China's Progress toward the Significant Reduction of the Rate of Biodiversity Loss

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In 2002, parties to the Convention on Biological Diversity adopted a decision "to achieve by 2010 a significant reduction of the current rate of biodiversity loss." Comprehensive assessment of the progress toward this "significant reduction" is rare at the national level. We therefore developed national indicators and time-series data sets to evaluate whether China had made progress toward the 2010 biodiversity target, and found that considerable progress has been made: Forest resources have increased stably since 1989, the integrity of marine ecosystems has improved since 1997, water quality has remained stable, and desertified land is less extensive than it used to be as a result of various conservation initiatives. However, trends toward the loss of grasslands, threatened species, and genetic resources were not effectively checked. It is imperative that China undertake a more active and integrated strategy for biodiversity conservation to stem projected increases in wastewater discharges, nutrient loading, invasive alien species, and climate change.

Keywords: biodiversity, 2010 target, marine trophic index, Red List index, invasive alien species

Over the past few hundred years, humans have caused species extinction rates to increase 1000 times as much as the background rates that were typical over Earth's history (Pimm et al. 1995, MEA 2005). Motivated by continued biodiversity loss and its far-reaching impacts on human well-being, in April 2002 the parties to the Convention on Biological Diversity (CBD) pledged "to achieve by 2010 a significant reduction of the current rate of biodiversity loss," a target also endorsed later that year by the United Nations World Summit on Sustainable Development (Balmford et al. 2005a, Mace and Baillie 2007). Comprehensive assessment of progress toward meeting the 2010 biodiversity target is rare at the national level, however.

One way to measure progress toward the 2010 biodiversity goal is to employ indicators chosen to reflect the target (Mace and Baillie 2007). Biodiversity indicators are communication tools that summarize data on complex environmental issues and can be used to signal key information for policies or management interventions. Difficulties in identifying indicators stem largely from the complex, multidimensional nature of biodiversity (Scholes and Biggs 2005) and the lack of monitoring data. Since 2003, however, efforts to develop biodiversity indicators have been under way in the CBD and at the international level (Mace and Baillie 2007). A conference of the parties to the CBD identified 7 focal areas and 22 headline indicators for assessing progress toward the 2010 target (Balmford et al. 2005a, Mace and Baillie 2007), and the European Environment Agency is coordinating the Streamlining European 2010 Biodiversity Indicators effort, which has so far proposed 26 indicators (EEA 2007).

China is one of the Earth's megadiverse countries (China EPA 1998, Huang et al. 2002, Wu et al. 2004, Xu HG et al. 2008). Biodiversity provides significant ecosystem goods and services (Costanza et al. 1997) and generates considerable economic benefits (Balmford et al. 2002) that play an important role in ensuring the well-being of society in China (Xu HG et al. 2008). We developed national indicators on the basis of indicators identified by the CBD and the European Commission (EEA 2007) to evaluate China's progress toward the 2010 target. By developing and implementing a national biodiversity strategy and action plan (China EPA 1994, Li 1998), China has advanced considerably (table 1).

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Indicators

Many organizations now use the DPSIR (driving forces, pressure, state, impact, response) framework to structure and analyze indicator sets (Turner et al. 1998, EEA 1999, Mace and Baillie 2007). Indicators should reflect the loss of biodiversity, cover main elements of biodiversity, be sensitive to change, and be acceptable to decisionmakers and the public. Given known gaps in the information available on key aspects of biodiversity, we developed indicators on the basis of what is available (Mace and Baillie 2007). We developed national indicators for assessment of the 2010 biodiversity target addressing the state, threats (including driving forces and pressure), and response, and constructed time-series data sets to analyze the trends of these indicators (table 1).

Table 1. National indicators for assessment of the 2010 biodiversity target.

Indicator	Time period	Percentage rate of change per year (standard deviation)
Status and trends of the components of biodiversity		
Land cover		
Afforested land	2000–2005	0.02
Grassland	2000–2005	–0.08
Inland waters	2000–2005	0.07
Annual average net primary productivity	1980–2003	0.51 to 0.96
Annual net increase of growing stock, and area and growing stock of natural forest		
Net annual increment of growing stock	1989–2003	11.21 ± 8.30
Area of natural forest	1973–2003	1.02 ± 2.10
Growing stock of natural forest	1973–2003	1.34 ± 2.43
Area of desert land	1999–2004	–0.07
Marine trophic index	1997–2006	0.38 ± 0.51
Water quality in marine ecosystems	2001–2007	4.25 ± 9.07
Water quality in freshwater ecosystems	2001–2006	7.90 ± 11.27
Red List index (equal steps approach)		
Mammals	1998–2004	–2.77
Birds	1998–2004	2.43
Fish	1998–2004	–1.84
Plants	1998–2004	–2.33
Genetic diversity of domesticated animals, cultivated plants, fish species of major socioeconomic importance		?
Threats to biodiversity		
Discharge of major pollutants		
Chemical oxygen demand	1998–2007	–0.79 ± 3.95
Sulfur dioxide in waste gases	1998–2007	2.14 ± 7.49
Toxic and harmful pollutants in waste water	1998–2006	–12.24 ± 15.64
Intensity of chemical oxygen demand of key industries	1999–2006	–21.62 ± 6.72
Soot dust and industrial dust in waste gases	1998–2007	–5.16 ± 7.15
Solid wastes	1998–2007	–16.89 ± 12.62
Waste water	1998–2007	3.90 ± 2.22
Application of fertilizers and pesticide		
Application of fertilizers	1980–2005	5.48 ± 3.16
Application of pesticide	1991–2005	4.82 ± 4.64
Density of railroad and expressway		
Density of railroad	1989–2007	2.19 ± 3.27
Density of expressway	1989–2007	36.27 ± 25.44
Number of invasive alien species newly discovered every 20 years	1850–2008	11.47 ± 28.32
Impact of climate change on biodiversity		?
Response		
Proportional coverage of nature reserves	1985–2007	10.99 ± 13.82
Status of access to and benefit-sharing of genetic resources and traditional knowledge		?
Percentage of gross domestic product invested in environmental pollution control and forestry conservation	1990–2006	18.50 ± 59.34

