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Ecosystem Services, Targets, and Indicators for the Conservation and Sustainable Use of Biodiversity

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Ecosystem services, targets, and indicators for the conservation and sustainable use of biodiversity

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After the collective failure to achieve the Convention on Biological Diversity's (CBD's) 2010 target to substantially reduce biodiversity losses, the CBD adopted a plan composed of five strategic goals and 20 "SMART" (Specific, Measurable, Ambitious, Realistic, and Time-bound) targets, to be achieved by 2020. Here, an interdisciplinary group of scientists from DIVERSITAS – an international program that focuses on biodiversity science – evaluates these targets and considers the implications of an ecosystem-services-based approach for their implementation. We describe the functional differences between the targets corresponding to distinct strategic goals and identify the interdependency between targets. We then discuss the implications for supporting research and target indicators, and make several specific suggestions for target implementation.

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In 1992, 167 countries signed the Convention on Biological Diversity (CBD) to ensure the conservation and sustainable use of biodiversity and the equitable sharing of the benefits from utilizing genetic resources. The 10th Conference of the Parties (COP) of the CBD took place in October 2010 in Nagoya, Japan, to determine next steps following the failure to achieve the 2010 target of substantially reducing the loss of biodiversity (Butchart *et al.* 2010; CBD 2010a). Those steps included adoption of a strategic plan with five goals and 20 "SMART" (Specific, Measurable, Ambitious, Realistic, and Time-bound) targets, to be achieved by 2020 (CBD 2010b). In an assessment of the draft 2020 targets published before the COP, the authors of this paper argued that the targets must be not only SMART but also relevant to human well-being (Perrings *et al.* 2010a). Moreover, we asserted that, to better ensure their relevance, targets should reflect peoples' interests in the ecosystem services delivered by biodiversity and should confront the genuine tradeoffs between these interests. In this paper, we explore the implications of an ecosystem-services-based approach for implementing the targets agreed upon in the Nagoya Protocol.

> **In a nutshell:**
>
> - The Convention on Biological Diversity's 2020 biodiversity targets are imprecise but do reflect an ecosystem services approach
> - Using three categories – "red" (urgent threats), "green" (conservation and sustainable use), and "blue" (socioeconomic drivers) – we find most targets to be blue, most green targets to address sustainable use, and few red targets
> - Targets should be supported by indicators that improve precision; indicators should include estimates of the value of ecosystem services and should reflect the urgency of the threats addressed; because targets are interdependent, indicators for one target should include progress in meeting other targets

There are two main reasons why the 2010 targets were not realized. First, the CBD does relatively little to address the underlying causes of biodiversity loss (Barrett 1994, 2003), such as the increasing demand for resources that drive land-use change and the release of harmful emissions; the close integration of the global economic system that drives the dispersal of pests and pathogens; and the incentives offered by private markets. The CBD does not, for example, address the private interest in land conversion (Sachs *et al.* 2009). Second, the 2010 target itself was vague and lacked an appropriate plan of action for its achievement (Mace and Baillie 2007; Mooney and Mace 2009). To address the latter reason, the COP has approved a set of more precise targets and an action plan to achieve those targets (CBD 2010b).

We evaluate the 2020 targets using an ecosystem services approach (ie in terms of various benefits that those services offer). The Millennium Ecosystem Assessment reported, among other findings, that the interest people have in ecosystem services is highly sensitive to income, technology, gender, culture, and geographical location (MA 2005). In countries where most of the population lives in rural areas and derives their income from agricultural activities, changes in, for example, the abundance of

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agricultural pests matter "more" than in countries where agriculture accounts for one or two percentage points of the nation's gross domestic product. Similarly, the benefits that people derive from exploiting particular types of ecosystems differ depending on access rules, culture, and other factors. For instance, in some countries, the primary local interest in forests is for timber and watershed protection, whereas elsewhere it may be for the collection of fruits, herbs, and medicinal plants (Perrings and Gadgil 2003).

