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Global Biodiversity: Indicators of Recent Declines

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In 2002, world leaders committed through the Convention on Biological Diversity (CBD) to achieve a significant reduction in the rate of biodiversity loss by 2010. We compiled 31 indicators to report on progress toward this target. Most indicators of the state of biodiversity (covering species' population trends, extinction risk, habitat extent/condition, and community composition) showed declines, with no significant recent reductions in rate, whereas indicators of pressures on biodiversity (including resource consumption, invasive alien species, nitrogen pollution, over-exploitation, and climate change impacts) showed increases. Despite some local successes and increasing responses (including extent and biodiversity coverage of protected areas, sustainable forest management, policy responses to invasive alien species, and biodiversity-related aid), the rate of biodiversity loss does not appear to be slowing.

In 2002, world leaders committed, through the CBD "to achieve by 2010 a significant reduction of the current rate of biodiversity loss" (*1*), and this "2010 target" has been incorporated into the United Nations Millennium Development Goals in recognition of the impact of biodiversity loss on human well-being (*2*). The CBD created a framework of indicators to measure biodiversity loss at the level of genes, populations, species and ecosystems (*3*, *4*). While a minority have been published individually (*5*), hitherto they have not been synthesized to provide an integrated outcome. Despite suggestions that the target is unlikely to be (*6*–*8*), or has not been (*4*, *9*, *10*), met, we test this empirically using a broad suite of biodiversity indicators.

To evaluate achievement of the 2010 target we: (i) determined the trend and timing/direction of significant inflections in trend for individual indicators (*11*); and (ii) calculated aggregated indices relating to the state of biodiversity, pressures upon it, policy and management responses, and the state of benefits (ecosystem services) that people derive from biodiversity, using the best available sources. To calculate aggregate indices we first scaled each of 24 indicators (out of 31) with available trend information to a value of 1 in the first year with data from 1970 onwards (only 8 indicators had earlier trends) and calculated annual proportional change from this first year. Then we used a generalized additive modelling framework (*5*, *12*, *13*) and determined significant inflections (*12*). While absolute values are difficult to interpret because they aggregate different elements of biodiversity, this approach permits a synthetic interpretation of rate changes across the elements measured: e.g. the aggregated state index should show positive inflections if biodiversity loss has been significantly reduced.

Our analysis suggests that biodiversity has continued to decline over the past four decades, with most (8 out of 10) state indicators showing negative trends (Fig. 1 and Table 1). There have been declines in: population trends of (i) vertebrates (*13*) and (ii) habitat specialist birds; (iii) shorebird populations worldwide; extent of (iv) forest (*14*, *15*); (v) mangroves; (vi) seagrass beds; and (vii) the condition of coral reefs. None show significant recent reductions in the rate of decline (Table 1), which is either fluctuating (i), stable (ii), increasing (vii), based on too few data to test significance (iii-vi), or stable following a deceleration two decades ago (vii). Two indicators, freshwater quality and trophic integrity in the marine ecosystem, show stable and marginally improving trends respectively, which are likely explained by geographic biases in data availability for the former, and spatial expansion of fisheries for the latter (*5*). Aggregated trends across state indicators have declined, with no significant recent reduction in rate: the most recent inflection in the index (in 1972), was negative (Fig. 2). As there were fewer indicators with trend data in the 1970s, we recalculated the index from 1980, which also showed accelerating biodiversity loss: the most recent inflection (2004) was negative. Finally, aggregated species' extinction risk (i.e. biodiversity loss at the species level) has accelerated: the IUCN Red List Index (RLI), measuring rate of change (*16*, *17*), shows negative trends.

