Prospects for Biodiversity

Martin Jenkins, *et al.*

Science **302**, 1175 (2003);
DOI: 10.1126/science.1088666

and women based on parenthood and that the rise in divorce and cohabitation is weakening the ties between fathers and children. Nonmarital births increased as a percentage of all births in the United States from 5.3% in 1960 to 33.0% in 1999. In 1999, the United States had 1.3 million births to unmarried women (*13*). In 1998, Iceland, Norway, Sweden, Denmark, France, United Kingdom, and Finland all had higher proportions of nonmarital births than the United States. By contrast, in Germany, Italy, Greece, and Japan, less than 15% of births were nonmarital (*13*). Among United States women aged 15 to 29 years at first birth, when that first birth was conceived before marriage, the fraction who married before the birth fell from 60% in 1960–64 to 23% in 1990–94 (*14*). By 1994, about 40% of children in the United States did not live with their biological father (*12*).

In the United States, the number of widowed males aged 55 to 64 per thousand married persons fell from 149 in 1900 to 35 in 2000, whereas the number of divorced males aged 55 to 64 per thousand married persons rose from 7 to 129. Divorced males became more frequent than widowed males between 1970 and 1980. Divorced females became more frequent than widowed females between 1990 and 2000. By 2000, the number of divorced and widowed persons aged 55 to 64 per thousand married persons was 164 males and 426 females (2.6 such females for each such male) (*15*). Remarriages and stepfamilies are becoming increasingly common.

Three factors set the stage for further major changes in families: fertility falling to very low levels; increasing longevity; and changing mores of marriage, cohabitation, and divorce. In a population with one child per family, no children have siblings. In the next generation, the children of those children have no cousins, aunts, or uncles. If adults live 80 years and bear children between age 20 and 30 on average, then the parents will have decades of life after their children have reached adulthood and their children will have decades of life with elderly parents. The full effects on marriage, child bearing, and child rearing of greater equality between the sexes in education; earnings; and social, legal, and political rights have yet to be felt or understood.

References and Notes

1. J. E. Cohen, *How Many People Can the Earth Support?* (W. W. Norton, New York, 1995).
2. L. Shriver, *Popul. Dev. Rev.* **29** (no. 2), 153 (2003).
3. United States Census Bureau, *Historical Estimates of World Population* (online). Available at www.census.gov/ipc/www/worldhis.html (cited 21 June 2003).
4. United Nations Population Division, *World Population Prospects: the 2002 Revision, Highlights* (online database). ESA/P/WP.180, revised 26 February 2003, p. vi. Available at: http://esa.un.org/unpp/ (consulted 1 to 30 June 2003).
5. United Nations Population Division, *Partnership and Reproductive Behaviour in Low-Fertility Countries*, ESA/P/WP.177, revised May 2003. Available at www.un.org/esa/population/publications/reprobehavior/partrepro.pdf (cited 29 June 2003).
6. United Nations Population Division, *World Urbanization Prospects: The 2001 Revision*. ESA/P/WP.173. (United Nations, New York, 2002).
7. J. Bongaarts, R. A. Bulatao, Eds. *Beyond Six Billion: Forecasting the World's Population* (National Academy Press, Washington, DC, 2002).
8. J. E. Cohen, in *Seismic Shifts: the Economic Impact of Demographic Change*, J. S. Little, R. K. Triest, Eds., Federal Reserve Bank of Boston, conference series no. 46, 11 to 13 June 2001 (Federal Reserve Bank of Boston, Boston, MA, 2001), pp. 83–113.
9. J. E. Cohen, in *What the Future Holds: Insights from Social Science*, R. N. Cooper, R. Layard, Eds. (MIT Press, Cambridge, MA, 2002), pp. 29–75.
10. P. Demeny, *Popul. Dev. Rev.* **29** (no. 1), 1 (2003).
11. United Nations Population Division, *World Population Prospects: The 1998 Revision: Volume III: Analytical Report*. ESA/P/WP.156, revised 18 November 1999 (United Nations, New York, 1999).
12. F. K. Goldscheider, *Futurist* **32**, 527 (2000).
13. S. J. Ventura, C. A. Bachrach, *National Vital Statistics Reports* **48** (no. 16, revised), 18 October 2000. Available at www.cdc.gov/nchs/data/nvsr/nvsr48/nvs48_16.pdf (cited 25 June 2003).
14. A. Bachu, *Current Population Reports;* P23–197 (U.S. Census Bureau, Washington, DC, 1999).
15. P. Uhlenberg, in *United Nations, Department for Economic and Social Information and Policy Analysis, 1994. Ageing and the Family.* Proceedings of the United Nations International Conference on Ageing Populations in the Context of the Family, ST/ESA/SER.R/124 (United Nations, New York, 1994), pp. 121–127.