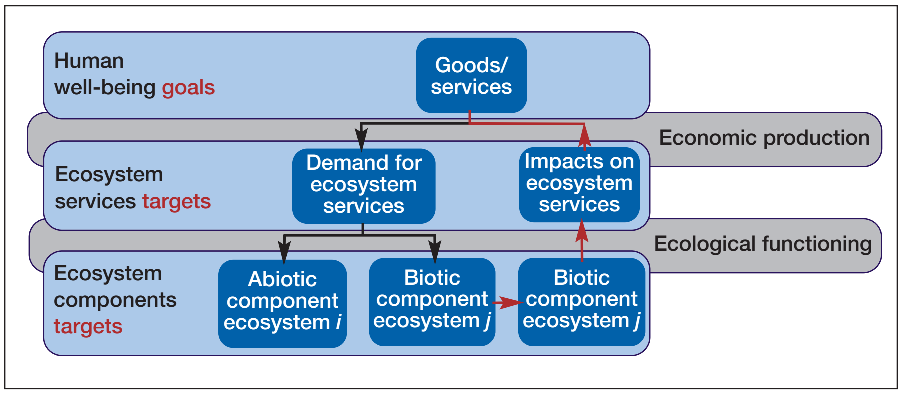

Figure 1. *The relationship between demand for ecosystem services and biodiversity conservation. Goals for human well-being lead to demand for ecosystem services and the ecosystem components (including biodiversity) needed to produce those services (black arrows), which generate feedbacks (red arrows).*

What ecosystem services people want is context-dependent. For example, the growth rate of sperm whale (*Physeter macrocephalus*) populations became important in the 18th century when spermaceti replaced tallow as the candle wax of choice (Whitehead *et al.* 1997), but declined in importance during the 19th century when mineral, vegetable, and terrestrial animal products replaced spermaceti (Davis *et al.* 1997). Similarly, the salt tolerance of rice (*Oryza sativa*) varieties gained prominence in the 20th century when irrigation led to the increasing salinity of farmlands (Maas and Hoffman 1977). More recently, the capacity of many ecosystems to maintain function has been tested by an increasingly variable climate (Smith *et al.* 2000). Simplification of ecosystems to enhance average yields of food, fuel, and fiber has reduced their capacity to operate in highly variable conditions (Elmqvist *et al.* 2003; Lobell and Field 2007).

Here, we first discuss the implications of an ecosystem services perspective for target setting and implementation. Using the color-coding scheme introduced by Mace *et al.* (2010), we then assess the interdependence of distinct targets – whether they involve synergies or tradeoffs – and evaluate the implications of these relationships for supporting indicators. Finally, we offer several specific recommendations for target implementation.

Target setting and implementation

An ecosystem services approach has four immediate implications for target setting and implementation. First, what and how much biodiversity should be targeted for conservation depends on what services are important. Second, the temporal and spatial scale of targets depends on the temporal and spatial scale of the "production" and "distribution" of ecosystem services. Third, interdependencies between ecosystem services imply that there are interdependencies between targets. Fourth, implementation of interdependent targets should be coordinated and should include all agencies involved with the management of ecosystem services (Perrings *et al.* 2010a).

Biodiversity targets should be based on the services they support

What species are conserved depends on what benefits they provide (Figure 1). For some species, these benefits are quite direct. The reasons for conserving charismatic megafauna such as tigers (*Panthera tigris*), for example, include their contribution to ecotourism; their place in history, culture, and religion; or their wider role as icons for nature conservation. For most species, however, the reasons for their conservation will be less direct. Conservation of tigers, for instance, requires conservation of the trophic levels upon which they depend (Srivastava and Vellend 2005). For these latter species, functional diversity may be more relevant than species diversity (Naeem and Wright 2003).

Biodiversity is frequently treated as being synonymous with taxonomic diversity, which is usually tabulated as the number of species observed in an ecosystem (a component of species richness). This may be because taxonomic diversity is readily measured for highly visible, well-studied groups, such as mammals, birds, amphibians, butterflies, and many plants. However, while individual species do play a major role in the provision of particular ecosystem services, the biodiversity that supports these services is generally functional diversity, not species richness. Ecosystem services generally depend on the maintenance of functional diversity. The taxonomy of species present in a given ecosystem is less relevant to the functioning of that ecosystem than the functional traits those species possess.

