THE DEVELOPMENT AND VARIABILITY OF BIODIVERSITY

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Summary

Biodiversity refers to the variety of life forms of the planet. It can be expressed at three levels, which are interrelated: genes within species, species, and ecosystems. It is the product of a long evolutionary process. As far as species are concerned, 1.75 million have been described today—half of them insects—but the total number may be ten times as much. There are hot spots of biodiversity, especially in tropical rainforests, coral reefs, coastal wetlands, and ancient lakes. Species have always emerged and become extinct through geological times but, at present, the rate of extinction has increased by a factor of 100 to 1000 due to human action. Similarly, genetic diversity

has decreased, especially in cultivated plants and domesticated animals and ecosystems have been degraded. The main cause of biodiversity loss is the destruction and fragmentation of habitats for human settlements, farming, ranching, transport infrastructures, etc. Other causes are overexploitation and competition from invasive species.

Biodiversity has a utilitarian value for humankind as it provides resources for food, medicines, pesticides, fibers, shelter, etc., as well as ecological services to maintain the life support systems of the planet. It should also be respected on ethical grounds. It can be preserved mostly by in-situ, but also by ex-situ measures at local, national and international levels. The main international agreement in this respect is the Convention on Biological Diversity presented at the 1992 Rio Earth Summit. This requires countries to develop national strategies and programs to conserve biodiversity and to integrate this objective in sectoral and cross-sectoral policies It recognizes the sovereign rights of states over their own biological resources and promotes equitable arrangements to share these resources. Progress in the implementation of the Convention has been very slow and spotty but there are now signs of improvement.

1. Introduction: What is Biodiversity?

The diversity of life forms, as E. O. Wilson rightly said, is the greatest wonder of this planet. It is now under serious threat by human action. How can biodiversity be defined? According to the UN Convention on Biological Diversity of 1992: “it is the variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” The convention considers that the term “Biological resources” includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity. More simply, it can be said that the term “biodiversity” is used to describe the number, variety, and variability of living organisms, and that it can be expressed at three different levels: genes, species, and ecosystems.

Genetic biodiversity is the heritable variation within the gene pool of a species. At the species level, biodiversity refers to the number of species inhabiting a certain area. Ecosystem diversity is the variety of ecosystems (or biological communities) found in a given area. These three aspects of biological diversity are interrelated, but are often treated separately, and it is the diversity of species of plants, animals, and microbes that is most apparent to lay people. To take into account the relations and hierarchy within this trilogy of biodiversity, a more sophisticated definition has been proposed by di Castri: “The ensemble and the hierarchical interactions of the genetic, taxonomic and ecological scales of organization, at different levels of integration.” The following is an overview of the issue of biodiversity as affected by human action, excluding genetic diversity in the human species.

2. The Development and Variability of Biodiversity

Biodiversity today is the result of a 4-billion-year evolutionary process, through which species appeared and disappeared. A species is a population, or a series of populations, within which free gene flow occurs under natural conditions, which means that individuals within a species can potentially breed with all other individuals of the opposite sex and have fertile offspring. On the basis of their degree of morphological resemblance (and now of DNA closeness), species are grouped into genera, these in turn into families, orders, classes, and phyla.

A very slow process called geographic speciation has formed species generally. When some physical barrier divides a population, the isolated subpopulations diverge slowly from each other through evolution because they are submitted to somewhat different environments. Given enough time, their genomes differ to the point that the capacity to interbreed is lost. If the barrier disappears they will be able to coexist distinctly.

Species disappear over time through modification of their environment (e.g. the glaciations combined with lack of refuge sites), and competition. It is believed that species diversity has been maintained through geological eras at an approximately even level, although there have been brief periods of accelerated extinction every few tens of millions years (e.g. the disappearance of dinosaurs about 60 million years ago) caused by cataclysmic events. Studies in island biogeography have shown that the number of species is a fairly constant power function (exponent 0.25) of the area of the island, so that a tenfold increase in area results in a doubling of the number of species.