16. I acknowledge with thanks the support of U.S. National Science Foundation grant DEB 9981552, the assistance of K. Rogerson, and the hospitality of Mr. and Mrs. W. T. Golden during this work.

Web Resources

www.sciencemag.org/cgi/content/full/302/5648/1172/DC2

Prospects for Biodiversity

Martin Jenkins

Assuming no radical transformation in human behavior, we can expect important changes in biodiversity and ecosystem services by 2050. A considerable number of species extinctions will have taken place. Existing large blocks of tropical forest will be much reduced and fragmented, but temperate forests and some tropical forests will be stable or increasing in area, although the latter will be biotically impoverished. Marine ecosystems will be very different from today's, with few large marine predators, and freshwater biodiversity will be severely reduced almost everywhere. These changes will not, in themselves, threaten the survival of humans as a species.

What will be the state of the world's biodiversity in 2050, and what goods and services can we hope to derive from it? First, some assumptions: that the United Nations median population estimate for 2050 holds, so that Earth will have roughly nine billion people—just under half again as many as are currently alive (*1*, *2*); that the Intergovernmental Panel on Climate Change scenarios provide a good indication of global average surface temperatures and atmospheric CO_2 concentrations at that time, with the former ~1°C to 2°C and the latter ~100 to 200 parts per million higher than today (*3*); and, perhaps most important, although most nebulous, that humanity as a whole has not determined on a radically new way of conducting its affairs. Here, then, is a plausible future.

In this future, the factors that are most directly implicated in changes in biodiversity—habitat conversion, exploitation of wild resources, and the impacts of introduced species (*4*)—will continue to exert major influences, although their relative importance will vary regionally and across biomes. In combination, they will ensure continuing global biodiversity loss, as expressed through declines in populations of wild species and reduction in area of wild habitats.

Extinction Rates

To start, as it were, at the end: with extinction, perhaps the most tangible measure of biodiversity loss. The uncertainties that still surround our knowledge of tropical biotas (which include the great majority of extant species); the difficulty of recording extinctions; and our ability, when we put our minds to it, to bring species back from the brink

United Nations Environment Programme–World Conservation Monitoring Centre, 219c Huntingdon Road, Cambridge, CB3 ODL, UK. E-mail: martin.jenkins@unep-wcmc.org

make it extremely difficult to assess current global extinction rates, let alone estimate future ones. However, an assessment of extinction risk in birds carried out by BirdLife International—using the criteria of IUCN–The World Conservation Union's Red List of Threatened Species—has concluded (with many caveats) that perhaps 350 species (3.5% of the world's current avifauna) might be expected to become extinct between now and 2050 (*5*). Indications are that some other groups—mammals and freshwater fishes, for example—have a higher proportion of species at risk of extinction, although data for these are less complete (*4*).

Just as it is hard to estimate future extinction rates, so is it difficult to extrapolate forward from current rates of habitat alteration, even where these are known (*6*). However, some general patterns are clear. With the harvest of marine resources now at or past its peak (*7*), terrestrial ecosystems will bear most of the burden of having to feed, clothe, and house the expanded human population. This extra burden will fall most heavily on developing countries in the tropics, where the great majority of the world's terrestrial biological diversity is found.

The Land

Most increased agricultural production is expected to be derived from intensification. However, the Food and Agriculture Organization (FAO) of the United Nations notes that, on the basis of reasonably optimistic assumptions about increasing productivity, at least an extra 120 million ha of agricultural land will still be needed in developing countries by 2030 (*8*). In a less than wholly efficient world, the amount converted will be much more. Historic precedent and present land availability indicate that almost all new conversion will be in South America and sub-Saharan Africa. More than half the unused suitable cropland is found in just seven countries in these regions: Angola, Argentina, Bolivia, Brazil, Colombia, Democratic Republic of Congo, and Sudan (*8*). Five of these are among the 25 most biodiverse countries; the exceptions (Angola and Sudan) are both also highly biodiverse (*9*, *10*). Large-scale conversion will continue in most or all of these, with a disproportionately high impact on global biodiversity.

Much conversion here and elsewhere will be of land currently under tropical forest. Fragmentation and loss of such forests will thus continue, albeit overall possibly at a slower rate than at present. The great, largely contiguous forest blocks of Amazonia and the Zaire basin will by 2050 be a thing of the past, with unknown (and hotly debated) impacts on regional weather patterns and global climate. Deforestation pressure will remain high in the immediate future in a number of other tropical developing countries, including those such as Indonesia, Madagascar, and the Philipppines, which hold many endemic forest-dependent species, often with small ranges (*11*, *12*). Forest loss here will also have a particularly high impact on biodiversity.

