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The 2010 challenge: data availability, information needs and extraterrestrial insights

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At the 2002 Johannesburg World Summit on Sustainable Development, 190 countries endorsed a commitment to achieve, by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national levels. A wide range of approaches is available to the monitoring of progress towards this objective. The strengths and weaknesses of many of these approaches are considered, with special attention being given to the proposed and existing indicators described in the other papers in this issue. Recommendations are made about the development of indicators. Most existing and proposed indicators use data collected for other purposes, which may be unrepresentative. In the short term, much remains to be done in expanding the databases and improving the statistical techniques that underpin these indicators to minimize potential biases. In the longer term, indicators based on unrepresentative data should be replaced with equivalents based on carefully designed sampling programmes. Many proposed and existing indicators do not connect clearly with human welfare and they are unlikely to engage the interest of governments, businesses and the public until they do so. The extent to which the indicators already proposed by parties to the Convention on Biological Diversity are sufficient is explored by reference to the advice an imaginary scientific consultant from another planet might give. This exercise reveals that the range of taxa and biomes covered by existing indicators is incomplete compared with the knowledge we need to protect our interests. More fundamentally, our understanding of the mechanisms linking together the status of biodiversity, Earth system processes, human decisions and actions, and ecosystem services impacting human welfare is still too crude to allow us to infer reliably that actions taken to conserve biodiversity and protect ecosystem services are well chosen and effectively implemented. The involvement of social and Earth system scientists, as well as biologists, in collaborative research programmes to build and parameterize models of the Earth system to elucidate these mechanisms is a high priority.

Keywords: 2010 target, biodiversity loss, monitoring, indicator, wild nature

1. THE CONTEXT

The natural world is declining fast. Current rates of species extinction are at least three orders of magnitude above average, so-called background rates in the fossil record, and are set to increase (Pimm *et al.* 1995). Around one-fifth of all extant species of mammals, birds, amphibians, conifers and cycads (the only groups whose conservation status has been comprehensively assessed) are at appreciable risk of global extinction within the next hundred years (Baillie *et al.* 2004). Other measures of the rate of loss of wild nature (such as population decline or habitat loss) far exceed that for species extinction. More than half of all natural habitat on agriculturally useable land has already been cleared for cropland or permanent pasture, and much of the rest has been altered by temporary grazing (FAOSTAT 2001; Groombridge & Jenkins 2002; Green *et al.* in press). At sea, three-quarters of harvested fish populations monitored by the FAO are already overexploited, or will become so without stringent management intervention (FAO 2000). Specific losses are often even more severe: Caribbean turtle numbers have declined by over 99.9% since the arrival of Columbus (Jackson 1997), Australian dugong populations and Chesapeake Bay oyster harvests by over 98% in the past century (Jackson 2001; Jackson *et al.* 2001), and shark numbers in the northwest Atlantic by over 75% in the last 15 years alone (Baum *et al.* 2003).

These losses have serious implications for our own species. Humanity depends on wild nature, not just for

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harvested goods such as fishes, timber and medicinal plants, but for the provision of a broad array of ecosystem services, ranging from climate regulation, storm protection and carbon storage though to the maintenance of aesthetic, cultural and spiritual values (Costanza *et al.* 1997; Daily 1997; Millennium Ecosystem Assessment 2003; Turner *et al.* 2003). Limitations to economic valuation techniques, inequalities in power, short-term viewpoints and market distortions mean that the ongoing conversion of natural habitats and the depletion of free-ranging populations typically remain profitable for private decision-makers. However, when examined through a more inclusive and long-term lens, it becomes clear that the continued erosion of wild nature can result in substantial net costs to society as a whole (Balmford *et al.* 2002; Turner *et al.* 2003). Recent illustrations include the greater than $2 billion bill for income support and retraining following the loss of tens of thousands of jobs when the Newfoundland cod fishery collapsed through over-exploitation (Commission for Environmental Cooperation 2001); and the $4.5 billion estimated cost of lost industrial production, lost tourism, and illness owing to the burning in 1997/98 of 3 million km^2 of Indonesia's forests (Glover & Jessup 1999). A major, four-year review of such linkages—the Millennium Ecosystem Assessment (MA)—is now underway (Reid & Mace 2003), and is due to report in early 2005.

