to ban chlorofluorocarbons (chlorine-containing substances) and halons (bromine-containing substances).

The issue of climate change is being taken seriously in nearly all countries. Based on the scientific, technical and economic conclusions of the Intergovernmental Panel of Climate Change (IPCC 2001*a*,*b*,*c*,*d*), all industrialized countries, except for the US, Australia and the Russian Federation, have ratified the Kyoto protocol (as of May 2004). While the US and Australia have stated that the Kyoto protocol is flawed and that they will not ratify it, the Russian Federation have stated that they will ratify, but have not indicated when[2]. The IPCC, which began in 1988 as an intergovernmental process, has strong expert *and* government peer-review, and has been highly influential on the policy process, not only within governments, but also within many parts of the private sector as well. For example, many multi-national companies, including British Petroleum, Shell, Dupont and Toyota argue that, based on the conclusions of the IPCC, the issue of climate change should be taken seriously by the private sector—this is the kind of impact a good scientific assessment should have.

Biodiversity assessments have not had the same profound effect so far as those for stratospheric ozone and climate change. The Global Biodiversity Assessment (Heywood & Watson 1995) was peer-reviewed by experts, and while an excellent academic document, it had almost no impact on policy formulation because it was conducted as a non-governmental exercise with inadequate government ownership. It lacked the appropriate mandate. A group of the world's best scientists decided on the scope of the assessment without asking potential users (e.g. governments, private sector or NGOs) what information was needed. There was also a second mistake—there was inadequate outreach and communication during preparation and after completion of the assessment report. Therefore, prior to starting the Millennium Ecosystem Assessment (MA) we recognized that the scope of the assessment must be based on user needs, not simply on what the scientific community believed were the important issues, and in addition, priority was placed on outreach and communication throughout the assessment process. The MA, which began in 2001, is a non-governmental process, but is closely tied to several intergovernmental processes such as the Convention on Biological Diversity (CBD), the Convention to Combat Desertification, the Convention on Migratory Species (CMS) and the Ramsar Convention on Wetlands. The MA is subject to both expert *and* government peer-review. The MA has a multi-stakeholder board of directors, which includes representatives from the scientific community, private sector, NGOs, international organizations and governments, and is responsible for approving the scope of the assessment, finalizing the selection of the authors and peer-reviewers and approving the summary for decision-makers.

The MA developed a framework that links the indirect drivers of change (e.g. demographic, economic, socio-political, scientific and technological and behavioural), to the direct drivers of change (e.g. changes in land-use and land cover, technology adaptation and use, resource use, air and water pollution, climate change, species introductions or removals, external inputs (e.g. use of fertilizers, pesticides and irrigation), harvest and resource consumption, as well as natural physical and biological drivers (e.g. volcanoes, evolution)) to biodiversity and ecosystem services and then to human well-being (Millennium Ecosystem Assessment 2003). This framework allows us to examine and understand how the indirect drivers influence the direct drivers, and how these, in turn, affect ecological goods and services, which in turn influence human well-being. Unless we understand these linkages we will not be able to communicate the importance of the conservation of biodiversity and resulting ecosystem goods and services as an important issue to governments, the private sector and the general public.

Furthermore, we need to assess what kinds of interventions can be designed and implemented to effectively conserve and sustainably use biodiversity within the framework of national economic development. Equally important is the need to monitor and quantify the impact of different types of intervention. The point I am trying to make is that while the observation and monitoring of elements of biodiversity, such as birds and butterflies, are important, we need to go much further. We need to monitor the direct drivers of change and understand how they affect biodiversity and ecosystem goods and services, and how in turn they have an impact on issues that people care about, such as livelihoods, human health, security and human well-being. Therefore, useful policy-relevant indicators have to be developed for the direct and indirect drivers, ecosystem goods and services and human well-being, with an understanding of the relationships among them.