There will, however, still be considerable forest cover in the tropics, much of it in inaccessible or steeply sloping sites unsuitable for clearance and in some protected areas. Even outside such areas, forest cover will be increasing in some regions, paralleling the current situation in Northern hemisphere temperate forests (*13*), because growing urbanization will lead to the abandonment of marginally productive lands (*1*), allowing reversion to a more natural state. However, uncontrolled and frequent fires will mean that abandoned lands in many areas will remain relatively degraded. In addition, almost all wild lands in the tropics will be impoverished in numbers and diversity of larger animal species, thanks to persistent overexploitation of wild resources such as bushmeat. Although there have been some local successes, the goal of large-scale sustainable harvest of these resources has so far been elusive and will remain so (*14*). This means that populations of many species will survive largely or exclusively in heavily managed protected areas.

Although tropical developing countries will continue to suffer quite possibly accelerating biodiversity loss, much less change can be expected in developed temperate countries. Temperate forest cover will continue to increase, or at least stabilize, and many forest species will thrive, although with changes in distribution and relative abundance as a result of climate change. The recent declines in many wild species that are primarily associated with agricultural land (*15*) may or may not continue. Much will depend on whether the current consumer-led drive to "greener" forms of agriculture has a major long-term impact.

Aquatic Ecosystems

Our most direct and pervasive impact on marine ecosystems and marine biodiversity is through fishing. If present trends [(reviewed in detail in (*7*)] continue, the world's marine ecosystems in 2050 will look very different from today's. Large species, and particularly top predators, will be by and large extremely scarce, and some will have disappeared entirely, giving the lie to the old assertion that marine organisms are peculiarly resistant to extinction. Marine ecosystems, particularly coastal ones, will also continue to contend with a wide range of other pressures, including siltation and eutrophication from land runoff, coastal development, conversion for aquaculture, and impacts of climate change (*9*). Areas of anoxia will increase; most coral reefs will be heavily degraded, but some adaptable species may benefit from warming and may even have started to expand in range.

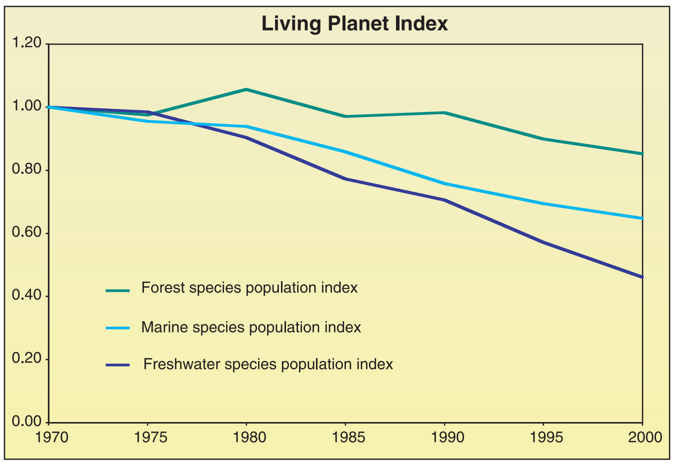

Fig. 1. Species population indices from 1970 to 2000 for forest, marine, and freshwater ecosystems, as included in the 2002 WWF Living Planet Index. Data for 1996 to 2000 are drawn from small samples (*16*).

Available information suggests that freshwater biodiversity has declined as a whole faster than either terrestrial or marine biodiversity over the past 30 years (Fig. 1) (*16*). The increasing demands that will be placed on freshwater resources in most parts of the world mean that this uneven loss of biodiversity will continue (*17*). Pollution, siltation, canalization, water abstraction, dam construction, overfishing, and introduced species will all play a part, although their individual impacts will vary regionally. The greatest effects will be on biodiversity in fresh waters in densely populated parts of the tropics, particularly South and Southeast Asia, and in dryland areas, although large-scale hydroengineering projects proposed elsewhere could also have catastrophic impacts (*18*). Although water quality may stabilize or improve in many inland water systems in developed countries, other factors, such as introduced species, will continue to have an adverse impact on biodiversity in most areas.

How Much Does It Matter?

In assessing the importance of environmental change, we must distinguish between wholesale degradation, such as reduction of a productive, forested slope to bedrock, and reduction in biodiversity per se through the loss of particular populations or species of wild organisms or the replacement of diverse, species-rich systems with less diverse, often intensively managed systems of nonnative species. The former can, of course, have devastating direct consequences for human well-being. It is much more difficult to determine the impacts of the latter. In truth, ecologists and conservationists have struggled to demonstrate the increased material benefits to humans of "intact" wild systems over largely anthropogenic ones. In terms of the most direct benefits, the reverse is indeed obviously the case; this is the logic that has driven us to convert some 1.5 billion ha of land area to highly productive, managed, and generally low-diversity systems under agriculture. Even with regard to indirect ecological services, such as carbon sequestration, regulation of water flow, and soil retention, it seems that there are few cases in which these cannot adequately be provided by managed, generally low-diversity, systems. Where increased benefits of natural systems have been shown, they are usually marginal and local (*19*).