The majority of indicators of pressures on biodiversity show increasing trends over recent decades (Fig. 1 and Table 1), with increases in: (i) aggregate human consumption of the planet's ecological assets; (ii) deposition of reactive nitrogen; (iii) number of alien species in Europe; (iv) proportion of fish stocks over-harvested; and (v) impact of climate change on European bird population trends (*18*). In no case was there a significant reduction in the rate of increase (Table 1), which was stable (i, iii, v), fluctuating (iv), or based on too few data to test significance (ii), although growth in global nitrogen deposition may have slowed, and this may explain why the most recent inflection in aggregated trends (in 2006) was negative (Fig. 2) (*5*). Global trends for habitat fragmentation are unavailable, but it is probably increasing, e.g. 80% of remaining Atlantic Forest fragments are <0.5 km^2 in size (*19*) and 59% of large river systems are moderately or strongly fragmented by dams and reservoirs (*20*).

All indicators of policy and management responses show increasing trends (Fig. 1 and Table 1), with increases in: (i) extent of protected areas (PAs, Table 2); (ii) coverage by PAs of two subsets of Key Biodiversity Areas (*21*) [39% of the area of 10,993 Important Bird Areas and 42% of the area of 561 "Alliance for Zero Extinction" sites (*22*)]; (iii) area of sustainably managed forests (1.6 million km^2 under Forest Stewardship Council certification by 2007); (iv) proportion of eligible countries signing international agreements relevant to tackling invasive alien species [IAS; reaching 82% by 2008 (*23*)]; (v) proportion of countries with national legislation to control and/or limit the spread and impact of IAS [reaching 55% by 2009 (*23*)]; and (vi) biodiversity-related aid (reaching $3.13 billion in 2007). The rate of increase was stable (i, iv), slowing (ii, iii, v) or based on too few data to test significance (vi, Table 1). The last three inflections in aggregated trends (2002, 2004, 2008) were all negative (Fig. 2), indicating that the rate of improvement has slowed. Two other indicators have only baseline estimates: management effectiveness was "sound" for 22% of PAs ("basic" for 65% and "clearly inadequate" for 13%), and the proportion of genetic diversity for 200–300 important crop species conserved ex situ in gene banks was estimated to be 70% (*24*).

Only three indicators address trends in the benefits humans derive from biodiversity (Fig. 1 and Table 1): (i) population trends of utilized vertebrates have declined by 15% since 1970; and aggregate species' extinction risk has increased at an accelerating rate (as shown by the RLI) for (ii) mammals, birds and amphibian species used for food and medicine (with 23-36% of such species threatened with extinction); and (iii) birds that are internationally traded (principally for the pet trade; 8% threatened). Trends are not yet available for plants and other important utilized groups. Three other indicators, which lack trend data, show: (iv) 21% of animal breeds are at risk of extinction (and 9% are already extinct); (v) languages spoken by fewer than 1,000 people (22% of the current 6,900 languages) have lost speakers over the past 40 years and are in danger of disappearing within this century (loss of linguistic diversity being a proxy for loss of indigenous biodiversity knowledge); and (vi) over 100 million poor people live in remote areas within threatened ecoregions, and are therefore likely to be particularly dependent upon biodiversity and the ecosystem services it provides.

Indicator development has progressed substantially since the 2010 target was set. However, there are considerable gaps and heterogeneity in geographic, taxonomic and temporal coverage of existing indicators, with fewer data for developing countries, non-vertebrates, from before 1980 and after 2005 (*4*, *5*, *25*). Interlinkages between indicators and the degree to which they are representative are incompletely understood. In addition, there are gaps for several key aspects of state, pressures, responses, and especially benefits (*4*, *5*, *7*, *26*).

Despite these challenges, there are sufficient data on key dimensions of biodiversity to conclude that at the global scale it is highly unlikely that the 2010 target has been met. Neither individual nor aggregated indicators of the state of biodiversity showed significant reductions in their rates of decline, apart from coral reef condition for which there has been no further deceleration in decline since the mid-1980s. Furthermore, all pressure indicators showed increasing trends, with none significantly decelerating. Some local system-specific exceptions with positive trends for particular populations, taxa, and habitats (Table 2) suggest that, with political will and adequate resources, biodiversity loss can be reduced or reversed. More generally, individual and aggregated response indicators showed increasing trends, albeit at a decelerating rate (and with little direct information on whether such actions are effective). Overall, efforts to stem biodiversity loss have clearly been inadequate, with a growing mismatch between increasing pressures and slowing responses.