Triggered by this emerging appreciation of the impact of biodiversity decline on human well-being, 123 Ministers at the Sixth Conference of the Parties of the Convention on Biological Diversity (CBD) in April 2002 committed themselves 'to achieve, by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on Earth' (United Nations Environment Programme 2002). This target was endorsed by the leaders of the 190 countries at the 2002 Johannesburg World Summit on Sustainable Development, and has since been adopted formally by the parties to the CBD. Similar (or indeed more ambitious) targets have been adopted at regional levels, with the European Union Council, for example, agreeing in 2001 'that biodiversity decline should be halted … by 2010' (European Council 2001).

These agreements represent an unprecedented opportunity for conservation, but also a real challenge for conservation science. Thus far, we have not even recognized the existence of the great majority of the other species with whom we share our planet, let alone obtained data on trends in their status, and our understanding of how these organisms interact with each other and with geophysical and geochemical processes to contribute to human well-being is rudimentary at best. Given the scale of our ignorance, how will we know whether the 2010 targets are being met? What information is already available, and is it sufficiently relevant, sensitive, unbiased and long-running to yield robust estimates of changes in the rate of loss of biodiversity by 2010? Do we have the empirical data or theoretical understanding to help policy-makers identify those interventions best capable of delivering the targets?

Efforts to develop indicators for the 2010 target have progressed on a number of fronts, but most importantly through the work of the CBD. Carrying forward the recommendations of its Subsidiary Body on Scientific, Technical and Technological Advice, the CBD's seventh Conference of the Parties (COP7) agreed in February 2004 to test a limited set of indicators of progress in seven focal areas (UNEP 2004): reducing the rate of loss of the components of biodiversity; promoting its sustainable use; addressing the major threats it faces; maintaining ecosystem integrity; protecting traditional knowledge; ensuring the fair and equitable sharing of benefits arising from the use of genetic resources; and mobilizing financial and technical resources for implementing the CBD (table 1). At present there are 8 indicators identified for immediate testing and a further 10 under development.

However, nearly all of these indicators rely on existing datasets. Making the best use of immediately available data is obviously a sensible first step, but is it enough? In this context, it is worth nothing that the Heinz Center has proposed no fewer than 103 indicators for taking the pulse of US ecosystems, of which full data are as yet available for only 33 (Heinz Center 2002). Do we likewise need additional data and additional indicators to measure progress against the 2010 target? If so, what attributes should these data and the indicators derived from them have? What further analysis, interpretation and modelling are needed? A useful device is to consider how an external audit of the Earth might be planned by a creature from another planet.

2. THE EXTRATERRESTRIAL CONSULTANT

Suppose that a disinterested Martian scientist heard about the 2010 target and offered its services as a consultant to advise our species on how to set up an appropriate monitoring system. The Martian might begin by asking us why we are concerned about the loss of nature and what our purpose is in monitoring it.

Representatives of our species would presumably reply that they are worried about the extent to which their actions are causing the loss of things derived from biodiversity, not only as they affect their own interests as individuals, but also as they affect the interests of other people with no power or formal representation, such as children, future generations, and those with little political or economic influence. People might also say that they are ethically disquieted about the destruction they are inflicting on other species, including those that they do not think of as having any value. The answer about the purpose of the monitoring would be that it is to quantify the loss of wild nature, while establishing the extent to which actions taken to reduce that loss are being successful.