For this reason, the study of biodiversity and ecosystem functioning has recently focused more on functional rather than on taxonomic diversity (Figure 2), and several important studies have shown how traits can be used to understand the relationship between biodiversity and ecosystem functioning (Solan *et al.* 2004; Bunker *et al.* 2005; McIntyre *et al.* 2007; Bracken *et al.* 2008; Kattge *et al.* 2011). The biodiversity targets implied by an interest in protecting a particular ecosystem service should relate to diversity within the functional groups that support the

The Jena Experiment

Figure 2. *A grassland biodiversity experiment in Jena, Germany (www.the-jena-experiment.de), which quantifies the role of plant biodiversity for nutrient cycling and species interactions.*

service. How much diversity is needed depends on the range of environmental conditions expected. The greater the expected variation in those conditions, the greater the required diversity within functional groups will be (Elmqvist *et al.* 2003).

The sector-specific 2020 targets are consistent with this approach. For example, Target 13 requires that "the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives…is maintained". However, non-sector-specific targets (eg Targets 5, 10, 11, and 12) still have a more traditional species- or habitat-based focus.

The spatial and temporal signatures of biodiversity targets should reflect the processes involved

Climate- or trade-induced alterations in species ranges would be expected to change the spatial extent of targets relating to those species. For example, previously discrete herds of caribou (*Rangifer* spp) are expected to converge in the Arctic as suitable habitat increases as a result of global warming (Tyler 2010). The conservation of the genetic diversity of caribou populations remains a localized problem, but its spatial characteristics will change. Similarly, localized changes in the proximity between livestock and wildlife have been behind the emergence of several zoonotic diseases, such as severe acute respiratory syndrome (SARS) and the Nipah virus, but the spread of such diseases is limited by the geographical extent of trade and travel networks and the speed and frequency of the modes of transport used (Guan *et al.* 2003; Cassey *et al.* 2004; Semmens *et al.* 2004; Daszak *et al.* 2006; Kilpatrick *et al.* 2006; Daszak *et al.* 2007).

Most of the 2020 targets have a global reach and a 10-year horizon to completion. Some are restricted to particular biomes (eg Targets 6 and 10), but the only concessions made to the urgency of the conservation challenges involved were the adoption of a 5-year horizon for targets for the implementation of the Nagoya Protocol (Target 16), adoption of national biodiversity action plans (Target 17), and the protection of coral reefs (Target 10).

Interdependencies between ecosystem services should be reflected in biodiversity targets

The Millennium Ecosystem Assessment defined ecosystem services as the benefits that people obtain from the functioning of ecosystems. It distinguished between provisioning, cultural, regulating, and supporting services, and noted that management of ecosystems for different services implies different things for biodiversity. Management of ecosystems for agriculture or aquaculture, for example, intentionally eliminates many plants and animals. Similarly, management for human health and water conservation intentionally eliminates disease vectors and plants with high evapotranspiration rates, respectively. Ecosystems that are managed for a single service – such as the production of food, fuel, or fiber, or the control of particular pests or pathogens – frequently lose the services provided by the species removed in the process (Naeem *et al.* 2009).

One noteworthy advance in the 2020 targets over the 2010 targets is the recognition that the failure to address interdependencies between the services produced by particular ecosystems has social origins. The failure of markets to signal the importance of non-marketed services is the most well-known social driver of biodiversity loss. Market incentives encourage the production of commodities that can be sold (the provisioning services), and simultaneously discourage production of non-marketed ecosystem services, such as water or habitat, the benefits of which landowners are unable to capture. In some cases, the effects of market failures are exacerbated by policies that subsidize environmentally harmful market activities. One result has been the promotion of systems of payments for ecosystem services and the establishment of intellectual property rights for genetic information.

Target 3 explicitly recognizes the importance of such institutional and policy failures, requiring that "incentives, including subsidies, harmful to biodiversity are eliminated, phased out, or reformed in order to minimize or avoid negative impacts". Similarly, Target 16 requires implementation of the Nagoya Protocol on access and benefit sharing, acknowledging the importance of establishing both intellectual and other property rights. Although the inclusion of targets for the reform of social institutions is a major step forward, many targets may be difficult to achieve because of their interdependence.