Our results show that, despite a few encouraging achievements, efforts to address the loss of biodiversity need to be substantially strengthened, by reversing detrimental policies, fully integrating biodiversity into broad-scale land-use planning, incorporating its economic value adequately into decision making, and sufficiently targeting, funding and implementing policies that tackle biodiversity loss, among other measures. Sustained investment in coherent global biodiversity monitoring and indicators is essential to track and improve the effectiveness of these responses.

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Supporting Online Material
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Methods
SOM Text
Figs. S1 and S2
Tables S1 to S4
References
Data File 1

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Fig. 1. Indicator trends for (**A**) the state of biodiversity, (**B**) pressures upon it, (**C**) responses to address its loss, and (**D**) the benefits humans derive from it. Data scaled to 1 in 1970 (or for first year of data if >1970), modeled (if >13 data points; see Table 1) and plotted on a logarithmic ordinate axis. Shading shows 95% confidence intervals except where unavailable (i.e. mangrove, seagrass and forest extent, nitrogen deposition and biodiversity aid). WBI = Wild Bird Index, WPSI = Waterbird Population Status Index, LPI = Living Planet Index, RLI = Red List Index, IBA = Important Bird Area, AZE = Alliance for Zero Extinction site, IAS = invasive alien species.

Fig. 2. Aggregated indices of (**A**) the state of biodiversity based on 9 indicators of species' population trends, habitat extent/condition and community composition; (**B**) pressures on biodiversity based on 5 indicators of Ecological Footprint, nitrogen deposition, numbers of alien species, over-exploitation, and climatic impacts; and (**C**) responses for biodiversity based on 6 indicators of protected area extent and biodiversity coverage, policy responses to invasive alien species, sustainable forest management and biodiversity-related aid. Values in 1970 set to 1. Shading shows 95% confidence intervals derived from 1,000 bootstraps. Significant positive/upward (○) and negative/downward (●) inflections are indicated.