Before advising on the design of the monitoring programme, the Martian would ask for more information on our understanding of the nature, origins, magnitude and distribution of the benefits that we derive from biodiversity. It would immediately

Table 1. The CBD framework for monitoring progress against the 2010 target, showing the 7 focal areas, 8 indicators identified for immediate testing, and 10 indicators under development.

focal area	indicators for immediate testing	indicators under development
components of biological diversity	forest area abundance and distribution of selected species coverage of protected areas	status of threatened species genetic diversity of domesticated animals, cultivated plants and fish species of major socioeconomic importance
sustainable use		area of forest, agricultural and aquaculture ecosystems under sustainable management proportion of products derived from sustainable sources
threats to biodiversity	nitrogen deposition	numbers and cost of alien invasions
ecosystem integrity and ecosystem goods and services	Marine Trophic Index water quality in aquatic ecosystems	Freshwater Trophic Index connectivity and fragmentation of ecosystems incidence of human-induced ecosystem failure health and well-being of people living in biodiversity-dependent communities biodiversity use in food and medicine
traditional knowledge, innovations and practices	linguistic diversity and numbers of speakers of indigenous languages	
access and benefit-sharing		
resource transfers	official development assistance provided in support of the CBD	

be obvious that the benefits are diverse. They include provisioning benefits, in particular food, fibres, water, pharmaceuticals and other goods obtained from wild ecosystems; regulating benefits, such as controls exerted by ecosystems on climate, disease, fire and flood; supporting benefits, such as nutrient cycling and the pollination of crops; and cultural benefits derived from the appreciation and enjoyment of nature. Some of these benefits are spread widely across many people, while others are enjoyed only by particular groups. It would also be evident that many benefits involve long-distance connections, so that the beneficiaries may not live near the resource providing the benefit. A marine fishery may depend on the existence of intertidal habitats for young fishes hundreds of kilometres away, and the food and financial benefits it provides may accrue to people living hundreds or thousands of kilometres away. The Martian would conclude that, partly as a result of this diversity and complexity, the benefits derived from biodiversity are large but mostly not well quantified, and that our understanding of the mechanisms linking the delivery of these benefits to the state of ecosystems, the abundance of their component species, and internal and external drivers of change, is crude at best.

Arguing from the viewpoint that it is unwise to discard parts of a mechanism whose function and importance you do not understand, the Martian would advise that it would be unsafe to focus monitoring exclusively on a few aspects of biodiversity that we perceive to be delivering many benefits (though these should certainly be covered). Measurements should instead be made of a wide range of attributes of wild nature, including (i) the population size and risk of extinction of species, (ii) the extent and condition of habitats and (iii) the rate of delivery of benefits. In addition, the Martian would advise that, because one purpose of the monitoring is to assess whether action to achieve the target is succeeding, measurements should also be made of (iv) drivers that cause biodiversity loss, such as habitat conversion and over-exploitation of wild species; and of (v) activities undertaken to conserve biodiversity, such as protected areas (PAs) and programmes for sustainable resource use. In many cases, measurement would concentrate on unconverted habitats, free-ranging populations, or the services they provide, but in more transformed parts of the planet wild species living on farmland or even races of domesticated species could be legitimate subjects for monitoring.

Having suggested what kinds of attributes ought to be measured, the Martian would give some guidance on how to carry out the measurements. The advice would be that the methods chosen should be practical given the time and resources available, and accurate and precise enough for the purpose. Answers are required quickly and resources are limited. Therefore, sampling, rather than measuring every population or the total extent of every habitat, would be recommended in most cases. If estimates based upon samples are to be accurate, the sample of species or locations must be representative of the whole—geographically, taxonomically, across habitat types, and across levels of threat or degradation. The precision of the estimates will be driven by the size and stratification of the sample and should be decided based on how the results will be used for decision-making and the cost of each sample; it might be sensible to direct disproportionate sampling effort towards components likely to be of most importance in terms of benefit delivery, those that are richest in biodiversity, and those that are changing fastest. Composite indicators derived from combined data from many areas or species should be based on data that can be disaggregated to examine their components and recombined into different groupings. Measurements should be carried out in a standardized way that can be repeated comparably later and by other people, and the assumptions and uncertainties in measurement protocols must be made explicit. Measurements should be repeated on several occasions to measure trends over time. The CBD target calls for a reduction in the rate of biodiversity loss, which would require us to have a minimum of three measurements by 2010. However, if short-term fluctuations occur or the measurements are imprecise, many more sampling occasions may be needed. The Martian would recommend pilot studies and inputs to programme design by statisticians to optimize the estimation of trends.