In addition to developing policy-relevant indicators for the direct and indirect drivers, biodiversity, and ecosystem goods and services and human well-being, we need to recognize the importance to policy formulation of understanding the inertia and built-in time-lags of natural as well as socio-economic systems, possible nonlinear responses and threshold functions between drivers and impacts, uncertainties associated with different types of interventions, and the differential costs of action and inaction. Simply monitoring a species, or a single ecosystem parameter, is not enough information for us to understand the relationship between the drivers of change and a particular observation at some point in time. Specifically, we need to understand whether the species or the ecosystem being observed responds slowly or rapidly to drivers of change and why they are responding. We need to understand whether there are nonlinear responses and thresholds linking the drivers of change to the species or specific aspects of the ecosystem being observed. We also need to quantify the differential costs of action and inaction to different elements of society. Economic ministers have significant control over much of the financial government decision-making, and unless we can understand and communicate the costs of action and inaction, we will rarely be successful in getting our message across.

To illustrate what types of information are thought to be policy-relevant, I will use the example of how the MDG Task Force on Environmental Sustainability addresses a number of key environmental issues. For each environmental issue (e.g. loss of biodiversity, water quantity and quality, coastal zones, climate change, air quality and chemicals), the task force posed the following questions: (i) What is the problem (e.g. loss of biodiversity)? (ii) What is the impact of the environmental problem on the other MDG (e.g. how does the loss of biodiversity affect poverty and hunger alleviation)? (iii) What are the underlying direct and indirect drivers of change from the local to the global level (e.g. what are the major drivers of biodiversity loss globally and regionally)? (iv) What needs to happen at the local and the global level to address the environmental issue? (v) What environmental targets should be set given the MDG environmental target is qualitative rather than quantitative (e.g. what are appropriate regional and global biodiversity targets?), and given the MDGs are relatively short-term, i.e. aimed at 2015, what are appropriate goals for 2030, 2050, and beyond? (vi) What are the actions and who are the actors, i.e. who needs to do what and when (what actions are needed to conserve biodiversity and what actions are relevant for national governments, local governments, the private sector, NGOs, foundations, etc.)? and (vii) What are the costs of action and inaction? The MDG environmental task force believes that this is the type of information that is relevant to policy-makers if we want to persuade them of the importance of biodiversity and ecosystems such as forests, grasslands, coral reefs, mangroves, lakes and rivers.

Besides direct observations of change, one of the most important tools for helping to foster policy changes are plausible future scenarios. In most of the scientific assessments mentioned above (e.g. stratospheric ozone depletion, acid deposition and climate change), the use of scenarios has played an absolutely critical role in describing plausible future changes and identifying the implications of different policy choices and convincing policy-makers to take action. Scenarios are plausible futures, *not* predictions or projections of the future. The initial step is to develop a set of internally consistent storylines among the various indirect and direct drivers of change, which are then coupled to environmental models (e.g. ozone, air quality, climate or ecosystems) that link the various drivers to the probable consequences. In addition to being an invaluable tool for environmental assessments, the development of scenarios has been found to be invaluable for, *inter alia*, playing war games, projecting the prices of agricultural commodities and projecting energy demand. Multi-national companies, such as Dutch Royal Shell and Morgan Stanley, use scenarios as a basis for planning their business strategies. The goal for decision-makers is to explore plausible futures and understand the underlying factors that determine those futures so that interventions can be crafted to realize the positive outcomes and avoid the negative outcomes.

Four storylines were developed for the MA linking plausible ranges of direct and indirect drivers (i.e. different assumptions of demographic changes, economic growth, socio-political frameworks, technological and behavioural changes) to changes in biodiversity, ecological services and elements of human well-being over the next 50 years at a range of spatial scales from local to global. The MA storylines were developed in a manner similar to those developed and used by the IPCC.

