13

Science to Policy Linkages for the Post-2010 Biodiversity Targets

Georgina M. Mace[1], *Charles Perrings*[2], *Philippe Le Prestre*[3], *Wolfgang Cramer*[4], *Sandra Díaz*[5], *Anne Larigauderie*[6], *Robert J. Scholes*[7], *and Harold A. Mooney*[8]

[1]Imperial College London, Centre for Population Biology, Ascot, UK
[2]ecoSERVICES Group, School of Life Sciences, Arizona State University, Tempe, AZ, USA
[3]Institut Hydro-Québec en environnement, développement et société, Université Laval,Québec, Canada
[4]Mediterranean Institute of Biodiversity and Ecology (IMBE), Aix-en-Provence, France
[5]Instituto Multidisciplinario de Biología Vegetal, Universidad Nacional de Córdoba, Cordoba, Argentina
[6]DIVERSITAS, Muséum National d'Histoire Naturelle, Paris, France
[7]CSIR Natural Resources and Environment, Pretoria, South Africa
[8]Department of Biology, Stanford University, Stanford, California, USA

Introduction

It is increasingly widely appreciated that biodiversity loss and ecosystem degradation jeopardize human well-being, both now and in the future. The Convention on Biological Diversity, established at the Earth Summit in 1992, took this issue firmly into its remit in 2002 when governments committed to work towards an international goal to reduce the rate of biodiversity loss by 2010 (Balmford *et al*., 2005b). The '2010 target' was agreed at the sixth session of the Conference of the Parties to the Convention on Biological Diversity (CBD) and then adopted by the broader

Biodiversity Monitoring and Conservation: Bridging the Gap between Global Commitment and Local Action, First Edition. Edited by Ben Collen, Nathalie Pettorelli, Jonathan E.M. Baillie and Sarah M. Durant.

international community at the World Summit on Sustainable Development in 2002 in the Johannesburg Plan of implementation. In 2008 the influence of the 2010 target was further enhanced when a target for 'reducing biodiversity loss' was added as a sub-target to the United Nations Millennium Development Goal 7 (MDG7b), which aims to 'ensure environmental sustainability'. The 2010 target was reflected in commitments at national and regional levels too, most notably in Brazil and Europe. It thus became an important political commitment for improved biodiversity conservation and management among almost all countries.

In October 2010, the tenth Conference of the Parties (COP10) adopted a revised strategic plan that included a new formulation of its mission, as well as 20 sub-targets. Whereas in 2002, Parties had resolved 'to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth', they have now pledged to 'take effective and urgent action *to halt* the loss of biodiversity to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication'. This new mission focuses not on results to be achieved, but on actions to be undertaken in the context of a more ambitious objective ('to halt'). The 20 individual targets associated with the five strategic goals identified, however, are themselves largely results-oriented (Table 13.1).

In this context, it is useful to return briefly to the implementation of the 2010 target in order to reflect on the challenges that lie ahead of the new ones. In order to implement such a broad and ambitious target, the CBD identified seven focal areas of particular interest to the Parties, for each of which goals, sub-targets, and indicators were agreed (see http://www.cbd.int/2010-target/focal.shtml). Datasets, measures, and indicators were developed through a collaborative partnership globally (the 2010 Biodiversity Indicators Partnership – 2010 BIP; www.twentyten.net) and within Europe (SEBI2010 – Streamlining European 2010 Biodiversity Indicators; http://ec.europa.eu/environment/nature/knowledge/eu2010_indicators/index_en.htm).

During the period from 2002 onwards, activities to publicize and implement the 2010 target in government and non-governmental organizations proceeded in parallel with growing interest from the scientific community. While the scientific focus was largely on the structure and design of the indicator set (Balmford *et al.*, 2005a; Dobson, 2005), implementation was directed at using the 2010 biodiversity target as a focus for campaigns and actions at local, national, and international level. For example, one of the most high-profile activities, Countdown 2010 (http://www.countdown2010.net), includes a network of partners each of which has committed to specific efforts to tackle the causes of biodiversity loss. It has proved to be effective at raising awareness and promoting actions with clear benefits for biodiversity, although it must be recognized that this is a campaign that aims to facilitate and coordinate action among the partners.

Table 13.1 **Twenty biodiversity targets for 2020. From http://www.cbd.int/sp/targets/**

Strategic goal	#	Target
DRIVERS *Strategic goal A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society*	1	By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably
	2	By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems
	3	By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socioeconomic conditions
	4	By 2020, at the latest, governments, business, and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits
PRESSURES *Strategic goal B. Reduce the direct pressures on biodiversity and promote sustainable use*	5	By 2020 the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced
	6	By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally, and by applying ecosystem-based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems, and the impacts of fisheries on stocks, species, and ecosystems are within safe ecological limits
	7	By 2020 areas under agriculture, aquaculture, and forestry are managed sustainably, ensuring conservation of biodiversity
	8	By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity
	9	By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment
	10	By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification, are minimized, so as to maintain their integrity and functioning

(*continued overleaf*)

Table 13.1 (*continued*)

Strategic goal	#	Target
STATE *Strategic goal C: To improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity*	11	By 2020, at least 17% of terrestrial and inland water, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative, and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascapes
	12	By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained
	13	By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socioeconomically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity
IMPACTS *Strategic goal D: Enhance the benefits to all from biodiversity and ecosystem services*	14	By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods, and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable
	15	By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification
	16	By 2015, the Nagoya protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation
RESPONSES *Strategic goal E. Enhance implementation through participatory planning, knowledge management, and capacity building*	17	By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory, and updated national biodiversity strategy and action plan
	18	By 2020, the traditional knowledge, innovations, and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels

Table 13.1 (*continued*)