The equal-steps approach is from Butchart and colleagues (2007).

Land cover. Land cover was classified into cultivated land, afforested land, grassland, inland waters, residential quarters, and unused land. Unused land is land not used for agriculture and construction; this includes beaches, deserts, glaciers, and rock mountains. The definitions and measurements for land cover were from Liu JY and colleagues (2003, 2005a, 2005b). Data were from the National Land Utilization Data Set, developed by the Data Center for Resources and Environmental Sciences of the Chinese Academy of Sciences for the late 1980s, mid-1990s, and 2000; and the National Land Utilization Data Set for 2005, developed by the Institute of Remote Sensing Applications, and the Institute of Geographic Sciences and Natural Resources Research, of the Chinese Academy of Sciences.

Net primary productivity. The net primary productivity (NPP) of vegetation is defined as gross primary production (organic matter produced by photosynthesis) minus plant autotrophic respiration per unit area per unit time. The NPP plays a key role in maintaining the global carbon balance. The annual average NPP of China was generated from monthly statistics simulated by the CEVSA (carbon exchange between vegetation, soil, and atmosphere), GLOPEM (the global production efficiency model), and CASA (Carnegie-Ames-Stanford approach) models (Gao and Liu 2008).

Annual net increase of growing stock, and area and growing stock of natural forest. The annual net increase of growing stock and of the area and growing stock of natural forest are indicators for the ranges and functions of forest ecosystems. Total growing stock is the aboveground volume of all living, standing trees, including trees in forests; sparse forests; scattered trees; and trees planted by the side of villages, farmhouses, and along roads and rivers (State Forestry Administration 2000). "Forest" refers to areas where the canopy density (vertical projection of tree crowns) of trees and bamboos is more than 0.2. "Sparse forest" refers to areas where canopy density is greater than or equal to 0.1 but less than 0.2. The phrase "scattered trees" refers to trees growing in bamboo forestland, shrubbery, nonstocked forestland, land suitable for growing trees, and nonforestland. According to provisions of the National Forest Inventory Program of China (State Forestry Administration 2000), the growing stock of an individual standing tree will be measured only when the tree's diameter at breast height reaches 5.0 centimeters (cm); the growing stock of forest and sparse forest is calculated according to standard measurement methods; and the growing stock of scattered trees and trees planted by the side of villages, farmhouses, and along roads and rivers is calculated on the basis of the growing stock of an individual tree. Total growing stock of sampling population in provincial and national forest inventory is estimated through a systematic sampling method. The net annual increment in growing stock is defined as the difference between the annual increment in growing stock and annual consumption. "Natural forest" refers to forest that was not planted by humans and that has a canopy density over 0.2 (State Forestry Administration 2000).

In the National Continuous Forest Inventory Program, forests of one-fifth of 31 provinces were surveyed every year, thus all provinces were surveyed in five years. The first national forest inventory was made in 1973. By the end of 2003, six national continuous forest inventories had been made. Large amounts of fixed and temporary sample plots were established, and GIS (geographic information system), remote sensing, and GPS (global positioning system) have been applied in the inventories. For instance, there were 250,000 sample plots during 1984 to 1988, and 333,000 sample plots during 1989 to 1993. Data were taken from the National Continuous Forest Inventory Program of China and from the forestry statistical yearbook (1973–2006), published by China's State Forestry Administration.

Area of desert land. An increase in the amount of desert land can indicate degradation of terrestrial ecosystems. The first, second, and third national desertification monitoring efforts took place in 1994, 1999, and 2004. In the third wave of monitoring, field surveys were conducted in 5.02 million patches, in combination with GIS, remote sensing, and GPS (State Forestry Administration 2005). Data on the distribution of desert land were obtained during the national desertification monitoring.