Interdependent targets should be coordinated

A second dimension of interdependence is the coordination of implementation. The easiest problems to address are those that have a single agency overseeing their respective environmental impacts, but such situations are rare. It is more common for multiple agencies and communities to share responsibility for the system affected by the indirect effects of biodiversity change. In such cases, target implementation requires coordination and/or cooperation between those agencies. In cases where the dispersal of pests or pathogens is influenced by the global trade network, for example, management requires coordination with the World Trade Organization (and its instruments, the General Agreement on Tariffs and Trade and the Sanitary and Phytosanitary Agreement), the World Organisation for Animal Health, and the International Plant Protection Convention (Perrings *et al.* 2010b).

Because different agencies have distinct objectives, targets will only be viable if they are consistent with these objectives. If targets – set independently by different agencies – are inconsistent, then some will likely fail. Although the 2020 targets include global objectives for awareness (Target 1), the importance of coordination between multiple agencies, multilateral agreements, and nation states is not formally recognized within the targets.

■ Assessing the 2020 targets

Following Mace *et al.* (2010), we identify three types of target (Table 1; WebPanel 1):

(1) "red" (addressing imminent biosecurity threats);

(2) "green" (addressing threats to valued species and the ecosystem services they support); and

(3) "blue" (addressing the preconditions for reaching red and green targets).

Nearly half of the 2020 targets are classified as blue targets; that is, they are designed to address the underlying social drivers of biodiversity loss. These are associated with strategic goals A – "Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society" – and E – "Enhance the benefits to all from biodiversity and ecosystem services" – in Table 1.

Most of the blue targets address the information needed for the conservation and sustainable use of biodiversity (Targets 1, 2, 4, 7, 17, 18, 19) or the mobilization of resources for the implementation of the strategic plan of action (Target 20). These targets recognize that a precondition for national action on conservation is awareness that the loss of biodiversity affects human well-being. They seek to build understanding of the benefits that ecosystem services confer (Targets 1, 18, 19) and to develop strategies to promote the sustainable use of ecosystem services and supporting biodiversity (Targets 2, 4, 7, 17).

Information, though important, must translate into incentives to landholders and others whose actions affect biodiversity loss. Accordingly, the enabling targets also address the problem of incentives and, in particular, the effects of an absence of well-defined property rights. Target 3, for example, requires that "incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts…". This includes the incentive effects of weak property rights. For example, open or weakly regulated access to fish stocks in international waters leads to overharvesting (Costello *et al.* 2007).

Achievement of targets to eliminate perverse incentives implies the need to establish institutions or governance mechanisms that will correct for such effects. Such mechanisms fall into two broad categories: (1) mechanisms to improve the quality of price signals to ensure that private decision makers are properly informed, and (2) mechanisms to enable decision makers to track biosphere change in the same way that national income accounts track changes in other assets. The object of the first category is to ensure that those responsible take full account of the social cost of their actions, and implies the introduction of mechanisms that confront landholders with the full consequences of their actions. Such potential mechanisms include access fees, user charges, taxes, payments for ecosystem services, and the like (OECD 2004). The object of the second category is to inform public policy (Nordhaus and Kokkelenberg 1999; Nordhaus 2006).

Target 16, as an additional example, addresses implementation of the Nagoya Protocol on "Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization", but does not address incentives. The issue here is intellectual property rights with regard to the genetic material contained in endemic species within national boundaries. Once again, implementation of the Protocol may be expected to improve conservation incentives; if countries are able to realize the gains from conserving valuable species, they will have an incentive to do so.

The green and red targets are grouped around strategic goals B, C, and D: (B) "Reduce the direct pressures on biodiversity and promote sustainable use", (C) "Improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity", and (D) "Enhance the benefits to all from biodiversity and ecosystem services". Goal C is served by traditional species and habitat conservation targets, including targets for protected areas (green Target 11) and threatened species (red Target 12). The strategic goal D includes a target for the conservation of "The genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives…" (green Target 13). The latter addresses the need to ensure future security of food and other provisioning services, and acknowledges that one important reason for conserving wild living species is their potential to deliver benefits through future exploitation.