The Martian would also argue that because people do not yet know enough about their planet and its biota, the monitoring system must be adaptive and capable of shedding light on how management actions can best reduce the loss of biodiversity. Monitoring must therefore be based around a set of competing provisional models of the system, each of which makes explicit the linkages between its components and identifies the levers that decision-makers can use to deliver desired changes. Each model can be used to make predictions about the consequences of different courses of action. Monitoring should be designed to reveal whether or not the expected outcomes actually happen. Several plausible (and some not so plausible) variants of the model should exist and the monitoring results should be compared with the predictions of all of them. The models should compete to satisfy our demands for understanding and utility. The Martian would note the similarity of this process to one of our species' great triumphs of understanding, the theory of evolution by natural selection.

Who should fund this programme? The Martian would suggest it should perhaps be those who would derive most benefit from it. If the programme helps protect biodiversity then many species would benefit. But among the human species there seems to be a constant tension between the subspecies who extract resources from the environment and the subspecies trying to protect and monitor it. These interactions frequently lead to punitive retrospective legal cases which seem mainly to benefit a third, largely parasitic subspecies of humans. Surely it might be better if the monitoring could be done as some form of collaboration between the extractive and the protective subspecies. The extractive group seems to have significant resources to devote to the task and much to benefit from knowing the current and future impact of their activities. The broader alliances that might develop between these two groups might even allow them to modify or overrule the decisions of the largely parasitic subspecies, who currently seem to dominate the decision-making processes.

The Martian might also advise us to expect the real returns from actions and monitoring to accrue over a longer period than the next five years. Among these will be a better appreciation of what our targets should be. Merely reducing the rate of loss of biodiversity is unlikely to be what we really want. Reducing the rate of decline of the global population of a plant or animal species, for example, would delay, but not prevent, its extinction. Likewise, preventing further decline and even allowing modest recovery of a seriously depleted fish stock might not be sufficient to allow sustainable exploitation, even over the medium term. Instead, improved understanding is likely to lead away from a focus on slowing negative trends to the identification of targets for restoring important components of the Earth system to desired states different from those of recent decades.

In writing its report, the Martian supposes that all of this advice is pretty obvious, but just before leaving thinks it would be sensible to check that we are indeed collecting robust data on the biomes and taxonomic groups that include the greatest variety of our fellow life-forms and that supply the most valuable and irreplaceable services. Disappointingly, it appears instead that we are concentrating our monitoring efforts on species which most closely resemble ourselves, in places where people with the most money and spare time happen to live. In the final recommendation of its report, the Martian therefore tactfully suggests that we might want to review what, where and how we are monitoring, and what the weaknesses and gaps in our measurements and understanding are, in case there is any room for improvement.

3. THIS VOLUME

It was with this kind of thinking in mind—formalized in its report on *Measuring biodiversity for conservation* (Royal Society 2003)—that The Royal Society hosted a Scientific Discussion Meeting in July 2004 entitled *Beyond extinction rates: monitoring wild nature for the 2010 target*. Charting progress since a meeting a decade earlier on *Extinction rates* (Lawton & May 1995), the event brought scientists from non-governmental, governmental and intergovernmental organizations together with academics to discuss the global and regional monitoring of biodiversity that is already in place, its strengths and weaknesses, and where the main gaps lie. This issue of *Philosophical Transactions of The Royal Society* is a product of that meeting.

The issue is top-and-tailed by three papers on broad issues of measurement, sampling and communication. Andy Dobson begins by examining the difficulties of inferring underlying trends and their drivers from sampled data on natural systems, and discusses the potential of modelling for estimating changes in the delivery of ecosystem services. Steve Buckland and colleagues then look in greater detail at the statistical properties required of effective measures of biodiversity, especially when these are intended for detecting changes in rates of change. At the end of the issue, Bob

Watson draws on his experience from chairing international assessments of ozone depletion, climate change and biodiversity to examine what sorts of information are most likely to cause effective changes in policy and decision-making. He concludes, somewhat disturbingly in light of the content of the rest of the issue, that just quantifying losses of biodiversity will not be enough to bring about practical steps towards its conservation. To be successful, we must also understand and communicate the ways in which changes in biodiversity cause changes in human health and well-being. We must also formulate and communicate model-based scenarios for plausible futures that illustrate the possible consequences of decisions made by governments, businesses and individuals.