Marine trophic index. The marine trophic index (MTI), or mean trophic level, is the mean position in a food web that an organism occupies, and indicates the integrity of a marine ecosystem (Pauly et al. 1998, Pauly and Watson 2005). Each fish or aquatic consumer is assigned a trophic level ranging from 2.0 to 5.0 on the basis of its position in the food chain. Overfishing results in smaller and more short-lived fish in catches, leading subsquently to a decline of the MTI. Two data sets are needed to calculate the MTI: (1) catch data by taxonomic group, and (2) estimates of the trophic level for each of these groups. The Food and Agriculture Organization (FAO) of the United Nations has collected data on fishery catches by species groups (species or genus or family) from all maritime countries since 1950. The data sources for catches in China were the FAO's statistical database, FishStat (capture production for the period 1950–2006). Two steps were followed when calculating the catches in China. The first step was to use catch data for the northwestern Pacific (FAO statistical area 61), which reflects the state of China's nearshore marine ecosystems because the northwestern Pacific encompasses the Bohai, Yellow, East China, and South China Seas. The second step was to combine data on the same group from the mainland, Hong Kong, Macao, and Taiwan, because the FAO calculated catch data separately for these four regions.

The trophic levels of the catches came from the Sea Around Us Project conducted by the Fisheries Centre, University of British Columbia, and FishBase (*www.fishbase.org*). Groups and their trophic levels in coastal ecosystems of China are shown in table S1 (see the supporting material at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*).

Water quality in marine ecosystems. Water quality in marine ecosystems refers to the cleanliness index of water in the seas around China. Marine water quality index is defined as the proportion of area with grade I water × 100 + the proportion of area with grade II water × 80 + the proportion of area with grade III water × 60 + the proportion of area with grade IV water × 40 + the proportion of area with grade V water × 20. Data were from the China Environment Status Communique for 2000–2007 (published by the China Environmental Protection Agency [EPA]) and the China Marine Environmental Quality Communique (published by the State Oceanic Administration in 2007).

Water quality in freshwater ecosystems. We took into account the largest seven bodies of inland waters—the Yangtze, Yellow, Pearl, Songhua, Huaihe, Haihe, and Liaohe Rivers. Water quality in freshwater ecosystems is defined as the proportion of the monitored section with grade I water × 100 + the proportion of grade II water × 80 + the proportion of grade III water × 60 + the proportion of grade IV water × 40 + the proportion of grade V water × 20. Data came from the China Environment Status Communique for 2001–2006 (promulgated by the China EPA); the data are available at *www.sepa.gov.cn*.

Red List index. The IUCN (International Union for Conservation of Nature) Red List of Threatened Species is widely recognized as the authoritative listing of species that are globally at risk of extinction (Lamoreux et al. 2003). Several categories describe the degree of extinction risk: extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, and least concern; the category "data deficient" is assigned to species whose status cannot be determined because data are inadequate. The Red List index (RLI) is a measure of the relative rate at which a particular group of species (birds, say) change in overall threat status (Lamoreux et al. 2003, Butchart et al. 2004, 2005). It is calculated by determining how many species in each Red List category change categories between assessments as a result of genuine improvement or deterioration in their status (Butchart et al. 2004, 2005). The RLI can therefore be calculated for any group of species that has been assessed at least twice.

We calculated the RLI for China using the method described in Butchart and colleagues (2007). Animal data came from the *China Red Data Book of Endangered Animals* (Wang 1998) and the *China Species Red List,* published in 2004 (Wang and Xie 2004); plant data came from the IUCN Red List in 1998 (*www.iucnredlist.org/*) and the 2004 *China Species Red List.* Species are listed in the *China Red Data Book of Endangered Animals* in accordance with IUCN Red List categories published in the 1960s, with modifications to suit specific conditions in China—in particular, a "rare" category was added to describe species with small populations whose rarity is not human induced (Wang 1998). Therefore, in our analysis the "rare" category corresponds to "near threatened" on the IUCN Red List. Our "indeterminate" category ("data deficient" is the IUCN term) refers to species that are suspected of being endangered or vulnerable, but data are insufficient to unequivocally determine their status (Wang 1998); we did not include species with indeterminate status in the calculation of the RLI. In the *China Species Red List,* species were categorized in accordance with the IUCN Red List categories and criteria (version 3.1 in 2001). The categories of threat status of the two Red List assessments conducted in China are shown in table S2 in the supporting material at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf.* The IUCN Red List in 1998 covered 419 species of plants, and those plants endemic to China were used to compare plants covered by the *China Species Red List* to calculate the RLI for plants.

The following species were excluded from our calculation of RLI value: (a) species that were listed as extinct in the last assessment; (b) species shown as "not evaluated," "data deficient," or "not applicable" in any of the previous assessments; (c) previously assessed species that were no longer being assessed; and (d) newly added species for which there was no evidence of change in threat status. Data for amphibians and reptiles were insufficient for the calculation of RLI values.

Genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance. Genetic diversity is important for maintaining the fitness and adaptability of species and agricultural productivity (CBD 2006). Many valuable traditional breeds have been lost as a result of the intensification of agricultural systems and large-scale dissemination of single new breeds. However, great gaps exist in the measure of the status and trends of genetic diversity. We used two cases, rice and corn, to illustrate the trend of this indicator.