IPCC projected a range of future energy demands and changes in land-use, resulting in a range of projected emissions of greenhouse gases and aerosol precursors, which were then coupled to a large number of climate models, resulting in a set of projected changes in temperature, precipitation and sea level. When the observed temperature record of the last 1000 years was coupled with the projected changes in temperature over the next 100 years it proved to be the type of information that really grabbed the attention of the policy-makers. However, the IPCC did not stop with projecting future changes in temperature and other climatic parameters, but asked the question of why governments and the general public should care about these changes. IPCC assessed: (i) the risks associated with a changing climate for water resources, agriculture, human settlements, human health and ecological systems (e.g. forests and coral reefs); (ii) the risks associated with globally averaged changes in global temperature of 1–5 °C as well as the risks associated with the increased incidences in extreme climatic events such as heat waves, floods, droughts and so forth; (iii) distributional effects, i.e. the differential economic and social effects of climate change on developing and developed countries, and different sectors; and (iv) at what stage large-scale discontinuities would occur, i.e. melting of the West Antarctic ice cap and shut-down of the ocean conveyor belt.

The use of plausible scenarios had an even bigger and more immediate impact on national and global ozone depletion policy formulation. Once the scientific community had developed a sound understanding of the chemical and dynamical processes that were causing stratospheric ozone depletion, policy-makers acted immediately, both nationally and internationally to limit the emissions of ozone-depleting substances. There was an incredible sequence of scientific advances throughout the 1980s and 1990s, with each scientific advance leading to a change in the international policy situation within no more than 24 months, and often considerably faster. The world acted because there was good scientific information, and the governments, the private sector and NGOs were working well together. But most critically, we had developed a set of plausible futures that highlighted the implications of inaction as well as the implications of different policy actions. As a consequence of the resulting national and international policy actions, the build-up of ozone-depleting chemicals in the atmosphere has been halted and even reversed, with the ozone layer expected to recover fully within the next 50 years or so.

Another use of plausible futures, i.e. scenarios, is to ask which drivers are endogenous and which drivers are exogenous at individual, local and national government levels. At each level of decision-making, we need to ask what drivers of change can be controlled. For example, in the MA, we are examining what drivers are under the control of the individual farmer, forest manager or fisher-person (i.e. endogenous drivers), and what the implications are of decisions and policies taken by others, for example, government policies (exogenous drivers). Thus, the MA assesses which drivers are endogenous and which are exogenous at each level of decision-making. It also assesses how the situation changes at different spatial and temporal scales; for example, the global population in approximately 2015 is largely exogenous to any policy decisions, national or international, whereas the global population in 2050 is clearly dependent upon national and international policy decisions.

In addition to observations, scenarios and ecosystem models, there is a wide range of tools and processes available for making, evaluating and monitoring decisions, which we need to use more in the future than we have in the past (Millennium Ecosystem Assessment 2003; IPCC 2001*c*). For example, while we need to use environmental and social impact assessments, we have to realize that these are only applicable at the project level, and there is a need to move further upstream and use sectoral and regional environmental and social assessments, which are of much greater strategic importance. We should also develop and use indicators (see below), valuation techniques and decision-analytic frameworks (DAFs). These tools can be used to assess the environmental and social implications of policies and projects and to make the best choice among the range of alternative options. Examples of DAFs include decision analysis, cost–benefit analysis, cost-effectiveness analysis, policy exercise approach and cultural prescriptive rules. DAFs can be used to assess trade-offs among different possible alternative decisions. In practical terms, an ecosystem can be used to increase agricultural production, which may result in loss of biodiversity, or we can protect an ecosystem at the loss of agricultural production options. To understand the implications of optimizing one set of ecosystem services over another is absolutely critical. In my opinion, we have not been using the full range of available tools to understand the implications of different policy-choices from the local to the global scale.

Ecosystems have both intrinsic and utilitarian value (Millennium Ecosystem Assessment 2003). While the concept of total economic value is a useful framework for assessing the utilitarian value of both the use and non-use values of ecosystem services (table 1), it is important to remind decision-makers that ecosystems have intrinsic value. Several methods are available to assess the utilitarian value of ecosystems; for example, valuation techniques can be used to assess the economic implications of changes in ecological goods and services resulting from different management decisions or from climate change mitigation and adaptation projects and policies.