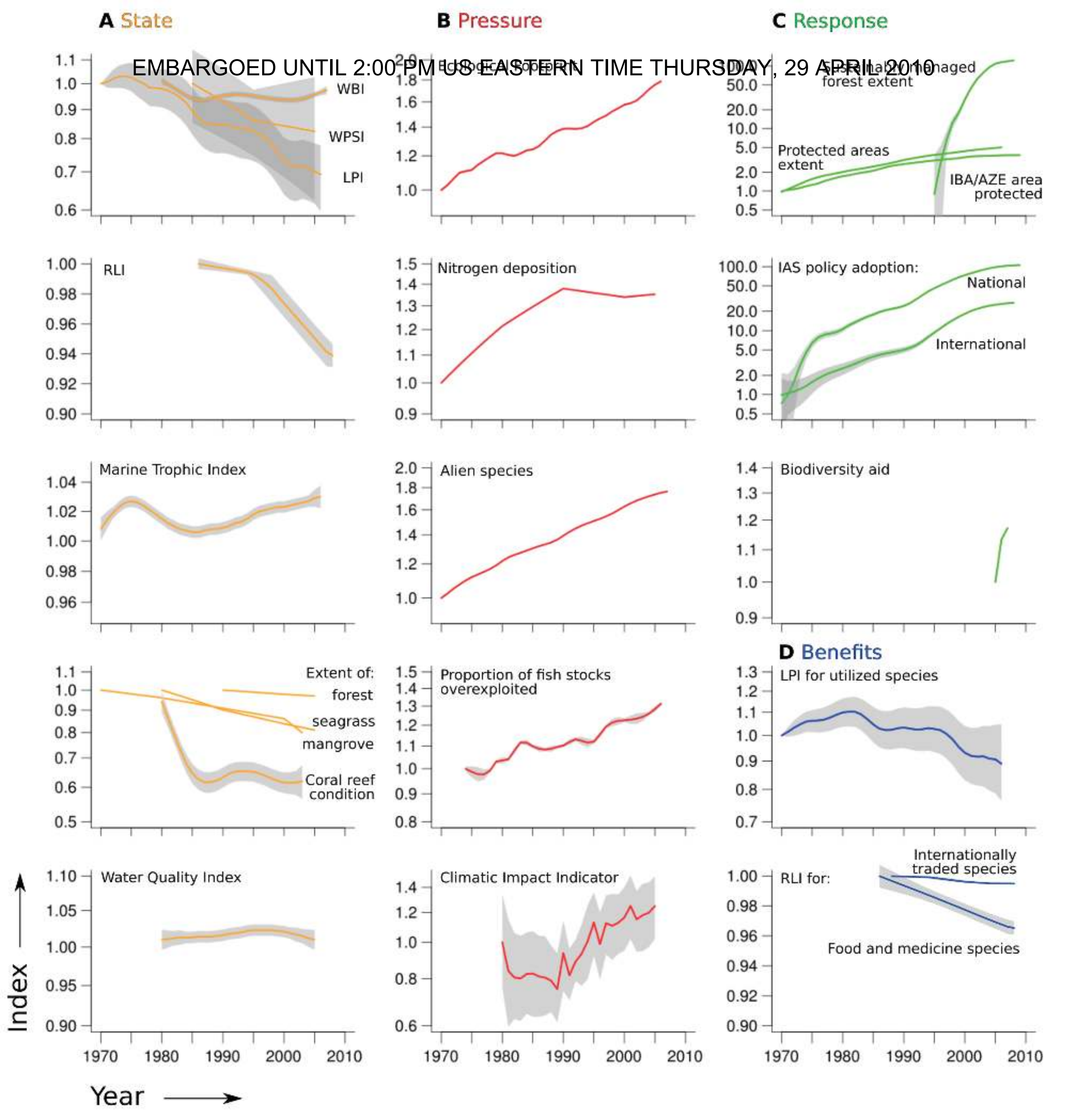
Table 1. Summary of global biodiversity indicator trends. † identifies indicators with insufficient data to test significance of post-1970 trends, usually because annual estimates are unavailable. ‡Or since earliest date with data if this is post-1970; asterisks indicate significant trends ($P < 0.05$). §Note that as the indicators measure different parameters, some comparisons of mean annual % change between indicators are less meaningful than comparisons between decades for the same indicator. ‖Rate of change decelerating (D), accelerating (A), stable (S, i.e. no years with significant changes), fluctuating (F, i.e. a sequence of significant positive and negative changes), or with too few data points to test significance (?); years indicate periods in which second derivatives differed significantly from zero ($P < 0.05$).