Discharge of major pollutants. Emissions of major pollutants comprise the annual discharge of sewage, exhaust gas, and solid waste, which pose threats to biodiversity through chemical oxygen demand (the amount of oxygen required to decompose organic matter in water), sulfur dioxide, soot dust and industrial dust in waste gas, toxic and harmful pollutants (mercury, cadmium, hexavalent chromium, plumbum [lead], arsenic) in wastewater, chemical oxygen demand by key industries, and solid wastes. Data were from the *Report on the Environment in China* (1998–2007), published by the China EPA.

Application of fertilizers and pesticide. Change in the application of fertilizers and pesticide reflects the impact of agricultural activities on agricultural biodiversity. High nitrogen input and nitrogen imbalance often pose major threats to biodiversity. Data were from the *China Agricultural Statistical Report* (2002–2006), published by the Ministry of Agriculture.

Density of railroad and expressway. Density of railroad and expressway refers to the mileage of railroad and expressways in operation in a unit of area, which reflects indirectly the degree of fragmentation of wildlife habitats. Railroad density = total mileage of railways ÷ 960 (unit: kilometers [km]/10,000 km^2). Expressway density = total mileage of expressways in the year ÷ 960 (unit: km/10,000 km^2). Data were from *China Railway Yearbook* (1989–2007), issued by the Ministry of Railway (*www.china-mor.gov.cn*), and *Statistics of Development of Highway and Waterway and Transportation Industry* (1989–2007), issued by the Ministry of Transport (*www.moc.gov.cn*).

Number of invasive alien species newly discovered every 20 years. Invasive alien species can have devastating impacts on native biota, causing extinctions and affecting natural and cultivated ecosystems (CBD 2006). It is very difficult to collect data that would allow damage to ecosystems, native species, and genetic resources by invasive alien species to be expressed in terms of economic losses in an area, but that damage can be measured indirectly by determining the number of invasive alien species newly discovered in a specified period of time (for instance, 20 years). There is a delay, however, between the time an invasive alien species colonizes a new area and the time that the species is discovered. Data were from the *Inventory of Invasive Alien Species of China* (Xu HG and Qiang 2004), supplemented by data from the recent literature on newly discovered invasive alien species.

Impact of climate change on biodiversity. Climate change is projected to exacerbate the loss of biodiversity and increase the risk of extinction for many species (MEA 2005). Climate change has already had an impact on biodiversity in China (State Council, People's Republic of China 2007), but because important gaps exist in monitoring the impacts of climate change on biodiversity, we do not assess this indicator in this article.

Proportional coverage of nature reserves. The proportional coverage of nature reserves refers to the proportion of the national terrestrial area that is devoted to terrestrial nature reserves; it reflects the status of *in situ* conservation of biodiversity. Data were from the *China Environment Status Communique* (1985–2007), issued by the China EPA (see *www.sepa.gov.cn*).

Status of access to and benefit-sharing of genetic resources and traditional knowledge. The fair and equitable sharing of the benefits arising from the utilization of genetic resources and traditional knowledge is one of the three objectives of the CBD (CBD 2006). These benefits would mobilize resources for biodiversity conservation. However, because of important gaps in information on the status of, access to, and benefit-sharing of genetic resources and traditional knowledge, we do not assess that indicator in this article.

Percentage of gross domestic product invested in environmental pollution control and forestry conservation. Investment in pollution control and forestry conservation plays a vital role in protecting biodiversity. Data on this major investment in biodiversity in China were from *China Statistical Yearbook on Environment* (1990–2006), published by the China EPA (*www.sepa.gov.cn*), and *China Statistical Yearbook on Forestry* (1990–2006), published by the State Forestry Administration (*www.forestry.gov.cn*).

Status and trends of the components of biodiversity

Indicators that focus on the status and trends of the components of biodiversity are the most direct measure of the 2010 target (Mace and Baillie 2007). To reflect the status and trends of various ecosystems and genetic resources, we chose the following indicators: change in land cover; NPP; growing forest stock; area of desert land; marine trophic index; water quality in marine and freshwater ecosystems; the Red List index; and the genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance (table 1).

Land cover. The area of cultivated land, inland waters, and residential quarters increased, but the area of afforested land, grassland, and unused land decreased from the late 1980s to 2000 (figure 1). This increase in cultivated land and decrease in afforested land and grassland was due to conversion of a great majority of afforested land and grassland into cultivated land (table S3, see supporting material at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). The area of cultivated land, grassland, and unused land decreased, while the area of afforested land, inland waters, and residential quarters grew between 2000 and 2005 (figure 1). Decrease in grassland had been primarily caused by turning grassland into cultivated land, accounting for 48% of total area of other types of land that had been converted from grassland. Besides, some grassland had been reclaimed as afforested land and unused land. The growth in afforested land had been primarily because arable land and grassland had been converted into afforested land, which accounted for 96% of afforested land that had been converted from other types of land (table S4, see supporting material at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*).