Sandwiched between these conceptual papers, 15 empirical studies evaluate existing global and regional measures of wild nature. They are loosely organized into four of the five attribute groupings suggested by the Martian consultant (there are no papers dedicated to monitoring the drivers that cause biodiversity loss, as these are instead discussed in the context of other measures such as forest cover and fish population sizes). In practice, several measures address more than one attribute type.

Over half of the papers deal with species-level measures. Stuart Butchart and colleagues outline progress in developing a global measure of change in species' extinction risk—the Red List Index (summarizing movements between threat categories of those few taxa whose status has been comprehensively assessed). Richard Gregory and co-workers next discuss the need, alongside the Red List index, for synthetic indicators of continuous changes in the population sizes of suites of representative species; they introduce arguably the most influential such measure to date, the UK Wild Bird Indicator (adopted by the UK government as a headline measure of sustainability), and explain the ongoing development of an equivalent Europe-wide indicator based on farmland birds.

But while some the risk of extinction of species in some of the best-studied taxa and population trends of birds in some European countries are well known, monitoring also needs to address a far broader range of species. Butchart's group propose the development of a Sampled Red List Index, designed to capture trends in extinction risk for all taxa by sampling representative species within each of them. Another approach is to collate and synthesize population trend data on as many species as possible, and try to adjust retrospectively for possible bias caused by unevenness in data coverage. Jonathan Loh and colleagues set out one attempt to do this, the Living Planet Index, and explain how, given more data, post-stratification might help to adjust for its inevitable geographical and taxonomic unrepresentativeness. A multi-taxon approach is also adopted in the paper by Mireille de Heer and co-authors, which develops an index of Pan-European trends in population sizes.

These indicators of extinction risk and population trend highlight the limited population data available for groups other than better known vertebrates. The remaining four papers in this section examine in detail the availability of population-level information on other groups. Jim Collins and Tim Halliday review the availability and limitations of data on amphibians. Jeff Hutchings and Julia Baum use fisheries data to quantify trends in marine fish population sizes and to address a series of questions about their implications for species persistence and the appropriateness of the 2010 target (such as whether slowing the rate of loss of a severely depleted population is enough). Jeremy Thomas and co-workers next document the development in the UK of population monitoring of invertebrates, especially butterflies, and consider the potential for expanding these schemes further afield. Last, Eimear Nic Lugadha and colleagues propose a research programme aimed at ensuring that the 2010 measures include information on population trends in plants. Rejecting the use of existing population data on the grounds that they are simply too unrepresentative of plants as a whole, they opt instead for the integration of bioclimatic modelling of location records from herbarium collections with current and retrospective satellite imagery to estimate temporal changes in the conservation status of a carefully selected subset of species.

Three papers then address the second set of attributes flagged by the Martian—the extent and condition of habitats. Philippe Mayaux and colleagues review recent efforts to estimate changes in the global extent of the most high profile habitat of all—tropical moist forest—and report encouraging agreement across different programmes. Their results rely largely on remote sensing. Although this approach can be very cost-effective for habitat types that are lost primarily through clearance, it is less well suited for habitats whose loss proceeds initially via degradation. Working with one such habitat, Isabelle Côté and co-authors use data on benthic cover in coral reefs to illustrate instead the power of meta-analytical techniques to quantify large-scale trends from disparate small-scale field studies. In the final paper in this section, Carmen Revenga and co-workers review data on freshwater ecosystems and conclude that, although these are both crucial to human well-being and highly threatened, information on their extent and condition consists almost entirely of a series of one-off assessments rather than ongoing and coordinated monitoring of the same attributes over time.