	Indicator	**Data availability (years)†**	**% change since 1970‡**	**Mean annual % change§**					**Trends in rate of change‖**
				'70s	**'80s**	**'90s**	**'00s**	**Since 1970**	
State	Living Planet Index (LPI; mean population trends of vertebrates)	1970-2006	- 31*	-0.2	-1.4	-1.4	-0.9	-1.0	F
	Wild Bird Index (mean population trends of habitat specialists in Europe & N. America, disaggregated for terrestrial [t] and wetland [w] species)	1980-2007	-2.6* -16*(t) +40* (w)		-0.6 -1.3 +1.1	-0.2 -0.7 +1.3	+0.6 +0.3 +1.1	-0.1 -0.7 +1.2	S D 1982-2007 S
	Waterbird population status index (% shorebird populations increasing, stable or decreasing)	1985-2005†	-33		-1.4	-2.0	-2.4	-2.0	A?
	Red List Index (RLI; extinction risk of mammals, birds, amphibians & corals)	1986-2008	-6.1*		-0.1	-0.2	-0.5	-0.3	A
	Marine Trophic Index (shift in fishing catch from top predators to lower trophic levels)	1950-2006	+3.0*	+0.1	-0.1	+0.1	+0.1	+0.1	S
	Forest extent	1990-2005†	- 3.1			-0.2	-0.2	-0.2	S?
	Mangrove extent	1980-2005†	-19		-1.0	-0.7	-0.7	-0.8	S?
	Seagrass extent	1930-2003†	-20	-0.4	-0.5	-0.5	-2.4	-0.7	A?
	Coral reef condition (live hard coral cover)	1980-2004	-38*		-3.9	-0.3	+0.2	-1.8	D 1985-1988
	Water Quality Index (physical/chemical quality of freshwater)	1980-2005	0		+0.1	+0.0	-0.2	+0	S
	Number of indicators declining			**2/3**	**8/9**	**8/10**	**7/10**	**8/10**	
Pressures	Ecological Footprint (humanity's aggregate resource-consumption)	1961-2006	+78*	+2.0	+1.3	+1.3	+2.1	+1.6	S
	Nitrogen deposition rate (annual reactive N deposited)	1850-2005†	+35	+2.0	+1.3	-0.3	+0.2	+0.9	D?
	No. alien species in Europe (Mediterranean marine, mammal & freshwater)	1970-2007	+76*	+2.0	+1.4	+1.6	+1.1	+1.5	S
	Exploitation of fish stocks (% over-exploited, fully exploited, or depleted)	1974-2006	+31*	+0.6	+0.6	+1.1	+1.2	+0.9	F
	Climatic Impact Indicator (degree to which European bird population trends have responded in the direction expected from climate change)	1980-2005	+23*		-0.8	+3.2	+1.2	+1.2	S
	Number of indicators increasing			**4/4**	**4/5**	**4/5**	**5/5**	**5/5**	

Responses	Extent of Protected Areas (PAs)	1888-2006	+400*	+7.6	+4.5	+3.4	+2.4	+4.7	S
	Coverage by PAs of Important Bird Areas and Alliance for Zero Extinction sites	1888-2009	+360*	+5.6	+4.6	+2.6	+0.8	+3.4	D 1999-2008
	Area of forest under sustainable management (FSC certified)	1995-2008	+12000*			+100	+20	+46	D 2006
	International IAS policy adoption (no. signatories to conventions with provision for tackling IAS)	1952-2008	+2700*	+10	+6.9	+14	+5.1	+9.1	S
	National IAS policy adoption (% countries with relevant legislation)	1964-2009	+10000*	+30	+8.7	+12	+4.1	+13	D 2004-2009
	Official development assistance ($$ per year provided in support of CBD)	2005-2007†	+17				+8.4	+8.3	D?
	Number of indicators increasing			**4/4**	**4/4**	**5/5**	**6/6**	**6/6**	
Benefits	LPI for utilized vertebrate populations	1970-2006	-15*	+1.0	-0.3	-1.3	-1.7	-0.4	A 1972-2006
	RLI for species used for food and medicine	1986-2008	-3.5*		-0.2	-0.2	-0.2	-0.2	A
	RLI for bird species in international trade	1988-2008	-0.5*		-0.01	-0.03	-0.02	-0.03	A
	Number of indicators declining			**0/1**	**3/3**	**3/3**	**3/3**	**3/3**	

Table 2. Examples of successes and positive trends relevant to the 2010 target (*5*).