In terms of natural longevity, the very incomplete fossil record indicates that species (at least marine invertebrates and fish as well as flowering plants) have persisted for 1–10 million years. Each species contains a very large amount of genetic information (hundreds of thousands of genes in flowering plants and mammals) and, except for vegetative reproduction (cloning) and parthenogenesis, no two individuals of the same species have exactly the same genome. Thus natural genetic diversity is many times greater than species diversity. Moreover, it has been enhanced by human action through selection, crossbreeding, and mutagenesis of cultivated plant species, microorganisms, and domesticated animals. The development of biotechnologies has added a new dimension to genetic biodiversity by allowing the introduction of genes from other species in the genome, producing genetically modified organisms (GMOs).

The third type of biodiversity, that of ecosystems, results from the combined effect of species and genetic diversity in a region on one hand, and on the other of the diversity of physical habitats, or biotopes, present there, due to differences in climate/microclimate, geology, geomorphology, and hydrology, etc. It has been affected by changes in these factors through time and by human land use, which may cause either uniformization, or enrichment in habitat types in a given area. As to the number of species existing today, estimates vary broadly. Most are between 6 and 20 million. The Global Biodiversity Assessment published in 1995 by the United Nations Environment Programme (UNEP) places it at 13–14 million. Wilson thinks that the number varies between 5 and 30 million; others go as high as 100 million. What is certain is that most of them are unknown, since so far only about 1.75 million species

have been described; half of them insects, 41 000 vertebrates (about 9600 birds, 4600 mammals, 5800 reptiles, 20 000 fish, 4000 amphibians), plus 220 000 flowering plants. About 17 000 new species are described each year. Most of the yet unknown species are in the tropical rainforests, the oceans, and in soils.

Species biodiversity is unevenly distributed at the surface of the Earth. In general, it increases towards the equator and is greater in the tropical rainforests. It is lower in harsh environments such as the cold Arctic and high-altitude areas or the dry habitats in the desert and semi-desert zones. There are "hotspots" with a large number of species not found elsewhere, and thus more exposed to extinction from human activity. Twenty-five such hotspots have been recognized, covering only 1.4 percent of the Earth's land surface, but with more than 60% of all plant and animal diversity. They include areas in the Himalayas, South-East Asia, the Philippines, New Caledonia, Madagascar, Equatorial Africa, Amazonia, and the Andes.

Before being partly destroyed, tropical rainforests covered about 7% of the Earth's land surface but were estimated to contain more than half of the total number of species; other species may be found in rich ecosystems such as tropical coral reefs, coastal wetlands, and ancient lakes. Biological diversity has also been affected by geology and past climate changes. Thus, the relatively lower biodiversity of Europe is attributed to the East–West direction of its mountain ranges, which act as barriers for the southward migration of species during glaciations, while in America these run North to South. American biodiversity is in turn lower than that of China.

3. Human-induced Loss of Biodiversity

Species extinction is an irreversible phenomenon. Yet biodiversity is now declining rapidly as a result of human action, mostly through the destruction and fragmentation of habitats (in tropical forests for slash-and-burn agriculture, logging, cattle ranching; elsewhere for human settlements, modern agriculture, and transport infrastructure, etc). Another important threat to biodiversity is invasion by alien species, that is those which occur outside their natural range, through deliberate action or unintentionally. They are competitors, predators, pathogens and parasites which have invaded most types of native ecosystems and caused hundreds of extinctions, among them several species of marsupials in Australia and birds in New Zealand. Natural barriers, such as oceans and mountains, which maintained biological isolation for millions of years, have been overcome by international travel and transport of goods. Well-known examples of successful invaders are the water hyacinth *Eichornia crassipes* in tropical freshwater ecosystems, the rabbit *Oryctolagus cuniculus* in Australia, and the zebra mussel *Dreissena polymorpha* in the Great Lakes of North America. Economic costs of alien invasions are enormous (several billions of dollars a year).

Humans have also eliminated species through overkill, even in prehistoric times. Thus it is claimed that the disappearance of the native mega fauna, such as large marsupials, birds, and reptiles in Australia and New Guinea, was concomitant with the arrival of humans there 30 000– 40 000 years ago, and resulted from excessive hunting. More recently, the invasion of islands led to the extermination of animals, such as the

proverbial dodo bird of Mauritius. Nowadays, several mammal species are threatened with extinction as they are slaughtered for bush meat.

On the other hand, human action has allowed, in exceptional instances, the survival of a species, as is the case for the Ginkgo tree of China (a "living fossil"). Global warming may be another factor that will markedly increase biodiversity before the end of the twenty-first century. Species will have to adapt or migrate—which may not be possible if the rates of warming are rapid, as anticipated for the higher latitudes of the Northern Hemisphere. Mountain species will also be at greater risk.