Strategic goal	#	Target
	19	By 2020, knowledge, the science base, and technologies relating to biodiversity, its values, functioning, status, and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied
	20	By 2020, at the latest, mobilization of financial resources for effectively implementing the Strategic Plan 2011–2010 from all sources and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization should increase substantially from the current levels

Meanwhile, the focus of work by the scientific community was to develop robust and measurable biodiversity indicators based on the target, which could then be translated into monitoring and management systems (Green *et al.*, 2005). One view was that too little attention had been paid to the design of the indicator set with the risk that whatever the outcome in 2010, it would be hard to draw clear conclusions about whether or not the target had been met (Mace and Baillie, 2007). The opportunity to put meaningful baselines in place in practice could be missed. A key problem identified with the 2010 indicator set being implemented through the BIP was the weak relevance of many indicators to the overall target, due in part to the rushed process used to develop measures. Many measures were selected mainly because data were available but many of these also lacked baselines and scales, and most were poorly sampled. In addition to highlighting the importance of making the indicators relevant to the target and to the goals of biodiversity management, there were calls to distinguish measures of pressure, state, and response; to design and validate the measures in context; to ensure that indicators communicate effectively to relevant audiences; to decide when composite indicators would be more useful than multiple independent measures; and to maximize the cost-effectiveness of the process (Green *et al.*, 2005; Mace and Baillie, 2007).

Some of these concerns have been met in the new Strategic Plan, which is centred around five main goals that follow the D-P-S-I-R (Drivers-Pressures-State-Impacts-Responses) model, as well as 20 ‘headline targets’ (*20 for 2020*), which combine scientific and political concerns. For example, the level of each target may be political, but the type of target may have clearer scientific roots (see Table 13.1).

Given the short time between 2002 and 2010 and the breadth of the 2010 target, it is perhaps not surprising that many indicators were not developed in time to deliver clear outcomes (Walpole *et al.*, 2009). In fact, as it turned out, and despite perceived weaknesses in the measures, there was a clear consensus, at COP10, that the target had not been met (Butchart *et al.*, 2010). Several of the indicator measures were only developed at the end of the process, while many others are still under construction, so that the reporting in 2010 was necessarily limited in scope and relevance (Mace and Baillie, 2007; Walpole *et al.*, 2009). Undoubtedly this increases the risk of a loss of commitment to the overall process after 2010. At the same time, however, there is the opportunity to build on the initiative and develop robust targets and processes for the post-2010 period, and to learn lessons, especially about where there could be more profitable links between science and policy. Here we discuss how more effective multilateral biodiversity agreements might be built post-2010, including creating targets that are likely to have more impact, and enhancing the links between science and policy. In this regard, the establishment of a new intergovernmental process, the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), which the UN General Assembly formally approved in December 2010, could play a key role in the development, implementation, and measurement of the new post-2010 biodiversity targets (Larigauderie and Mooney, 2010).

Twenty targets for 2020

Understand the role of targets in international governance

The international governance of the biosphere is structured around the three 'Rio Conventions' on biodiversity, climate, and desertification, together with a large number of more specific multilateral environmental agreements. In many cases these establish broad goals only, but in some cases they also include quite specific targets for the environmental processes under consideration. The Long Range Transboundary Air Pollution Convention (LRTAP), for example, has detailed targets for the reduction of emissions of sulphur dioxide and nitrogen oxides under its eight protocols. Analyses of the effectiveness of multilateral environmental agreements have shown the kinds of targets that may be successfully negotiated, the way in which these vary with the environmental problem concerned, and the number of parties to an agreement (Sandler, 2004). The test of the effectiveness of any agreement is its capacity to support an outcome better than would occur in the absence of the agreement. To date, the multilateral environmental agreements that have been most effective in meeting their stated objectives are those that (i) involve a limited number of signatories; (ii) include commitments that have evolved through repeated renegotiation; and (iii) include effective penalties or disincentives to defect from a precisely defined set of objectives (Sandler, 2004). That is, they can only be effective if they are self-enforcing. The targets a particular agreement is able to agree upon depend on the same things that determine its effectiveness and enforceability. Barrett's analysis of the CBD (Barrett, 1994), for example, concluded that given the number of signatories, the agreement could not offer benefits that were significantly different from the non-cooperative outcome. In other words, any targets it was able to agree on could not be significantly different from the outcome in the absence of the agreement.

A later study of the Helsinki Protocol of the LRTAP, an agreement with many fewer signatories than the CBD, found that the initial abatement targets it contained were what the signatories would have expected to do in the absence of any agreement (Murdoch *et al.*, 1997). The initial targets of the Montreal Protocol of the Vienna Convention on the ozone layer were similarly close to the outcome that would have been expected in the absence of agreement. In both cases, however, while the initial targets negotiated in multilateral environmental agreements represented the non-cooperative outcome, these targets have been progressively strengthened through successive renegotiation (Sandler, 2004).

The implications of this for the post-2010 biodiversity target is that the outcome is likely to be sensitive to the process of target setting. A single target negotiated once and not revisited for a decade is likely to be a statement of what countries expect to happen in the absence of collective action. Initial targets may simply be agreed at levels that countries have already attained under current practices or were set to attain anyway, or need to have for ancillary benefits (e.g. aid, political legitimacy). A more effective approach would involve not just a single target, but a series of intermediate objectives and steps that need to be taken to implement each objective, with the target being re-evaluated on the completion of each step. After 20 years, for example, through a continuous political, scientific, and technical dialogue, the Montreal protocol on ozone-depleting substances, which has been ratified by over 190 countries and the European Union, has progressively expanded the range of substances under control, strengthened Parties' commitments (in the context of the principle of common but differentiated responsibilities), and shortened compliance deadlines. There is a robust monitoring programme that measures the atmospheric concentration of ozone-depleting substances, ozone layer thickness, and trends in production, consumption, emissions, and trade. In fact it is believed that with implementation of the Protocol's provisions the ozone layer should return to pre-1980 levels by 2050 to 2075. By contrast, most of the biodiversity protection targets still lack baseline benchmarks and the kind of regular monitoring that would permit real tracking of trends.