	Indicator	**Successes and positive trends**
State	Living Planet Index of Palearctic vertebrate populations	Increased by 43% since 1970 (e.g. Eurasian Beaver, Common Buzzard)
	Waterbird populations in North America & Europe	Increased by 44% since 1980 owing to wetland protection and sustainable management (but populations remain below historic levels).
	Species downlisted on the IUCN Red List	Species qualifying for downlisting to lower categories of extinction risk owing to successful conservation action include 33 birds since 1988 (e.g. Lear's Macaw), 25 mammals since 1996 (e.g. European Bison) and 5 amphibians since 1980 (e.g. Mallorcan Midwife Toad).
	Wild Bird Index and Red List Index for species listed on the EU Birds Directive	Annex 1-listed species' population trends have improved in EU countries (*27*) and extinction risk reduced (RLI increased 0.46% during 1994-2004) owing to designation of Special Protected Areas and implementation of Species Action Plans under the Directive (e.g. White-tailed Eagle).
	Extinctions prevented	At least 16 bird species extinctions were prevented by conservation actions during 1994-2004, e.g. Black Stilt (*28*).
	Water Quality Index in Asia	Improved by 7.4% since 1970.
Pressure	Deforestation in Amazonian Brazil	Slowed from 2.8 million ha in 2003–2004 to 1.3 million ha in 2007–2008, but it is uncertain to what extent this was driven by improved enforcement of legislation versus reduced demand owing to economic slow-down.
Responses	National biodiversity strategies and action plans (NBSAPs)	87% of countries have now developed NBSAPs and therefore have outlined coherent plans for tackling biodiversity loss at the national scale.
	Protected Areas (PAs)	Nearly 133,000 PAs designated, now covering 25.8 million km^2: 12% of the terrestrial surface (but only 0.5% of oceans and 5.9% of territorial seas), e.g. Juruena National Park, Brazil, designated in 2006, covering 19,700 km^2 of Amazon/cerrado habitat.
	Invasive alien species (IAS) policy, eradication and control	82% of eligible countries have signed international agreements relevant to preventing the spread, and promoting the control/eradication of IAS. Successful eradications/control of IAS include pigs on Clipperton Atoll, France, (benefiting seabirds and land crabs), cats, goats and sheep on Natividad, Mexico (benefiting Black-vented Shearwater) and Red Fox in SW Australia (benefiting Western Brush Wallaby).
	Official development assistance for biodiversity	Increased to at least $3.13 billion in 2007.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Coral reef condition
Proportion of fish stocks overexploited
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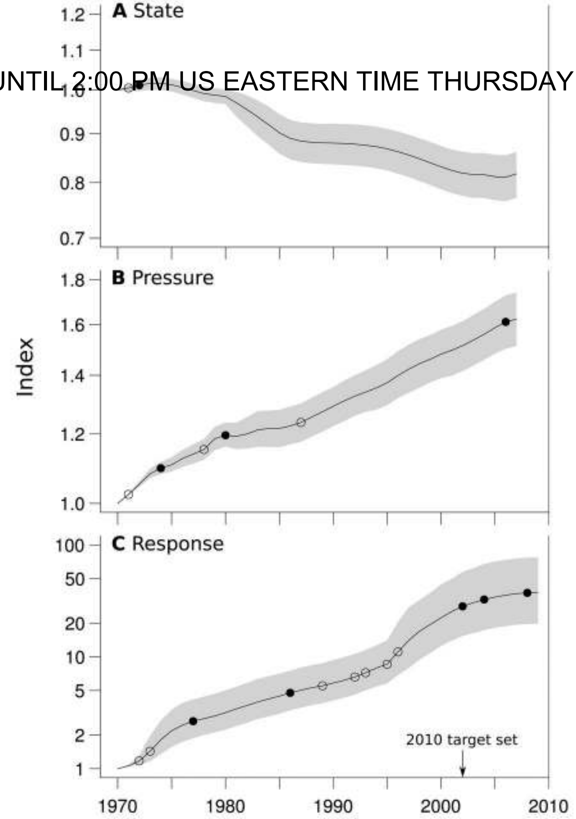
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