3.1 How Much Biodiversity is being Lost?

Rough estimates of the rate of species extinction due to habitat destruction have been made on the basis of the species number/area relationship mentioned above. Considering the rate of rainforest destruction, which is currently estimated at 76 000 km^2 per year (17 000 km^2 in Brazil in 1999 according to the government, twice as much according to NGOs), and the fact that many of their species are endemic (strongly localized), it has been calculated that about 17 000 species may disappear each year (some say 50 000). According to the Global Biodiversity Assessment of UNEP, the rate of species extinction since the year 1600 has occurred at 50–100 times the average estimated natural rate. Between 1960 and 1990, one-fifth of tropical rainforest cover was lost. Until recently, it was estimated that about 10% of the world's coral reefs had been degraded beyond repair, and an additional 30% would collapse over the next 1000 years. Damage to the reefs has increased dramatically, in the form of bleaching, apparently as the result of high sea temperatures in 1996 and 1998.

Coastal mangroves, which serve as nursery ground for many marine species, have been destroyed to a great extent. At these rates, if there were 10 million species, this would mean, according to Wilson, one extinction out of 1000 species per year. These estimates, however, are questioned by others on the basis that secondary forests grow after logging, as do some cultures with shade trees. Such extinction rates, if confirmed, would exceed those obtained from the fossil record by a factor of 100 to 1000 and more, approaching those of the catastrophes of the past, which were presumably due to the impact of large meteorites, with the difference that the latter affected mostly the animals, while now plant diversity is affected as well.

Genetic diversity, also, is reduced by the fragmentation of habitats with the result that the remaining populations have a reduced survival potential. It has also decreased in cultivated plants and domesticated animals, with the intensification of modern agriculture which favors monocultures in large fields with a reduction in the number of cultivars (cultivated varieties), as well as large-scale livestock raising of relatively few breeds. Similarly, these and other practices, such as the drainage of wetlands, large-scale irrigation, the use of fertilizers and pesticides, as well as the increasing use of land for buildings, roads, airports, etc. affect ecosystem diversity negatively, as population and per capita consumption keep increasing. All these man-made disturbances reduce the variety of biotopes and cause the fragmentation of natural and semi-natural ecosystems, whereas Western traditional agriculture tended to enrich biological

diversity in forest-climax regions by creating new habitats and ecotones (transition zones).

3.2 How Many Species are Threatened? The Red Lists

IUCN, the International Union for the Conservation of Nature, now called the World Conservation Union, is doing continuing work, through its Species Survival Commission, to assess the survival status of the known animal and plant species. Its Red Lists of Threatened Species are a compilation by the World Conservation Monitoring Center (WCMC) of species categorized as Critically Endangered, Endangered, or Vulnerable. Critically Endangered means an extremely high risk of extinction in the wild in the immediate future; Endangered means a very high risk of extinction in the wild in the near future; Vulnerable means a very high risk of extinction in the medium-term future. Other categories are: extinct, extinct in the wild, lower risk, data deficient, and not evaluated. Classification of species among these categories is done on the basis of strictly defined criteria, involving quantitative data on population size reduction, area of occurrence, and occupancy. More than 7000 species conservation experts, who volunteer for the Species Information Service of IUCN, apply these criteria.

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Bibliography

Di Castri F. and Younès T., eds. (1996). *Biodiversity, Science and Development, Towards a New Partnership*, 646 pp. CAB International. [This presents 61 papers covering the scientific aspects of biodiversity, conservation measures, relations with agriculture and industry, culture values, and ethics.].

Mooney H. A., Cushman J. H., Medina E., Sala O. E. and Schulze E-D., eds. (1996). *Functional Roles of Biodiversity: A Global Perspective*, 493 pp. SCOPE 55. Chichester: John Wiley and Sons. [This presents a review of the role of biodiversity in all main terrestrial and aquatic ecosystem types.]

Perrings Ch., Mäler K-G., Folke C., Holling C. S. and Jansson B-O., eds. (1995). *Biodiversity Loss: Economic and Ecological Issues*, 332pp. Cambridge, New York, Melbourne: Cambridge University Press. [This discusses in 11 papers the integration of ecology and economics in relation to biodiversity loss.]