Most current environmental targets aim at improving generic capacities (including adoption of plans, creation of policy frameworks, conducting assessments, and setting priorities), or at reducing pressures (lowering emissions, extraction, or conversion). It is rarer to find targets that aim to reduce drivers or to achieve specific states. The new Strategic Plan has made a welcome effort in this regard, even though the drivers and state targets are couched in very broad terms and often lack specific baselines and indicators. Regional air pollution in Europe is the best-developed example of a targeting process that focuses on environmental states (in this case, levels of deposition relative to critical loads). Such targets have the advantage that they include clear links to societal health and well-being and have therefore greater political leverage.

Adjust targets as external conditions change

Most of the comments in this chapter reflect a scientific view of targets. Scientists tend to evaluate targets in relation to their scientific relevance, how measurable they are, and how those measures meet the policy goal. However, governments are often more sensitive to what it means to miss targets; whether they can become political tools in the hands of domestic or foreign critics; or whether donors may use their achievement or non-achievement to reallocate development assistance. Targets may stimulate action, in part by clarifying objectives, rallying organizations around a common goal, empowering weak bureaucracies, and giving civil society a means to judge and publicize government efforts. However, an overemphasis on formal compliance with targets may in fact detract attention from the original objectives, as when states agree to do something they are already set to achieve. Moreover, efforts to present the achievement of the target in the best light possible may lead to information being presented in a manner that weakens the overall credibility of the policy in question. Indeed, meeting or missing a target often says little about the effectiveness of actions designed to further the general goal of policy.

Many of the political disadvantages of targets stem from the fact that they are seldom framed around external conditions, yet changes in external conditions may impede the achievement of targets. For example, unforeseen climate change impacts or the domino effects of a severe financial crisis may nullify policies and programmes that would otherwise be effective. To avoid the danger of missing targets, policy-makers tend to 'shoot low' and to set targets that are achievable in all conditions. Further, regimes tend to be less effective in a context of high uncertainty regarding the state of scientific knowledge, the distribution of costs and benefits, and the nature of the national interests. Thus, learning becomes a crucial pre-condition of effectiveness and needs to be built into the structure of target-setting itself, as it is in the Montreal Protocol. It would be more effective to set targets that recognize the potential conditionality on the state of knowledge, political coalitions, interests markets, or the physical environment, and allow the process to be more adaptive to such changes.

In a way, the targets of the new strategic plan allow for this in that they do not, except in some instances (as in the land area devoted to protected areas), presume how progress will be measured. That is, they set a desirable state of affairs (whose definition can itself evolve) but allow for change in how it is to be achieved, which takes into account both the evolution of knowledge and different national circumstances. What is unclear, however, is how this learning process will be institutionalized.

Organize an iterative process involving decision-makers and the relevant research community

Developing science-based targets for socially relevant biodiversity indicators will require a much stronger link between the science and policy communities. It will also require stronger links between the social sciences (notably economics, sociology, anthropology, and political science) and the natural sciences, and should connect the targets to policy and decision-making. The key topics are likely to lie at the interface of social and environmental concerns, and can benefit from modelling approaches that help to identify alternative kinds of interventions and then identify costs, benefits, and trade-offs (Alcamo *et al.*, 2005; Hezri and Dovers, 2006; Wätzold *et al.*, 2006; Gottschalk *et al.*, 2007; Carpenter *et al.*, 2009).

Compared to other environmental agreements, the science-policy process by which the CBD develops and implements recommendations is relatively unstructured. The CBD has a regular assessment process called Global Biodiversity Outlook, which produces regular scientific syntheses on the state of biodiversity to CBD policy-makers. COP10, for example, concluded that the 2010 target had been missed based on the evidence presented in the Global Biodiversity Outlook 3 (2010). There is, however, no mechanism for the delivery of science advice to be provided through the kind of credible, legitimate, and salient process that has been successful in other areas of environmental assessment, for example the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Ecosystem Assessment (Reid and Mace, 2003, Watson, 2005). This must confound decision-making processes within the CBD since independent scientific advice is not distinguished from recommendations made to align CBD processes with the priorities of individual organizations or parties. Without independent science advice, the Parties also lose out on technical analyses showing the costs and benefits of alternative policies or targets, and therefore underpinning better decisions. As we have seen, this process can also lead to targets or policies that are either trivial or impossible to achieve in practice.

The creation of the IPBES should help develop a more consistent and well-structured link between the international policy community and science than currently exists. Once established, an IPBES will have the capacity both to undertake regular assessments of biosphere change, and to respond to requests for more rapid assessment of emerging issues of potential importance (Larigauderie and Mooney, 2010).

Set goals and targets in context

A key element of a revised set of targets will be to ensure that the global interest in local biodiversity change is properly represented to avoid biodiversity change that threatens human well-being at all levels. This includes securing the current and future supply of ecosystem services as well as meeting broader needs that society has for biodiversity. For society to move towards realizing such a goal, Parties need to adopt a small set of focused, relevant, efficient, and achievable targets. Each of these targets should have scientifically and socially appropriate outcomes and timescales, support biodiversity's role in human well-being, be linked to legislative and regulatory processes, be relevant at global scales but reflect local and national interests, and be open to accurate and efficient reporting.

Although the number of 'headline targets' has remained about the same from the first to the second Strategic Plan, the 20 targets of the post-COP10 are often much more specific, even when they may not meet all the conditions above. Biodiversity in its broadest sense matters to people in different ways. It directly underpins certain ecosystem functions and services, it contributes to aesthetic and cultural values, and it is a part of the sustainable life support system upon which all life ultimately depends. Urgent versus important priorities under each of these headings will not be the same. Choosing among them will benefit from a clear articulation about why certain choices have been made. Here we define three different categories of targets. These are not mutually exclusive, but can be used to classify targets according to their primary motivation (Perrings *et al.*, 2010b). This classification should help decision-makers to clarify priorities among competing agendas, as well as to focus the science-based management strategies appropriately (Larigauderie *et al.*, 2010; Mace *et al.*, 2010).