Targets within strategic goal B are divided between those connected with (a) the environmental conse-

Table 1. Color codes for the 2020 targets

Strategic goals	Targets
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...
	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...
	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.
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 are significantly reduced.
	6. By 2020, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably...
	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...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...
C. 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...systems of protected areas.
	12. By 2020, the extinction of known threatened species has been prevented...
	13. By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives...is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity...
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 wellbeing, are restored and safeguarded...
	15. By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation...
	16. By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising...is in force.
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...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...are respected…
	19. By 2020, knowledge, the science base and technologies relating to biodiversity...are improved, widely shared and...applied.
	20. By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan 2011–2020 from all sources...should increase substantially from the current levels...

Notes: Data were derived from Conference of the Parties to the Convention on Biological Diversity, 10th Meeting, Nagoya, Japan, 18–29 Oct 2010, Agenda item 4.2, Updating and revision of the strategic plan for the post-2010 period, Decision as adopted Montreal, CBD. www.cbd.int/nagoya/outcomes/.

quences of agriculture, aquaculture, fisheries, forestry, industry, and trade, and (b) other ecosystem services. The first group is intended to control the main sources of stress on biodiversity – from deforestation (Target 5); fisheries (Target 6); agriculture, aquaculture, and forestry (Target 7); pollution (Targets 8, 10); and trade (Target 9). Since sustainable agriculture, aquaculture, and forestry is a precondition for the conservation and sustainable use of biodiversity, both by reducing stress on off-farm biodiversity and by enhancing on-farm habitat, we have identified those three as enabling blue targets. The remainder are classified as either red or green, depending on the immediacy of the threats they pose. In strategic goal D, the targets covering other ecosystem services are more diffuse. Target 14 addresses "Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods, and well-being", whereas Target 15 addresses "Ecosystem resilience and the contribution of biodiversity to carbon stocks".

The questions to be raised about the targets concern the degree to which they are in conflict or are mutually reinforcing. To illustrate, consider two ecosystem types that involve different tradeoffs between ecosystem services: agroecological and marine systems.

Agroecosystems

Agroecosystems are typically managed for a single service – the production of food, fuel, or fiber. This almost always affects the supply of many other services, both in the present and in the future. Provision of food and fuel has motivated conversion of many natural grasslands, forests, wetlands, peatlands, mangroves, and even marine coastal zones, and continues to be a primary driver of land-use change in many countries. Although aggregate production of wheat, corn, rice, and soybean may be sufficient to meet the energy and protein requirements of every person on the planet, productivity varies considerably from region to region (Latham 2002). As a result, the conversion of land to agriculture continues to be the main cause of biodiversity loss in low-income countries (Jackson *et al.* 2001). Target 5 involves a halving of the rate of conversion of land – and therefore a halving of the rate of extensive growth of agriculture (growth due to the expansion of agricultural land) – over the next decade. Target 5 does not, however, address the loss of habitat due to the conversion of forests and grasslands, agriculture's impacts on nutrient loads, soil erosion, freshwater quantity and quality, the spread of human, animal, and plant diseases, and greenhouse-gas emissions.

At present, farmers have few incentives to take account of ecosystem services or biodiversity beyond domesticated plants and animals, and their pests, predators, and food sources. Nor do farmers have an incentive to consider increased nutrient loads in water bodies caused by agrochemicals, or reductions in groundwater due to lower rates of water infiltration (Pascual and Perrings 2007). The results are frequently dramatic. The southwest region of the province of Buenos Aires, Argentina, provides a notable example, where grasslands and dry forests used for cattle were transformed into croplands and eventually into desert over the past two decades as a result of the combined effects of deforestation, winds, and drought (Pezzola *et al.* 2004; Figure 3).

The incentive effects of agricultural subsidies and the sustainability of on-farm production of grain and meat are addressed by Targets 3 and 7, respectively. Targets 14 and 15, in principle, also deal with agricultural impacts on other ecosystem services, as well as with the capacity of other systems to cope with fluctuating environmental conditions. The interdependence of these targets implies that the implementation of one may depend on the implementation of others – not sequentially, as is the case with the blue and green targets, but simultaneously.