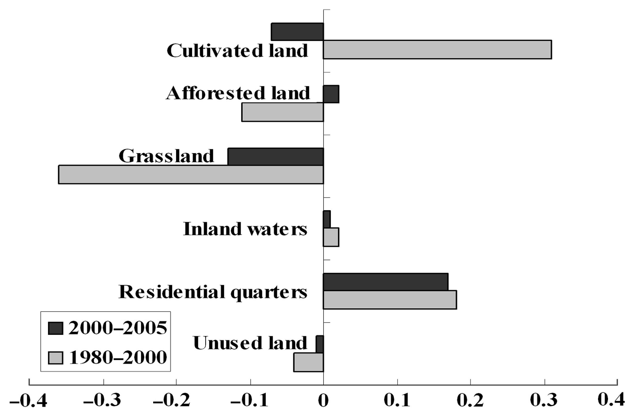

Figure 1. Percentage change of land cover in total land area in mainland China from the late 1980s to 2000, and from 2000 to 2005.

Net primary productivity. The growth rates of annual average NPP of China in the past two decades estimated by CEVSA, GLOPEM, and CASA were 0.67%, 0.96%, and 0.51% (Gao and Liu 2008), respectively, showing an increasing trend of carbon storage.

Forest ecosystems. China's forests have been threatened and undergoing degradation since early imperial times (Harkness 1998, Liu and Diamond 2005). However, in the last two decades forest resources have been increasing in China. The forest coverage rate increased from 12.7% in 1973 to the current 18.2%, and forest growing stock increased from 9532.27 million cubic meters (m^3) in 1973 to the current 13,618.10 million m^3. The net annual increment of growing stock, which has been increasing since 1989 (table 2), reached 143.29 million m^3 in 2003, with an annual growth rate of 11.21% (table 2). Increases in forest area and growing stock do not necessarily mean an increase in biodiversity (Harkness 1998), but in China's case, the long-accruing increases have been in the area and growing stock of natural forests. This means that biodiversity is increasing in China's forests. Indeed, China has the fastest growing forest resources in the world.

Table 2. Change in forest resources in mainland China (10,000 hectares, 10,000 m³).

Forest inventory period	Forest coverage rate (percentage)	Forest area	Growing stock	Net annual increment of growing stock	Area of natural forest	Growing stock of natural forest
1973–1976	12.7	12,186.00	953,227	–	9609.00	830,542
1977–1981	12.0	11,527.74	1,026,060	–	8791.00	770,487
1984–1988	12.98	12,465.28	1,057,250	–4083	8846.59	756,164
1989–1993	13.92	13,370.15	1,178,500	7015.76	9427.63	837,518
1994–1998	16.55	15,894.05	1,248,786	11,808.25	10,696.54	907,265
1999–2003	18.21	17,490.92	1,361,810	14,329.00	11,576.20	1,059,311

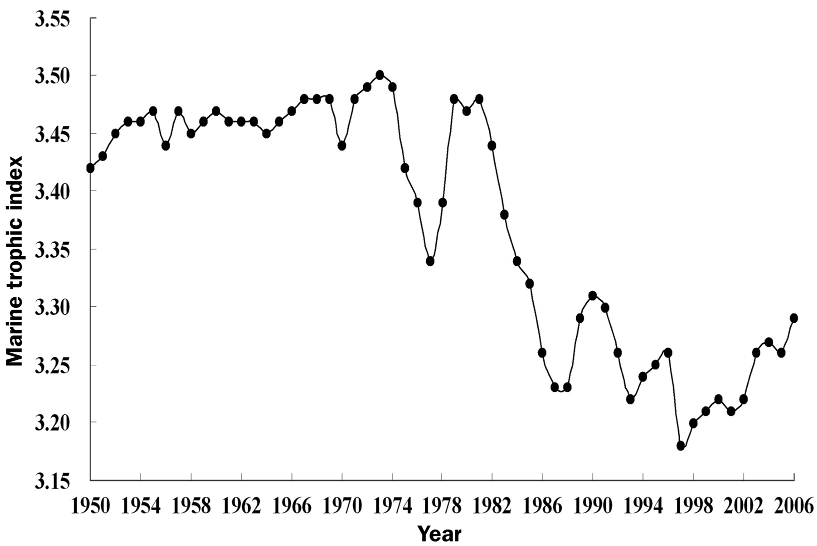

Figure 2. Change in the marine trophic index of all marine waters of China.

Marine ecosystems. From 1950 to 1980, the MTI of all marine waters of China ranged between 3.45 and 3.50 (figure 2), which was slightly higher than the global average over the same period. From the early 1980s to the mid-1990s, overfishing led to a significant decline in the MTI, with the lowest being 3.25 in the mid-1990s, which was lower than global average over the same period. However, statistics showed a steady increase in the MTI from 1997 to 2006 (figure 2). This growth may be attributed to the implementation of a summer fishing ban and the "zero-growth policy" on all marine waters of China. In addition, fry releases into marine ecosystems may also have played an active role in restoring fishery resources. China's MTI is still at a relatively low level despite the stable increase over the past 10 years. Water quality in marine ecosystems increased 4.25% per year between 2001 and 2007, and the area of red tides has decreased since 2006 (see tables S5 and S6, *www.nies.org/nies/new/uploadpic/200962956343 2194.09.pdf*). However, pollution in marine ecosystems is not effectively curbed and is still very severe.