- *Red targets* – addressing biodiversity change that is directly harmful to people. Red targets are designed to avoid or avert urgent and unacceptable changes in biodiversity that will be damaging to people in the near term. They largely map onto the biosecurity agenda.
- *Green targets* – conserving biodiversity components valued by society for non-utilitarian purposes. Green targets will focus on long-term priorities for the conservation of biodiversity often focusing on species and habitats. They largely map onto the conservation agenda.
- *Blue targets* – understanding and governing the system. In the long term, sustainable management of the biosphere depends on knowledge of the underpinning processes and an effective system to manage it. Blue targets focus on steps in progress towards this end and map on to the long-term sustainability agenda.

Embed the targets within a continuing process

We recommend that parties to the CBD develop, based on the 20 targets for 2020 agreed upon by CBD COP10 in Nagoya, a small set of focused, relevant, efficient, and achievable targets each of which has socially relevant outcomes and timescales, supports biodiversity's role in human well-being, is linked to legislative and regulatory processes, and is open to accurate and efficient reporting (Mace *et al.*, 2010). In contrast to the first Strategic Plan, which had a fixed 8-year period for all targets and sub-targets, a continuing process has many advantages. As any one specific target is met or if it becomes irrelevant it can be replaced or reformulated (Figure 13.1). Thus, three targets (10, 16, and 17) in the revised strategic plan have a shorter timescale (2015). Targets that necessarily involve longer timescales, because the processes involved

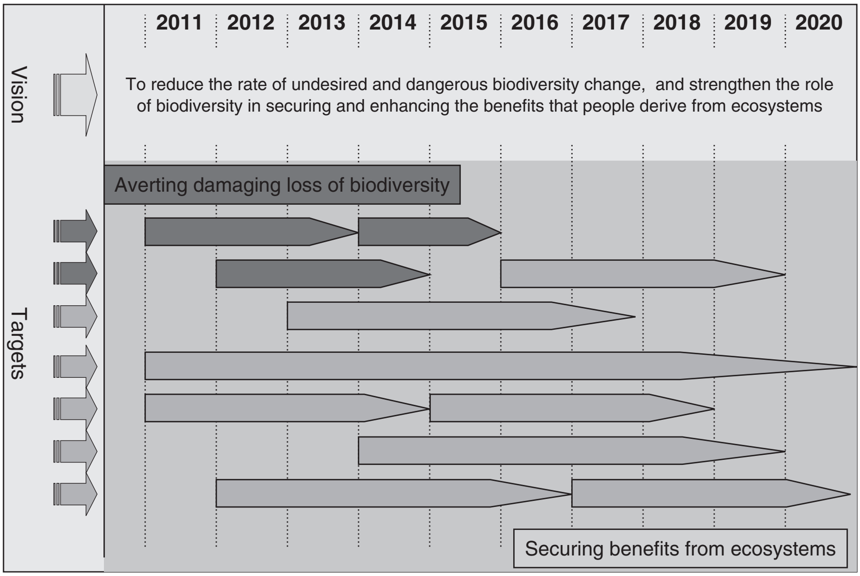

Figure 13.1 **A schematic representation for a post-2010 biodiversity target. The long-term vision outlines the ultimate goals. The vision is realized through setting specific short-term targets around averting dangerous or deleterious biodiversity loss and/or securing future benefits from ecosystems. Three different kinds of target are identified (see Mace *et al.*, 2010). Dark-grey targets (arrows 1 and 2 from top) address short-term threats to human well-being from biodiversity change. Mid-grey targets (arrows 3–5 from top) address the conditions needed to ensure long-term sustainability of ecosystem service supplies as well as the governance of biodiversity and for 'access and benefit sharing'. Light-grey targets (arrows 6 and 7 from top) address global conservation goals such as the establishment of protected areas and the prevention of species extinctions. Over the course of time it might be hoped that targets would increasingly focus on proactive measures rather than the reactive ones associated with avoiding dangerous change. Note this image is for illustrative purposes and is not intended to reflect the ideal number of targets nor their timespans.**

have longer-term dynamics, can be accommodated, and newly emerging issues and problems can be incorporated without delay.

Improve coordination in the provision and use of biodiversity data

Many biodiversity data still stem from national government sources or from national or international non-governmental organization (NGO) databases. In both cases they have often been collected for other purposes – mostly related to species conservation – leading to spatial, temporal, or taxonomic gaps in global coverage and rendering the information base less reliable for global indicators and less relevant for global assessment, monitoring, and decision-making than if data sampling were more directed or coordinated (Dobson, 2005; Lawler *et al.*, 2006; Pereira and Cooper, 2006). As a result there were important gaps in the data and measures being used for 2010, including key ecosystem processes, functions, and services and the biological taxa (often microorganisms) that underpin them; key drivers such as land-use change, disease, and climate change; or key benefits, such as human health, nutrition, and welfare (Balmford *et al.*, 2005a, 2005b; Mace and Baillie, 2007). The data are also widely dispersed, held in a wide variety of formats, and under diverse ownership with variable accessibility.