The total economic value of environmental assets can be subdivided into use and non-use values. The use values can be further subdivided into direct use values (output, e.g. food or fibres that can be consumed directly), indirect use values (functional benefits such as soil formation) and option values (future direct use and indirect use values created by conserving biodiversity), while the non-use values can be subdivided into existence and bequest values (the value gained from the knowledge of the continued existence of species and ecosystems) and indirect values (which are non-economic values that cannot be put into an economic framework). We can thus create a framework for assessing the value of environmental assets with subdivisions that range from very tangible economic value (direct use) to intangible or intrinsic value. By trying to quantify all these different values (except intrinsic values which are hard or impossible to quantify) in economic terms, we can then quantify what impact a policy change or an intervention will have on the economic value provided by the ecosystem, and we can assess the economic trade-offs of different policies and interventions. This clearly requires understanding how the ecosystem, and its goods and services, will be impacted by a management intervention or policy change, and then the resulting economic implications.

Returning to the issues of indicators, it is important to develop nationally or internationally agreed indicators for biodiversity and other environmental and social aspects of sustainable development that are also consistent with, and appropriate for, national sustainable development objectives. However, we also need to ask some questions about the indicators:

(i) Are the indicators a true measure of the status of the ecosystem in that they incorporate the relevant time lag between a change in the driver and the response of the ecosystem, given that we know that ecosystems respond differentially to a change in a driver, for example, coral reefs respond rapidly (weeks to months) to sea-surface temperature changes, whereas old-growth forests respond much more slowly (decades to centuries) to a change in temperature?

(ii) Do we need quantitative indicators along the full-driver-pressure-state-impact-response framework, or should we resort to using the simpler pressure-state-response framework (Millennium Ecosystem Assessment 2003)?
(iii) Is a 30-year record of species populations really meaningful when there may be long-term trends in populations that have not been taken into account?
(iv) Have we thought through how the issues of inertia and time lags, nonlinear responses and threshold functions, and complex feedback loops and synergistic effects will affect the choice of meaningful indicators?

These questions suggest that the role of 'integrated' models is going to be absolutely essential in interpreting observations. We need models that link the drivers of change to the response of ecosystems and their services, and ultimately to human well-being. Such models will not only help us to better understand how ecosystems respond to changes in the drivers, but they will also allow us to quantify the differential costs and trade-offs of various policies and interventions, which is the type of information that is needed to influence policy-makers to make informed decisions, which are beneficial to biodiversity and ecosystem functioning.

Finally, let me comment on the biodiversity target to 'significantly reduce the rate of biodiversity loss by 2010'. Obviously, a key issue is interpreting the word 'significant'. However, the spirit of this goal is unlikely to be obtainable in most countries and regions of the world, especially in developing countries, simply because the direct drivers that impact on biodiversity and ecosystems are still increasing and are projected to continue to increase over the next several years; for example, changes in land-use and land cover, the demand for biological resources, air and water pollution, introductions of non-native species and climate change. In most developing countries these drivers of change show no signs of abating. They could be decreased with major national policy interventions, but any business-as-usual scenario will not allow us to achieve the 2010 target. However, I view the 2010 target as an important 'stretch' target, but in reality it needs to be associated with a longer and more realistic time-frame. Nevertheless, the 2010 target should be adopted as a challenge to ourselves, the scientific community, to convince decision-makers and the general public that biodiversity matters, which to date we have failed to do. Simply discussing species loss will not be enough—we must emphasize the implications of biodiversity loss for the ecosystem services and human well-being (table 1). Therefore, we must address key decision-makers in the finance, energy, transportation, agriculture and forestry ministries, and must involve the private sector and civil society. In addition, we must learn to communicate better and cultivate the media as our friend.

The challenge of protecting the world's precious biodiversity is immense, but we can succeed if we make a compelling case.

ENDNOTES

[1]This paper is based extensively on the peer-reviewed comprehensive reports from the Intergovernmental Panel on Climate Change (IPCC), the international ozone assessments, the Global Biodiversity Assessment, the Convention on Biological Diversity Report on Biological Diversity and Climate Change, the Millennium Ecosystem Assessment Conceptual Framework, and Protecting Our Planet Securing Our Future.

[2]The Russian Federation ratified the Kyoto protocol in November 2004.

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