Inland water ecosystems. As shown in figure 1, the area of inland waters has been fairly stable with only a small increment of change since the late 1980s. The quality of inland waters has been improving in mainland China since 2001, with a growth rate of 7.9% per year (see table S7 at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). However, the biodiversity of China's inland waters faces severe threats such as habitat loss, modification or fragmentation, introduction of invasive alien species, and overfishing (Xie and Chen 1999).

Desert ecosystems. According to the third national monitoring of land desertification (State Forestry Administration 2005), the area of desertified land decreased from 1,743,100 km² in 1999 to 1,736,684 km² in 2004 in mainland China, reflecting a change from an average annual expansion of 3436 km² in the earlier year to an average annual reduction of 1283 km² in 2004, an annual reduction of 0.07%.

Grassland ecosystems. Grasslands have been declining at approximately 15,000 km² per year since the early 1980s, and 90% of China's grasslands are now considered degraded (Liu and Diamond 2005). Thirty-three percent of natural grasslands are overgrazed (MOA 2007), although grassland conservation programs have been initiated in recent years.

Threatened species. We calculated the RLI value for 138 bird species (10.45% of total bird species in China), 107 mammal species (18.45% of total mammal species), 81 fish species (8.87% of total freshwater fish species), and 162 higher plant species (0.47% of total higher plants) (see tables S8, S9, S10, and S11 in the supporting material at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). The RLI value of mammals, freshwater fish, and plants decreased by 2.77%, 1.84%, and 2.33% per year, respectively, from 1998 to 2004, indicating a continuing deterioration in the threat status of these species (table 3). Using the "equal-steps approach" (Butchart et al. 2007), the RLI value for bird species showed some improvement in threat status; if more weight is given to critically endangered species, however, the RLI value for bird species would indicate continuing deterioration in threat status (table 3). China's wetland conservation has contributed to better conservation of bird species, but those with higher threat statuses need even more conservation. Habitat loss has led to further deterioration in the threat statuses of mammal, fish, and plant species.

Genetic resources. The number of rice breeds in production was 46,000 in the 1950s and 1000 in 2006. The more than 10,000 traditional corn breeds in production in the 1950s are seldom found in production now. China has established and maintained many long-term genebanks and germplasm nurseries, which store 390,000 accessions of crop germplasm resources, and livestock and poultry breeding farms, which protect 576 breeds of domestic animals (China EPA 2005a). These resources have partially offset the losses of genetic diversity (MEA 2005).

Table 3. Red List index of threatened species of China (1998–2004).

Approach	Year	Birds	Mammals	Fish	Plants
Equal steps (Butchart et al. 2007)	1998	0.6652	0.5402	0.5827	0.5914
	2004	0.7623	0.4505	0.5185	0.5086
Extinction risk (Butchart et al. 2007)	1998	0.9894	0.9755	0.9811	0.9158
	2004	0.9725	0.8985	0.9667	0.8876

Threats to biodiversity

Indicators of threats are useful because they can reflect alterations in the proximate or ultimate causes of biodiversity loss (Mace and Baillie 2007).

Pollutants. The total discharge of chemical oxygen demand and the amount of sulfur dioxide in waste gas, two nationally targeted pollutants, decreased in 2007, down 3.14% and 4.66%, respectively, from the previous year (see table S12 at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). There was less discharge of toxic and harmful pollutants (mercury, cadmium, hexavalent chromium, plumbum, arsenic) in wastewater, in the emission intensity of chemical oxygen demand of key industries, in the emission of soot dust and industrial dust in waste gases, and in the discharge of solid wastes—the average annual reduction rates in these categories since 1998 are 12.24%, 21.62%, 5.16%, and 16.89%, respectively (table S12). However, China still faces severe environmental pressure because total pollutant emissions are still high, especially for wastewater discharge, which is increasing at a 3.90% average annual rate (see table S12 at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*).

Fertilizers and pesticide. Agricultural production is one of the major driving forces of biodiversity loss (Xu JC and Wilkes 2004, Xu HG et al. 2008). Agrochemicals have been mainly responsible for the remarkable increase in food production. The annual application of fertilizers has increased by 5.48% on average since 1980, and that of pesticide has also increased by about 4.82% since 1991 (see table S13 in the supporting material at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). However, as much as 60% of nitrogen fertilizer and 70% of pesticides applied may be lost to the environment (China EPA 2005b), which leads to soil pollution, lake eutrophication, and groundwater pollution, and so on.

Railways and expressways. The fast development of railways and expressways in China—on average, each year since 1989 railway density has increased 2.19 km per 10,000 km^2 and expressway density, 36.27 (see table S14 at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*)—has fragmented habitat for wild animals and plants. To minimize the impact of railways and expressways on wildlife and ecosystems, the Chinese government has been strictly enforcing the Law on Environmental Impact Assessment, which aims to keep railways and expressways away from protected areas and employ mitigating measures. For instance, the Qinghai-Tibet Railway has many wildlife underpasses to mitigate the impact on threatened animals (Yang and Xia 2008).