Instead of creating new datasets and generating new data-gathering activities, the processes behind emerging specific targets should interact with ongoing international efforts to devise a global biodiversity observation network and associated system (Pereira and Cooper, 2006; Scholes *et al.*, 2008). The Global Earth Observation System of Systems (GEOSS; www.earthobservations.org) is being developed under the aegis of the Group on Earth Observations (GEO) to address just such problems of international data sharing. It has recently established a Biodiversity Observation Network (GEO BON), a new global partnership to collect, manage, analyse, and report on data relating to the status of the world's biodiversity in a more coordinated and strategic way. Rather than creating new databases, the rationale for GEO BON is that it should add value to existing efforts by coordinating and linking the broad range of data-gathering and management that already exists. The links to GEO also provide new opportunities for integrating remote sensing observations with ground-based studies and surveys, and using emerging computational, imaging, and visualization tools to link diverse datasets in a way that is informative for users. The fact that GEO BON is in its early phase of development makes it timely for a discussion of how it could contribute to a new set of targets (www.earthobservations.org/geobon) (Walther *et al.*, 2007; Scholes *et al.*, 2008). The CBD has formally recognized GEO BON as a strategic partner for the implementation of its new strategic plan 2011–2020, and at COP10, tasked GEO BON with evaluating observation capabilities relevant to the 20 targets of the strategic plan.

Exploit the science base

The publication of the Millennium Ecosystem Assessment (2005) and the 2010 target both stimulated a great deal of new work on biodiversity and ecosystem services, building upon existing ecological studies undertaken in model and experimental systems (Carpenter *et al.*, 2006, 2009; Díaz *et al.*, 2006). This had the potential to support enhanced biodiversity assessment, but currently much policy development still lags far behind scientific discovery, and without the 'policy-pull' as well as the 'science-push' this is unlikely to change. As the IPCC has shown, effective interaction with policy can stimulate necessary and useful new science. We give some examples here of potentially useful scientific developments, but note that this is by no means a complete review.

1. *Biodiversity indices* developed in recent years could provide efficient ways for summarizing biodiversity condition and trends. While further work is needed to validate and fine-tune such measures and to assess their utility and efficiency, the Biodiversity Intactness Index (BII) (Scholes and Biggs, 2005; Rouget *et al.*, 2006; Nielsen *et al.*, 2007; Faith *et al.*, 2008) and the Human Appropriation of Net Primary Production (HANPP) (Imhoff *et al.*, 2004; Haberl *et al.*, 2007) are two examples of promising new approaches to the task of summarizing complex information in a way that can contribute to relevant indices (Dobson, 2005).
2. *Biodiversity processes.* Recent work has also demonstrated the important distinction between biological diversity (variability), which is important for the resilience and adaptability of ecological systems, compared to the role of composition (the presence of certain types of species) in many provisioning and some cultural and regulating services (Diaz *et al.*, 2007). Additionally, the emerging evidence is that it is trait variability and composition (called 'functional diversity') that influences both the responses and functions of species within ecosystems, and new compilations of trait values across species and ecosystems offer the potential to assess ecosystem effects that will result from ecosystem transformation or species loss (Diaz *et al.*, 2006, 2007). A communal worldwide repository of plant trait information, called TRY (www.try-db.org), has been established and already contains information on more than 60 000 species and populations. Potentially these emerging datasets could soon point to places or ecological systems where ongoing transformations or loss of biodiversity could be particularly risky or deleterious for specific ecosystem services. For example, we may be able to identify community changes that reduce decomposition rates, which limit productivity or reduce the flood regulatory role of an ecosystem. Quantifying and spatially mapping important ecological and evolutionary processes that drive the distribution and abundance of biodiversity can now explicitly be incorporated into prioritizations (see Klein *et al.*, 2009). Data and methods are now becoming available that attempt to quantify some of these processes at appropriate spatial scales (Pressey *et al.*, 2007; Mackey *et al.*, 2008), but incorporating all known major ecological and evolutionary processes in a target-driven process has not yet been done.
3. *Baselines and thresholds.* Unlike the 2010 target, which had no baselines or reference points, and where declines are treated the same regardless of the starting state of the system and the rate of change, scientific work could identify specific levels or rates of change that should not be exceeded. Several of the 2020 targets are

based around avoiding especially risky levels of exploitation (Milner-Gulland and Akcakaya, 2001); critical population sizes and structures that disproportionately increase extinction risk; and habitat areas or spatial configurations that lead to loss of key functions or local community compositions (Laurance and Williamson, 2001; Scheffer *et al.*, 2001; Laurance *et al.*, 2006; Chapin *et al.*, 2008). True thresholds such as these are far more defensible than arbitrary levels, or targets set at levels that are thought to be achievable or the likely outcome of current policies.

4. *Indicators of state changes*. Another emerging set of studies is investigating state changes and ecosystem shifts (Pace *et al.*, 1999; Scheffer and Carpenter, 2003; Chapin *et al.*, 2010). Such shifts are increasingly documented and are characterized by occurring suddenly and unpredictably in systems under change that may also be exposed to some external shock or pressure. The shifts often take ecosystems to new states and are hard to reverse, even when the shocks are removed and environmental conditions are returned to their original states (Scheffer *et al.*, 2001). New work focused on features of systems that are approaching state changes offers some hope that signals may be identified that might allow interventions to reverse the trend, at least for certain kinds of management (Biggs *et al.*, 2009). More generally, enhanced understanding of the biophysical processes involved will always contribute to more accurate predictions about how ecosystem processes and functions will respond to various kinds of environmental change – a key role for basic science.
5. *Enhanced efforts to understand and monitor new and interacting processes*. Climate change impacts on biodiversity loss, invasive species, and the emergence of novel diseases are processes that are escalating in impact as a result of interactions with a set of anthropogenic processes, of which the most important may be the growth of global trade, transport, and travel (Daszak *et al.*, 2000; McGeoch *et al.*, 2006; Mooney *et al.*, 2009). In some cases, and for some pathogen types, biodiversity loss may lead to the dominance of highly competent reservoir hosts of some human pathogens, and thus a greater disease risk in people (Perrings *et al.*, 2010a, 2010b; Thomas and Ohlemüller, 2010). Thus, conservation of biodiversity may buffer human populations from infectious disease risk. This has been shown using long-term field studies for Lyme disease, a tick-borne pathogen of humans with rodent and other reservoir hosts, and may occur for a number of other vector-borne diseases. In other cases, the link with biodiversity is more complicated. Emergent zoonoses depend on increasingly close contact between species – and especially between wildlife, domesticated livestock, and people (Perrings and Mooney, 2010).
6. *Integrated technologies for biodiversity assessment*. Emerging techniques and tools, for example in molecular genetics, biodiversity models, and remote sensing, may provide new and efficient means for biodiversity monitoring. There are relevant metrics to be developed based on genetic assessments of whole communities, genetic or phylogenetic measures of spatial and temporal turnover, and remote-sensed observations of biodiversity that contribute to global models (Ferrier *et al.*,

2000; Jennings *et al.*, 2008; Yahara *et al.*, 2010) or to assessments of ecosystem change (DeFries *et al.*, 2005).