Global-level coverage is similarly patchy when it comes to monitoring the rate of delivery of benefits. Daniel Pauly and Reg Watson show that catch data can be used to derive a powerful measure of the changing condition of fisheries, the Marine Trophic Index (which simultaneously reflects ecosystem integrity, the impact of exploitation, and the flow of key ecosystem goods). Although the development of other measures of ecosystem services is less advanced, the paper by Albert van Jaarsveld and colleagues, summarizing the Southern African component of the MA, highlights the substantial insights into changes in the provision of a range of services that can be achieved by linking empirical data with spatially explicit modelling. One remaining gap, not considered by these papers, but central to both the CBD and the 2010 target, is information on trends in the genetic diversity of domesticated animal and plant species.

The last two empirical papers deal with responses to the loss of biodiversity. Stuart Chape and co-authors analyse trends in the global extent of PAs, discuss the importance of other measures of PA extent (such as coverage of different taxa or biomes), and introduce new methods to quantify PA effectiveness that could be used to measure trends. Last, Nigel Dudley and colleagues review progress towards monitoring the scope and effectiveness of sustainable management initiatives in the forestry and agriculture sectors. These in part document activities inside PAs (as many encourage sustainable resource use), but are even more important in tracking activities in the great majority of the landscape that lies beyond PA boundaries.

4. CROSS-CUTTING ISSUES

Several cross-cutting points emerge from this compilation of schemes that are in place or underway to measure progress against the 2010 target. First, the majority of the schemes make use of data collected for other purposes (Loh *et al.* 2005; de Heer *et al.* 2005; Collins & Halliday 2005; Hutchings & Baum 2005; Thomas *et al.* 2005; Côté *et al.* 2005; Revenga *et al.* 2005; Pauly & Watson 2005; van Jaarsveld *et al.* 2005; Dudley *et al.* 2005; and the Sampled Red List Index of Butchart *et al.* 2005). This means they are potentially unrepresentative (from the perspective of the 2010 target) in their coverage. Some areas, habitats and taxa are inevitably better documented than others, and this will lead to biased estimates of the average trend if studies of declining species, populations or habitats are more (or indeed less) likely to be carried out or reported. In such cases great care must be taken, in analysing emergent trends, to retrospectively stratify the data (by region, taxon, etc.) and to then use weighting procedures to estimate overall trends (see Buckland *et al.* 2005; Loh *et al.* 2005; Côté *et al.* 2005; Nic Lugadha *et al.* 2005 for guidelines). There is considerable scope for the development and wider implementation of improved methods (Buckland *et al.* 2005) for post-stratification, and the calculation of indicators, but indicators that depend upon incomplete existing data collected for other purposes will always be weakened by the impossibility of excluding all potential sources of bias. In other cases, data are either complete (the Red List Index of Butchart *et al.* 2005), or made up of a carefully chosen sample (Gregory *et al.* 2005; Mayaux *et al.* 2005; and the scheme proposed by Nic Lugadha *et al.* 2005). However, even in these cases, it is important to assess critically the wider representativeness of the data (e.g. what can we infer about overall extinction risks from those of mammals, birds and amphibians (Butchart *et al.* 2005), and are common farmland birds representative of farmland biodiversity as a whole (Gregory *et al.* 2005)?).

A second general point is that the schemes presented here vary widely in their stage of development. Some are already fully operational and capable of providing data to decision-makers (e.g. the Red List Index for fully assessed taxa, the Pan-European common bird indicators, the Living Planet Index, data on forest area and PA extent, and the Marine Trophic Index). Other systems (such as Côté *et al.*'s (2005) regional measures of coral cover and van Jaarsveld *et al.*'s (2005) measures of ecosystem service delivery) look promising, but now need extending globally. Others are still in the initial stages of development (the sampled Red List Index; the indices of invertebrate and plant population trends discussed by Thomas *et al.* 2005 and Nic Lugadha *et al.* 2005; and the various measures of PA effectiveness). Last, it appears that for some aspects of biodiversity—such as the integrity of freshwater ecosystems, and the genetic diversity of domesticated species—the availability of representative, repeated measures is so limited that global-level measures of trends over time are still a distant prospect.