Invasive alien species. Invasive alien species, one of the most important factors endangering global biodiversity, spur biodiversity losses (Xu HG et al. 2006a, 2006b). China's annual economic losses because of invasive alien species account for 1.36% of the country's gross domestic product (GDP) (Xu HG et al. 2006a). In the recent past, the rate of alien species invasions and the risks associated with them have increased significantly because of the rapid growth of trade and tourism and environmental change. The number of invasive alien species newly discovered every 20 years was between 1 and 16 before the 1930s; the figure rose to 21 and 32 from the 1930s to 1960s, and exceeded 40 after the 1970s, with an average annual growth rate of 11.47%, showing a tremendous upward trend (figure 3).

Response

The response indicators help measure the extent to which efforts are beeing made to reduce the rate of biodiversity loss (Mace and Baillie 2007).

Nature reserves. The establishment of nature reserves is the most effective way to conserve biodiversity. As of the end of 2007, nature reserves have maintained stable development. The number of nature reserves was 2531, 32 times the number in 1978; the area devoted to reserves is 151.88 million hectares, which is 120 times the area in reserves in 1978, and it accounts for 15.2% of the national territory (China EPA 2008; see table S15 at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). However, the preliminary network of nature reserves that China has established is insufficient for conservation of all key components of biodiversity. Marine and grassland ecosystems and genetic resources are less well protected. The percentage of nature reserve area to provincial land area was not correlated with overall species richness, endemism, or threat; provinces rich in biodiversity with less than 10% coverage of nature reserves—including Guangxi, Guizhou, Guangdong, Hainan, Jiangxi, Fujian, Hunan, Hubei, Zhejiang, and Shaanxi—should increase the amount of land devoted to nature reserves (Xu HG et al. 2008). In many cases, reserves are

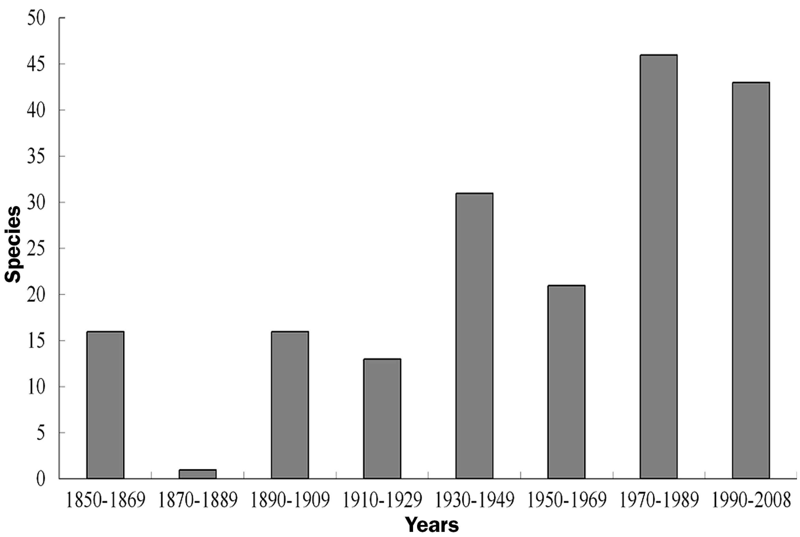

Figure 3. Number of invasive alien species newly discovered every 20 years. Data are from the Inventory of Invasive Alien Species in China (Xu HG and Qiang 2004) and supplemented by data collected since 2004.

too small in area to maintain genetic or ecological viability in the long run. Moreover, many nature reserves have no physical structures or signs delineating their borders, and about one-third of China's nature reserves have neither staff nor budgets—and the staff that are employed are poorly paid and even more poorly trained, with limited enforcement powers and limited incentives for protecting biodiversity (Harkness 1998, Liu JG et al. 2003). Nature reserves need to be better located, designed, and managed to improve their representativeness and effectiveness in biodiversity conservation.

Financial resources. The Chinese government has initiated environmental pollution control programs and forest conservation programs, which contribute to biodiversity conservation. The proportion of investment in environmental pollution control and forestry conservation to GDP has increased 18.50% per year since 1990 (see table S16 at *www.nies.org/nies/new/uploadpic/2009629563432194.09.pdf*). Together these investments have exceeded 1% of China's GDP since 2001. Although the Chinese government has been putting much effort into water pollution control, some segments of the Haihe, Liaohe, Huaihe, and Yellow Rivers, especially those parts running through cities, are heavily polluted. Some lakes and reservoirs have experienced heavy eutrophication. Therefore, China still faces grave challenges in pollution control and biodiversity conservation.

Discussion

A number of criteria need to be considered in selecting and designing indicators for biodiversity: Researchers must verify that the indicator is relevant to the purpose; distinguish between measures of state, threats, and response; design and validate the measures in context; ensure that the relevant audiences effectively understand the indicators; and maximize the cost-effectiveness of the indicators (Mace and Baillie 2007). Because of limited monitoring capacity and data availability, two indicators recommended by the CBD—"trends in extent of selected biomes, ecosystems and habitats" and "trends in abundance and distribution of selected species"—were not included in China's national indicator framework, although they are the best indicators for reflecting the state of biodiversity. Other indicators—"technology transfer," "official development assistance," and "linguistic diversity"—also were not considered, either because they are not appropriate for China or because they are difficult to measure and data are limited. Environmental pollution is one of the key threats to biodiversity in China, given China's fast economic growth; thus the indicator "discharge of major pollutants" was included in China's national indicator framework, and it will clearly reflect the change of pressures on biodiversity.