7. *Optimization of monitoring*. New research is identifying methods to optimize the allocation of effort in monitoring or measurement of biodiversity in context. While rarely considered, there is much potential for more explicit consideration of why global biodiversity indicators are needed, what characteristics such indicators should have, and how available measures perform with respect to those characteristics compared to new measures that could be developed from scratch (Jones *et al.*, 2011; see also Chapter 15). The optimization techniques can help decision-makers determine when they have enough information to act (Gerber *et al.*, 2005). Such approaches could demonstrably improve the cost-effectiveness of indicator development (Margules and Pressey, 2000; Wilson *et al.*, 2009).
8. *Strengthening of institutions for biodiversity management and the behaviour of agents that drive biodiversity change*. Increasing attention is being paid to the impact of interactions among various levels of governance, and the performance of various multi-scalar governance models, the role of various agents beyond the state (industry, non-profit organizations, private networks), the drivers of norm dissemination and the interactions among competing norms of justice, and the relationship between perceptions, legitimacy, and behaviour (Waddel and Khagram, 2005; Lebel *et al.*, 2006). Governance targets are likely to be amongst the most important of the blue targets discussed above, and their dominance in the emerging 2020 targets is one illustration of this trend (Perrings *et al.*, 2010b).

Conclusions

The development of an efficient set of biodiversity targets and indicators for the post-2010 period is a precondition for the coordination of efforts to address the most serious environmental problem the world faces. Without agreement on global objectives embodied in feasible targets, and supported by adequate measures, national action on biosphere change will continue to be wholly driven by domestic concerns, and will continue to neglect the consequences of national actions for the global public good. We have recommended, here and elsewhere, three sets of targets: 'red' targets to address changes in biodiversity that have imminent and grave consequences for human well-being (the biosecurity agenda); 'green' targets to implement the precautionary husbanding of the world's genetic resources (the conservation agenda); and 'blue' targets to protect the long-term capacity of the system to maintain the supply of valued ecosystem services (the sustainability agenda) (see Mace *et al.*, 2010). To be effective, each set of targets should be collectively agreed, be mutually consistent, be time-bound, be sensitive to changes in external conditions, and be supported by adequate measures (indicators). The central point made in this chapter is that these targets should also be defensible in terms of both the science of biodiversity and environmental change, and the science of the interactions between human society and the biosphere.

Different areas of science are relevant for each category of target. Red targets, for example, would address short-term threats to human well-being from biodiversity change. They would typically be related to the threshold effects associated with disease outbreaks, population collapse, or irreversible changes of state in ecosystems. Accordingly, they might be expected to focus on species abundance, habitat extent, concentrations of pollutants, and the like. Blue targets, on the other hand, would address the conditions needed to ensure long-term sustainability of ecosystem service supplies. The key indicators in this case would be volume and value measures of ecosystem services, including their importance for different groups of people. Since many services are marketed, such measures include indicators that are routinely monitored for other reasons – such as production and trade statistics. New indicators will need to be developed for non-marketed ecosystem services. The blue targets may be thought of as 'sustainable use' targets. But they might also include objectives for the governance of biodiversity and for 'access and benefit sharing'. The green targets would address global conservation goals as reflected in traditional conservation mechanisms, such as protected areas. However, they would also address conservation objectives outside of protected areas, including objectives for the 'restoration' of managed or converted ecosystems and for the protection of habitat in agricultural, urban, and industrial ecosystems.

The point is that target setting for the biosecurity, conservation, and sustainability agendas requires different indicators, supported by different areas of science. The legacy of the historical separation of production, conservation, and biosecurity is an institutional divide that is reflected in the supporting science. At both national and international levels, the institutions addressing agriculture, forestry, and fisheries are currently distinct from those addressing human, animal, plant, or ecosystem health or those addressing biodiversity conservation. So too are the branches of science. Following the Millennium Assessment, however, we have come to think of the biodiversity problem as the integration of these three areas. Indeed, the focus on ecosystem services suggests the need for targets that relate to all of the benefits that people obtain from ecosystems, with targets for species abundances, habitat area, and the like being derived from that. The areas of science, assessment, and monitoring described in this chapter are the necessary ingredients for the construction of an integrated set of targets.

Acknowledgements

This chapter arose from discussions facilitated by DIVERSITAS. We thank Nathalie Pettorelli, Belinda Reyers, and David Salt for helpful comments on an earlier version.

References

Alcamo, J., van Vuuren, D., Ringler, C., *et al*. (2005) Changes in nature's balance sheet: Model-based estimates of future worldwide ecosystem services. *Ecology and Society*, 10, 19.

Balmford, A., Crane, P., Dobson, A., Green, R.E., and Mace, G.M. (2005a) The 2010 challenge: Data availability, information needs and extraterrestrial insights. *Philosophical Transactions of the Royal Society B, Biological Sciences*, 360, 221–228.

Balmford, A., Bennun, L.A., ten Brink, B., *et al*. (2005b) The Convention on Biological Diversity's 2010 target. *Science*, 307, 212–213.

Barrett, S. (1994) The biodiversity supergame. *Environmental and Resource Economics*, 4, 111–122.