Nowhere is this more starkly revealed than in the extinction of species. There is growing consensus that from around 40,000 to 50,000 years ago onward (*20*), humans have been directly or indirectly responsible for the extinction in many parts of the world of all or most of the larger terrestrial animal species. Although these species were only a small proportion of the total number of species present, they undoubtedly exerted a major ecological influence (*21*, *22*). This means that the "natural" systems we currently think of in these parts of the world (North and South America, Australasia, and virtually all oceanic islands) are nothing of the sort, and yet they still function at least according to our perceptions and over the time scales we are currently capable of measuring. In one well-documented case, New Zealand, a flightless avifauna of at least 38 species has been reduced in a few centuries to 9, most of which are endangered. Here, as David Steadman recently put it, "much of the biodiversity crisis is over. People won: native plants and animals lost" (*23*). Yet, from a functional perspective, New Zealand shows few signs overall of suffering terminal crisis. There is currently little evidence to dissuade us from the view that what applies for New Zealand today could equally hold, more or less, for the world as a whole tomorrow.

This does not mean, of course, that we can continue to manipulate or abuse the biosphere indefinitely. At some point, some threshold may be crossed, with unforeseeable but probably catastrophic consequences for humans. However, it seems more likely that these consequences would be brought about by other factors, such as abrupt climate shifts (*24*), albeit ones in which ecosystem changes may have played a part.

References and Notes

1. J. Cohen, *Science* **302**, 1172 (2003).
2. *World Population Prospects: The 2002 Revision* (United Nations, ESA/P/WP. 180).
3. Intergovernmental Panel on Climate Change (IPCC), *Third Assessment Report* (IPCC, Geneva, 2001).
4. See summary data on threatened species at www.redlist.org.
5. BirdLife International, *Threatened Birds of the World* (Lynx Edicions and BirdLife International, Barcelona and Cambridge, UK, 2000).
6. M. Jenkins *et al.*, *Conserv. Biol.* **17**, 20 (2003).
7. D. Pauly *et al.*, *Science*, in press.
8. J. Bruinsma, Ed., *World Agriculture: Towards 2015/2030, an FAO Perspective* (Earthscan, London, 2003).
9. B. Groombridge, M. D. Jenkins, *World Atlas of Biodiversity* (Univ. of California Press, Berkeley, 2002).
10. J. O. Caldecott *et al.*, *Biodivers. Cons.* **5**, 699 (1996).
11. A. Balmford, A. Long, *Nature* **372**, 623 (1994).
12. P. Jepson *et al.*, *Science* **292**, 859 (2001).
13. Food and Agriculture Organization of the United Nations, *Global Forest Resources Assessment 2000*, FAO Forestry Paper 140.
14. N. Leader-Williams, in *Guidance for CITES Scientific Authorities*, A. Rosser, M. Haywood, compilers. Occasional Paper of the IUCN Species Survival Commission No. 27 (2002).
15. See, for example, the United Kingdom headline indicators of sustainable development at www.sustainable-development.gov.uk/indicators/headline/index.htm.
16. J. Loh *et al.*, *Living Planet Report 2002* (WWF, World Wide Fund for Nature, Gland, Switzerland, 2002).
17. *The United Nations World Water Development Report* (UNESCO & Berghahn Books, Paris and Oxford, 2003).
18. World Conservation Monitoring Centre (WCMC), *Freshwater Biodiversity: A Preliminary Global Assessment* (WCMC, World Conservation Press, Cambridge, 1998).
19. A. Balmford *et al.*, *Science* **297**, 950 (2002).
20. R. G. Roberts *et al.*, *Science* **292**, 1888 (2001).
21. P. S. Martin, R. G. Klein, Eds., *Quaternary Extinctions* (University of Arizona Press, Tucson, AZ, 1984).
22. W. Schüle, in *Tropical Forests in Transition*, J. G. Goldhammer, Ed. (Birkhäuser Verlag, Basel, 1992), pp. 45–76.
23. D. W. Steadman, *Science* **298**, 2136 (2002).
24. R. B. Alley *et al.*, *Science* **299**, 2005 (2003).
26. I thank two anonymous reviewers and many friends, in particular N. Ash, H. Coulby, J. Gavrilović, T. Hufton, V. Kapos, J. Loh, K. Mackinnon, E. McManus, A. Rosser, A. Stattersfield, and K. Teleki, for discussion and comments.

Web Resources

www.sciencemag.org/cgi/content/full/302/5648/1175/DC1