A third, very obvious point arising from this and other syntheses (Jenkins *et al.* 2003; Royal Society 2003; Green *et al.* in press; table 1) is that there are major gaps in what we are monitoring or even planning to monitor, at the global or regional level. Unless substantial new initiatives are undertaken, we will be able to say very little by 2010 about population trends in tropical habitats, among invertebrate or fungal taxa, or about changes in the extent or condition of most habitat types besides forests and (with luck) coral reefs. Crucially, far too little is known of trends in the delivery of key ecosystem services such as the provision of clean water, protection from storms and floods, nutrient cycling, and natural pollination and pest control. We do not have schemes in place to track many important threats, such as the impact of bottom-trawling on the sea-floor, and the spread of exotic diseases. And we lack established techniques for charting progress in the effectiveness of interventions (ranging from PAs to policy changes and education programmes) aimed at reducing threats. Suggestions for plugging some of these monitoring gaps do exist (Balmford *et al.* 2005). These include the broader application of careful meta-analyses of existing though scattered data (Côté *et al.* 2005), and the extension of remote-sensing techniques to biomes such as grasslands and seagrass beds. However, their timely implementation will require a considerable gearing-up of the financial, intellectual and human resources devoted to monitoring, and the development and validation of techniques.

Fourth, there is a clear need expressed in several papers of this volume (and by the Martian consultant) to develop better models describing how the human, biological, physical and chemical components of the Earth system interact (Dobson 2005; van Jaarsveld *et al.* 2005; Watson 2005). Such models, still presently in their infancy, would improve our understanding of the mechanisms by which wild nature affects human well-being, and help identify the most effective policy levers for slowing biodiversity loss. Competing models could be tested in part using data collected during monitoring (see above). Improved models could also in turn guide data collection, might enable the estimation of trends in those attributes not yet being monitored directly, and would facilitate improved projections for policy-makers about what might happen to both nature and human well-being under a range of plausible future scenarios (Watson 2005).

A final cross-cutting point is about who is currently engaged in global and regional monitoring (Balmford *et al*. 2005). To date this is an area that has attracted far too little attention from academic scientists, who have perhaps dismissed it as being rather routine. We disagree strongly with this perception. Improving our understanding of how we are impacting our fellow creatures, and how this will in turn affect us, represents a major intellectual challenge. By addressing it, ecologists, taxonomists and statisticians can make an enormous contribution to enhancing the rigour, scope and credibility of the 2010 measures. A related point is the need for far greater interdisciplinary collaboration. Most of the monitoring schemes developed so far have been designed by biologists and deal very largely with biodiversity itself. However, many of the components and linkages which we understand least are the primary focus of other disciplines, particularly Earth systems science and the social sciences. Much greater involvement of these disciplines is essential to strengthening the relevance of the 2010 indicators to other policy sectors in general, and to human well-being and poverty alleviation in particular. Last, it is clear from the names and addresses of our authors that most global-level monitoring is conducted by white males based in the developed world. Yet biodiversity, ecosystem services, and their erosion affect everyone, and broader involvement in the issues underpinning biodiversity policy is thus essential to efforts to manage it more sustainably. Routes to widening involvement include the increased use of local calibration and ground truthing of remotely sensed data (Mayaux *et al*. 2005), the development of volunteer networks for data gathering (Bennun *et al*. in press; Roberts *et al*. in press; Thomas *et al*. 2005), and the exploration of ways in which locally collected data (e.g. on the delivery of ecosystem services) can feed up into higher-level meta-analyses (see Bennun *et al*. in press; Danielsen *et al*. in press; Roberts *et al*. in press). However, their limited capacity looks set to remain a major obstacle to progress in many developing regions (Mayaux *et al*. 2005).

5. CONCLUSIONS

This overview suggests that much good work has been done and is in progress, most notably by the non-governmental and intergovernmental sectors, and using data collected largely for other purposes. However, a great deal still needs to be done if we are to deliver robust and timely measures of progress against what is probably the most significant conservation agreement of the decade. Established indicators need to be subjected to ongoing scrutiny; promising indicators need development and expansion; new measures and models, especially those addressing ecosystem services, need to be conceived; and many new partnerships must be forged. This will not be easy, and it will not be cheap. However, we contend that it is essential, it is achievable, and it will prove less costly and more rewarding than looking for life on a lifeless planet.

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