Biggs, R., Carpenter, S.R., and Brock, W.A. (2009) Turning back from the brink: Detecting an impending regime shift in time to avert it. *Proceedings of the National Academy of Sciences of the USA*, 106, 826–831.

Butchart, S.H.M., Walpole, M., Collen, B., *et al*. (2010) Global biodiversity: indicators of recent declines. *Science*, 328, 1164–1168.

Carpenter, S.R., DeFries, R., Dietz, T., *et al*. (2006) Millennium Ecosystem Assessment: Research needs. *Science*, 314, 257–258.

Carpenter, S.R., Mooney, H.A., Agard, J., *et al*. (2009) Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences of the USA*, 106, 1305–1312.

Chapin, F.S., Randerson, J.T., McGuire, A.D., Foley, J.A., and Field, C.B. (2008) Changing feedbacks in the climate-biosphere system. *Frontiers in Ecology and the Environment*, 6, 313–320.

Chapin F.S. III,, Carpenter, S.R., Kofinas, G.P., *et al*. (2010) Ecosystem stewardship: sustainability strategies for a rapidly changing planet. *Trends in Ecology and Evolution*, 25, 241–249.

Daszak, P., Cunningham, A.A., and Hyatt, A.D. (2000) Wildlife ecology – emerging infectious diseases of wildlife – threats to biodiversity and human health. *Science*, 287, 443–449.

DeFries, R., Pagiola, S., Adamowicz, W.L., *et al*. (2005) Analytical approaches for assessing ecosystem condition and human well-being. In: *Global Assessment Report, Vol. 1*: *Ecosystems and Human Well-being: Current State and Trends*. Millennium Ecosystem Assessment, Island Press, Washington, DC, Chapter 2.

Díaz, S., Fargione, J., Chapin, FS III,, and Tilman, D. (2006) Biodiversity loss threatens human well-being. *PLoS Biology*, 4, 1300–1305.

Díaz, S., Lavorel, S., de Bello, F., Quetier, F., Grigulis, K., and Robson, M. (2007) Incorporating plant functional diversity effects in ecosystem service assessments. *Proceedings of the National Academy of Sciences of the USA*, 104, 20684–20689.

Dobson, A. (2005) Monitoring global rates of biodiversity change: challenges that arise in meeting the Convention on Biological Diversity (CBD) 2010 goals. *Philosophical Transactions of the Royal Society B, Biological Sciences*, 360, 229–241.

Faith, D.P., Ferrier, S., and Williams, K.J. (2008) Getting biodiversity intactness indices right: ensuring that 'biodiversity' reflects 'diversity'. *Global Change Biology*, 14, 207–217.

Ferrier, S., Pressey, R.L., and Barrett, T.W. (2000) A new predictor of the irreplaceability of areas for achieving a conservation goal, its application to real-world planning, and a research agenda for further refinement. *Biological Conservation*, 93, 303–325.

Gerber, L.R., Beger, M., McCarthy, M.A., and Possingham, H.P. (2005) A theory for optimal monitoring of marine reserves. *Ecology Letters*, 8, 829–837.

Gottschalk, T.K., Diekotter, T., Ekschmitt, K., *et al.* (2007) Impact of agricultural subsidies on biodiversity at the landscape level. *Landscape Ecology*, 22, 643–656.

Green, R.E., Balmford, A., Crane, P.R., Mace, G.M., Reynolds, J.D., and Turner, R.K. (2005) A framework for improved monitoring of biodiversity: Responses to the World Summit on Sustainable Development. *Conservation Biology*, 19, 56–65.

Haberl, H., Erb, K.H., Krausmann, F., *et al.* (2007) Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *Proceedings of the National Academy of Sciences of the USA*, 104, 12942–12945.

Hezri, A.A. and Dovers, S.R. (2006) Sustainability indicators, policy and governance: Issues for ecological economics. *Ecological Economics*, 60, 86–99.

Imhoff, M.L., Bounoua, L., Ricketts, T., Loucks, C., Harriss, R., and Lawrence, W.T. (2004) Global patterns in human consumption of net primary production. *Nature*, 429, 870–873.

Jennings, S., Melin, F., Blanchard, J.L., Forster, R.M., Dulvy, N.K., and Wilson, R.W. (2008) Global-scale predictions of community and ecosystem properties from simple ecological theory. *Proceedings of the Royal Society B, Biological Sciences*, 275, 1375–1383.

Jones, J.P.G., Collen, B., Atkinson, G., *et al.* (2011) The why, what and how of global biodiversity indicators beyond the 2010 target. *Conservation Biology*, 25, 450–457.

Klein, C., Wilson, K., Watts, M., *et al.* (2009) Incorporating ecological and evolutionary processes into continental-scale conservation planning. *Ecological Applications*, 19, 206–217.

Larigauderie, A. and Mooney, H.A. (2010) The Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services: moving a step closer to an IPCC-like mechanism for biodiversity. *Current Opinion in Environmental Sustainability*, 2, 9–14.

Larigauderie, A., Mace, G., and Mooney, H. (2010) Colour-coded targets would help clarify biodiversity priorities. *Nature*, 464, 160.

Laurance, W.F. and Williamson, G.B. (2001) Positive feedbacks among forest fragmentation, drought, and climate change in the Amazon. *Conservation Biology*, 15, 1529–1535.

Laurance, W.F., Nascimento, H.E.M., Laurance, S.G., *et al.* (2006) Rapid decay of tree-community composition in Amazonian forest fragments. *Proceedings of the National Academy of Sciences of the USA*, 103, 19010–19014.

Lawler, J.J., Aukema, J.E., Grant, J.B., *et al.* (2006) Conservation science: a 20-year report card. *Frontiers in Ecology and the Environment*, 4, 473–480.

Lebel, L., Anderies, J.M., Campbell, B., *et al.* (2006) Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*, 11, 19.