Kate K. and Laird Sarah A. (1999). *The Commercial Use of Biodiversity*, 398 pp. London: Earthscan Publications. [This covers the use of genetic resources in medicine, the seed industry, crop protection, horticulture, and the cosmetics industry, including recommendations for institutional and corporate policies.]

UNDP, UNEP, WB, WRI (2000). *A Guide to World Resources 2000–2001: People and Ecosystems, The Fraying Web of Life*, 25pp. Washington, D.C.: World Resources Institute. [This presents a report on the condition of the Earth's ecosystems in order to adopt the ecosystem approach to managing the environment.]

Wilson, E. O., ed. (1988). *Biodiversity*, 521 pp. Washington, D.C.: National Academy Press. [This presents an overview of all aspects of the problem of biodiversity issue in 57 papers by mostly US authors.]

Wilson, E. O. (1992). *The Diversity of Life*, 424 pp. Cambridge, MA: The Belknap Press of Harvard University Press. (One of the world's authorities on the subject explains how biodiversity came about, evolved over time, and is now threatened, ending with a plea for stewardship of biological wealth.]

Wisnieski J. and Coleman W., eds. (1999). Managing for biodiversity: incentives for the protection of nature. *The Science of the Total Environment*, **240**(13). Special Issue: 210 pp. Amsterdam: Elsevier. [This includes 15 papers on economic instruments and other incentives for nature protection.]

Websites

Secretariat of Convention on Biological Diversity: http://www.biodiv.org

IUCN, The World Conservation Union: http://www.iucn.org

WWF, The World Wide Fund for Nature: http://www.wwf.org

Biographical Sketch

R. Philippe Bourdeau was born in 1926, of Belgian citizenship. From 1949 he studied at the Facult' des Sciences Agronomiques, Gembloux, graduating with an MA in 1951 and a Ph.D. in 1954 fom Duke University, Durham, N.C., USA, in Ecology. His current activities include the role of Chairman, Scientific Committee of the European Environment Agency (1994–); Member of the College d'Environnement of the Brussels Region (1994–); Coordinator, environmental research projects at Universit' Libre de Bruxelles, for Belgian federal and regional governments; Editor-in-chief, SCOPE (Scientific Committee on Problems of the Environment) of ICSU (International Council for Science) (1998–); Chairman, review committee for research in environmental sciences at universities in the Netherlands (2000–). Previously, he has held the roles of: Assistant Professor, North Carolina State University and Yale University; research associate, Brookhaven National Laboratory (1954–1962); Head of Radiobiology Laboratory, Euratom Joint Research Centre, Ispra, Italy (1962–1971); Head of Division (1971), Director (1982), Directorate General for Research (DGXII), European Commission, in charge of R&D programs in environment, marine sciences and technologies, non-nuclear energy, raw materials, etc.; responsible for PHARE environmental programmes in Poland and Czechoslovakia (1989–91); Professor, Universit' Libre de Bruxelles (1971–1997)—courses in environmental sciences, radioecology, ecotoxicology; special advisor to the European Commission, Head of European Environmental Agency Task Force (1992–1994), in charge of the production of the first Dobris assessment of the European environment; President of IGEAT (Institut de Gestion de l'Environnement et d'Am' management du Territoire) of ULB (Universit' Libre de Bruxelles) (1993–1997); Secretary General (1992–1995), President (1995–1998), SCOPE (Scientific Committee on Problems of the Environment) of ICSU (International Council for Science). His publications include: numerous monographs in ecology, radioecology, environmental science, and management; editor or co-editor of books in environmental sciences and management, including several SCOPE volumes: *Europe's Environment: The Dobris Assessment* (1995), and *Compendium of Environmental Information in Belgium* (in press). Other activities include: Member of Applied Sciences, Council of Royal Academy of Science of Belgium; Fellow of AAAS (American Association for the Advancement of Science); Member of the Belgian–American Educational Foundation; Member of various scientific societies; Chairman, EAEME (European Association for Environmental Management Education), 1992–1996; Chairman of the College of International Experts, charged by the Italian government to assess the mobile gates project in the Venice lagoon, 1997–1998; Member of the jury of the St. Francis Prize for the Environment (Assisi) 1992; Member of the jury of the Deutscher Umweltpreis (Deutsche Bundesstiftung Umwelt) 1994–1997.