The indicator "land cover" is not straightforward for biodiversity conservation. For instance, it does not distinguish between natural and artificial habitats. An increase in afforested area could be an increase in plantation forests rather than an increase in natural forests, in which case biodiversity might suffer. The indicator "growing forest stock" should be interpreted carefully. For instance, fast-growing nonnative species, fertilization, and other factors may contribute to an increase in growing stock, but may also be detrimental to biodiversity (EEA 2007). Red List index values have relatively coarse resolution because quite significant changes in species' population and range size may be necessary before the species Red List category can be changed, and RLIs can be practicably updated only every four years (EEA 2007).

Indicators of pressure can help detect both positive and negative changes before changes in state result, and these have the advantage that they can stimulate timely and effective actions for policy and management (Failing and Gregory 2003). However, it is not sufficient to monitor only pressure, and the relationship between pressure and state needs to be ascertained (Mace and Baillie 2007). The indicator "density of railroad and expressway" might produce results that deviate to some extent from the actual fragmentation of habitats, because biodiversity is rich in western China, moderate in central China, and low in eastern China, whereas the densities of railroads and expressways are opposite to this distribution. It is more appropriate to use the area of damage caused by invasive alien species to reflect trends in invasive alien species. However, it is difficult to obtain such data.

Response indicators will not provide strong information about whether the target is met; their roles are primarily to track the measures being implemented to mitigate pressures and improve the state of biodiversity (Mace and Baillie 2007). The indicator "proportional coverage of nature reserves" does not describe the effectiveness of management. The indicator needs to be complemented by information on management effectiveness or other elements that would indicate the potential of nature reserves in protecting biodiversity (EEA 2007). The indicator "percentage of GDP invested in environmental pollution control and forestry conservation" also does not describe the effectiveness of financial resources in protecting biodiversity.

Many efforts have been made to protect ecosystems and threatened species, and to restore degraded ecosystems in China. The Chinese government implemented six key forestry conservation programs, strengthened forest resources management, and oversaw large-scale afforestation. China has implemented a summer fishing ban in the East China Sea, the Bohai Sea, and the Yellow Sea since 1995. This policy has also been in place in the South China Sea since 1999. The fishing ban season is from June to September, and all capture fishery activities are prohibited in the fishing-ban area during that season. The Chinese government undertook a wide range of economic measures in finance, taxation, banking, credit, pricing, and trade to protect the environment and reduce emissions of pollutants. As a result, forest resources have been increasing, the integrity of marine ecosystem is improving, and the overall rate of habitat loss is now slowing in certain regions. However, this may not necessarily translate into lower rates of species loss for all taxa, because there is a lag between a driver's effect on biodiversity and its consequences for changes in biodiversity; and because other drivers of loss, such as economic growth, urbanization, nutrient loading, invasive alien species, and climate change, still exist and are projected to increase (MEA 2005). It will be a long march for China to completely stem or halt the rate of loss of all components of biodiversity.

There have been many discussions on the post-2010 target. Most researchers suggest that 2020 is an appropriate date for such a target, and that the target should be SMART—that is, specific, measurable, achievable, realistic, and time bound (UNEP 2009). China has established comprehensive national targets on the economy, the environment, and human well-being for 2020, including such environmental indicators as effective control of major pollutants, evident improvement of ecosystems, and effective protection of species. The 2020 target should more clearly highlight the links between biodiversity and human well-being and economics, and biodiversity considerations should be incorporated in all relevant sectoral and cross-sectoral policies, strategies, and planning processes (UNEP 2009). The target should consider impacts not only on biodiversity at home but also on biodiversity abroad. For instance, because China is importing a large amount of timber (Liu and Diamond 2005), the forest indicator, which in China indicates an upward trend, might be offset by deforestation in other relevant countries.

It is crucial that progress toward the 2010 biodiversity target and beyond be monitored (Balmford et al. 2003, Pereira and Cooper 2006). Monitoring populations and habitats is an extremely valuable and relevant way of assessing human impacts on nature (Balmford et al. 2003). Although a national environmental monitoring network with 4800 stations and a national forest inventory system has been established in China (China EPA 2005a), the lack of a national biodiversity monitoring system still hinders more timely and accurate assessment of biodiversity, and weakens the effectiveness of management interventions. The establishment of this system calls for properly planned partnerships, development of sampling regimes, design of data collection programs, and statistical analyses (Balmford et al. 2005b).

A significant reduction of biodiversity loss—or even a halt of it—can be achieved only if biodiversity conservation is mainstreamed into national and sectoral strategies and action plans. The next decade is a critical period for China to engage all stakeholders in protecting its rich and unique biodiversity, and ultimately to realize its strategic goals in building a harmonious society and improving human well-being.

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