Mace, G.M. and Baillie, J.E.M. (2007) The 2010 Biodiversity Indicators: challenges for science and policy. *Conservation Biology*, 21, 1406–1413

Mace, G.M., Cramer, W., Díaz, S., *et al.* (2010) Biodiversity targets after 2010. *Current Opinion in Environmental Sustainability*, 2, 3–8.

Mackey, B.G., Berry, S.L., and Brown, T.(2008) Reconciling approaches to biogeographical regionalization: a systematic and generic framework examined with a case study of the Australian continent. *Journal of Biogeography*, 35, 213–229.

Margules, C.R. and Pressey, R.L. (2000) Systematic conservation planning. *Nature*, 405, 243–253.

McGeoch, M.A., Chown, S.L., and Kalwij, J.M. (2006) A global indicator for biological invasion. *Conservation Biology*, 20, 1635–1646.

Milner-Gulland, E.J. and Akcakaya, H.R. (2001) Sustainability indices for exploited populations. *Trends in Ecology and Evolution*, 16, 686–692.

Mooney, H.A. (2010) The ecosystem-service chain and the biological diversity crisis. *Philosophical Transactions of the Royal Society B, Biological Sciences*, 365, 31–39.

Mooney, H., Larigauderie, A., Cesario, M., *et al.* (2009) Biodiversity, climate change, and ecosystem services. *Current Opinion in Environmental Sustainability*, 1, 46–54.

Murdoch, J.C., Sandler, T., and Sargent, K. (1997) A tale of two collectives: sulphur versus nitrogen oxide emission reduction in Europe. *Economica*, 64, 281–301.

Nielsen, S.E., Bayne, E.M., Schieck, J., Herbers, J., and Boutin, S. (2007) A new method to estimate species and biodiversity intactness using empirically derived reference conditions. *Biological Conservation*, 137, 403–414.

Pace, M.L., Cole, J.J., Carpenter, S.R., and Kitchell, J.F. (1999) Trophic cascades revealed in diverse ecosystems. *Trends in Ecology and Evolution*, 14, 483–488.

Pereira, H.M. and Cooper, H.D. (2006) Towards the global monitoring of biodiversity change. *Trends in Ecology and Evolution*, 21,: 123–129.

Perrings, C. and Mooney, H.M.W. (2010) The problem of biological invasions. In: Perrings, C., Mooney, H., and Williamson, M. (eds), *Globalization and Bioinvasions: Ecology, Economics*, Management and Policy. Oxford University Press, pp. 1–18.

Perrings, C., Burgiel, S., Lonsdale, W.M., Mooney, H., and Williamson, M. (2010a) International cooperation in the solution to trade-related invasive species risks. *Annals of the New York Academy of Sciences*, 1195, 198–212.

Perrings, C., Naeem, S., Ahrestani, F., *et al.* (2010b) Ecosystem services for 2020. *Science*, 330, 323–324.

Pressey, R.L., Cabeza, M., Watts, M.E., Cowling, R.M., and Wilson, K.A. (2007) Conservation planning in a changing world. *Trends in Ecology and Evolution*, 22, 583–592.

Reid, W.V. and Mace, G.M. (2003) Taking conservation biology to new levels in environmental decision-making. *Conservation Biology*, 17, 943–945.

Rouget, M., Cowling, R.M., Vlok, J.A.N., Thompson, M., and Balmford, A. (2006) Getting the biodiversity intactness index right: the importance of habitat degradation data. *Global Change Biology*, 12, 2032–2036.

Sandler, T. (2004) *Global Collective Action*. Cambridge University Press, Cambridge.

Scheffer, M. and Carpenter, S.R. (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. *Trends in Ecology and Evolution*, 18, 648–656.

Scheffer, M., Carpenter, S., Foley, J.A., Folke, C., and Walker, B. (2001) Catastrophic shifts in ecosystems. *Nature*, 413, 591–596.

Scholes, R.J. and Biggs, R. (2005) A biodiversity intactness index. *Nature*, 434, 45–49.

Scholes, R.J., Mace, G.M., Turner, W., *et al.* (2008) Toward a global biodiversity observing system. *Science*, 321, 1044–1045.

Thomas, C. and Ohlemüller, R. (2010) Climate change and species distributions: an alien future? In: Perrings, C., Mooney, H., and Williamson, M. (eds), *Bioinvasions and Globalization: Ecology, Economics, Management, and Policy*. Oxford University Press,

Waddel, S. and Khagram, S (2005) Multi-stakeholder global networks: emerging systems for the global common good. In: Glasbergen, P., Bierman, F., and Mol, A.P.J. (eds), *Partnerships*, Governance and Sustainable Development: *Reflections on Theory and Practice*. Edward Elgar Publishing, pp. 261–287.

Walpole, M., Almond, R., Besançon, C., *et al*. (2009) Tracking progress toward the 2010 biodiversity target and beyond. *Science*, 325, 1503–1504.

Walther, B.A., Larigauderie, A., Ash, N., Geller, G.N., Jürgens, N., and Lane, M.A. (2007) Toward a global biodiversity observation network. In: *GEOSS Components – Observing Systems. The Full Picture*. Tudor Rose, Geneva, pp. 79–81.

Watson, R.T. (2005) Turning science into policy: challenges and experiences from the science-policy interface. *Philosophical Transactions of the Royal Society B, Biological Sciences*, 360, 471–477.

Wätzold, F., Drechsler, M., Armstrong, C.W., *et al*. (2006) Ecological-economic modeling for biodiversity management: Potential, pitfalls, and prospects. *Conservation Biology*, 20, 1034–1041.

Wilson, K.A., Carwardine, J., and Possingham, H.P. (2009) Setting conservation priorities. *Annals of the New York Academy of Sciences*, 1162, 237–264.

Yahara, T., Donoghue, M., Zardoya, R., Faith, D.P., and Cracraft, J. (2010) Genetic diversity assessments in the century of genome science. *Current Opinion in Environmental Sustainability*, 2, 43–49.