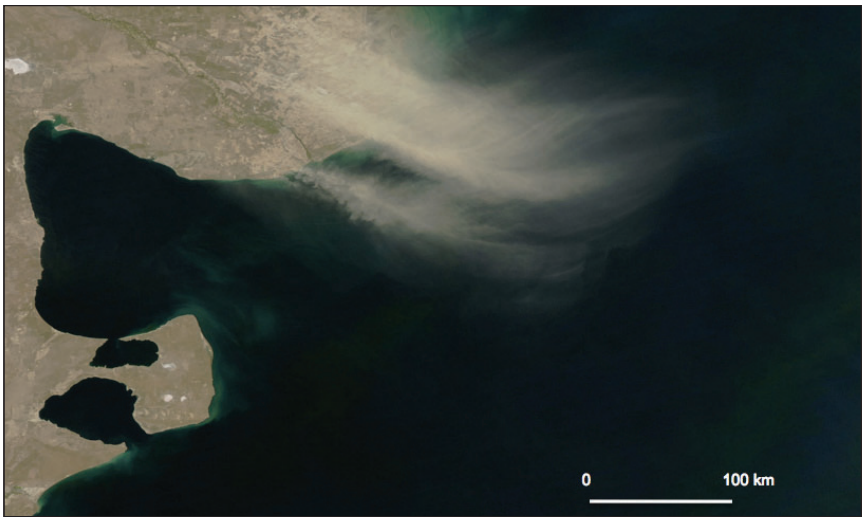

Figure 3. *Windblown soil erosion is one of the effects of desertification due to agricultural practices in the province of Buenos Aires, Argentina.*

Marine ecosystems

Marine ecosystems collectively form the largest ecosystem on Earth and yield some of the most critical ecosystem services. Although some marine ecosystem services are readily recognized, most are less well appreciated. One well-known service is the provision of food in the form of fish, and the relationship between harvested marine diversity and ecosystem services is well documented (Jackson *et al.* 2001; Worm *et al.* 2006); Target 6 addresses this most visible issue. But the oceans provide a wide range of ecosystem services that are less visible, though no less important. For example, the regulation of climate through marine biogeochemical pathways is roughly equivalent to terrestrial contributions (eg an estimated 92.2 gigatons of carbon per year [Gt C yr^{-1}] entering the ocean from the atmosphere and 90.6 Gt C yr^{-1} exiting the ocean to the atmosphere; Denman *et al.* 2007). Another important, but often overlooked, service is the production of oxygen: it is estimated that one out of every two breaths' worth of oxygen that we take is produced directly by marine phytoplankton (Behrenfeld *et al.* 2006). Marine microorganisms also degrade or purify very large amounts of waste that have been intentionally dumped into the sea for decades, such as the >10 trillion liters of domestic sewage released annually in the US alone (NRC 1993).

Marine biodiversity is affected by warming, acidification, altered upwelling and stratification patterns, and increased variability (Worm and Lotze 2009), in addition to more direct anthropogenic stresses. The Continuous Plankton Recorder Survey Program has demonstrated that major changes in the northerly movement of plankton in the North Atlantic Ocean have occurred in the past five decades – on the order of thousands of kilometers – as well as transfer of plankton from the Pacific to the Atlantic via thinning of the Arctic ice (Burkill and

Reid 2010). Polar bears (*Ursus maritimus*) and other high-latitude vertebrates, such as walruses (*Odobenus rosmarus*) and penguins (several species), are all charismatic sentinels of the effects of losses of polar sea ice (Schliebe *et al.* 2008). Populations of such organisms are expected to suffer serious declines, even potential extinctions. In all cases, changes in marine biodiversity have an impact on multiple services – some of them critical to life support. However, fishing practices have not, to date, been as strongly implicated in the loss of other marine ecosystem services as agricultural practices have been implicated in the loss of terrestrial services. So while there are targets for at least some of the non-provisioning services from marine ecosystems (eg Target 10), implementation of these is not contingent on implementation of Target 6.

Finally, although there is nothing in the strategic plan to distinguish between what we have categorized as "red" and other targets, the urgency attached to targets differs. Some stressors have the capacity to impose substantial harm on a short timescale, certainly less than 10 years, whereas others have the capacity to impose irreversible harm. Among the stressors that may impose harm in the short term are the land-use changes and trade patterns that favor the emergence of zoonotic diseases (Jones *et al.* 2008). Among the stressors that have the capacity to cause irreversible damage are those leading to the extinction of beneficial species. Targets 6, 8, and 9 are of the first type, whereas Target 12 is of the second type. We have re-colored Target 12 since the publication of Perrings *et al.* (2010a), given that some species' extinctions may cause substantial short-term damage. The most important implication of the red classification is that a red target needs to be met on a shorter timescale than blue or green targets. If a target protects some threshold, then it must do so all the time, not just by 2020.

Recommendations

What frequently drives demand for ecosystem services in both terrestrial and marine systems is the immediate interest of humans in particular species – the production of corn (*Zea mays*), the harvest of teak (*Tectona grandis*) or tuna (*Thunnus* spp), the conservation of charismatic megafauna. The degree to which management of ecosystems for a primary purpose should consider other services depends on the value of those services. Many valuable ecosystem services are still neglected, often because the beneficiaries of those services are distant in either space or time. Although designed to take account of the multiple benefits offered by biodiversity and welcomed as a major improvement over the 2010 targets, the 2020 targets are not perfect, and their implementation poses substantial challenges to both science and policy. We conclude by offering four main recommendations:

(1) Given that the 2020 targets are necessarily partial and often imprecise, they should be supported by indicators that both complete the picture and supply the needed precision. This is especially important for Targets 11 and 12, which are extremely broad-brush amalgamations of several political aims, but the recommendation applies to all targets to some degree.

(2) Because ecosystem services represent the benefits that people obtain from ecosystems (or at least the flows that are the source of benefits), the set of indicators should include estimates of the value of those services. A preliminary assessment of the value of ecosystem services (Kumar 2010) provides a baseline against which to measure changes, but this poses a real challenge to science. Estimating the value of ecosystem services requires an understanding both of the role of ecosystem services in producing things that people care about and of the tradeoffs and synergies between different ecosystem services. Accordingly, the development of indicators should be matched by supporting research on both the ecological and economic dimensions of the problem.

(3) Given differences in the urgency of achieving distinct targets, as well as differences in the irreversibility of changes in ecosystem services, indicators for implementation should have an appropriate time structure. Red targets should typically be monitored at shorter intervals than blue or green targets, and should be expected to turn over at a higher rate as some are achieved and new circumstances drive new urgencies.

(4) The interdependence between targets means that indicators for any one target should include progress in meeting other targets. For example, given that achievement of Target 7 depends on Target 3, an indicator for Target 7 would be progress toward Target 3. In general, indicators for red and green targets should include progress toward supporting blue targets. A mapping of interdependencies between targets will thus be essential for implementation.

An ecosystem services approach requires that targets – for the components of the biosphere – derive from society's long-term goals for human well-being. To that end, science's role will be to identify the biodiversity that needs to be conserved so as to deliver the services that society wants, and to provide advice on what can and cannot be achieved given the understanding of the biophysical basis for ecosystems and their functioning. Likewise, it is the role of society to set priorities for services that may or may not be mutually supportive or compatible, to identify services requiring cooperation among nation states, and to put mechanisms in place to secure that cooperation. The International Year of Biodiversity may be remarkable for the failure of the international community to meet the 2010 biodiversity targets, but it could also mark the moment that the CBD signatories make a step toward a more systematic approach to the identification of goals and the creation of action plans. As the CBD sets up its new priorities and initiates a process to define indicators for the new targets, international negotiations to establish an Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) have been concluded (Perrings *et al.* 2011). Given that it will create the capacity needed to evaluate progress toward a range of targets, IPBES can help the CBD and others to implement the 2020 targets by establishing a rational set of indicators for the management of biosphere change.

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