Dan Cogălniceanu • Biodiversity

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Dan Cogălniceanu

Biodiversity

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Foreword

The word *biodiversity*, an abbreviation of *biological diversity*, emerged first as a purely scientific term in the late 1980s, but became the key term of an international environmental law signed at the Rio Earth Summit in 1992.

Biodiversity, defined as “the variety of life on earth, including all genes, species and ecosystems and the ecological processes of which they are part“ has continued to grow as and has become one of the key buzzwords of the 1990s, even making the front cover of National Geographic in February 1999.

But the definition creates a problem for students of biodiversity. How does one become an expert on an estimated 5-10 million species, each comprising diverse populations of maybe billions of individuals, each containing up to 50,000 genes and interacting in ecological communities of maybe 10,000 species per hectare, some of which have persisted for thousands of years and some of which are newly created and rapidly evolving? Anyone claiming to be a biodiversity expert is in danger of being a “jack of all trades, master of none”

Yet it is vitally important for the future health of the planet that we build a generation of biodiversity experts and more importantly, biodiversity advocates, who will study, publish, lobby and campaign for the right of life forms, other than humans, to continue to coexist with us on the planet of their birth.

To study something as broad as biodiversity, it is important to have some kind of “mental map” or framework, within which to position or file so much information. Looking back over 20 years of slowly accumulating knowledge of biodiversity, I now realize how important it is to have some kind of organizational structure to allow one to file and retrieve so many interacting facets of biodiversity information.

There is no single prescription for such a mental map – each of us has to develop our own, specifically suited to our own particular predilections within the totality of biodiversity. No one sees the world, or biodiversity in the same way. For example, to an elephant biologist, dung may be a waste product, or perhaps the only practical way to estimate forest elephant populations. To an insect ecologist, dung is the habitat for a myriad of dung beetles and other insects. To a natural resource manager, the same dung may be a source of sustainable revenue as fertilizer or even for paper-making.

A primer on biodiversity is therefore an important, and useful, entry point in to a fascinating and endless sphere of study – but writing one is a hard challenge, requiring the author to be a total biodiversity expert, able to reduce vast amounts of information to less than 100 pages.

Dr. Dan Cogălniceanu has taken on that challenge, summarizing his own personal journey into, and through the biodiversity literature jungle, and cutting a path for the rest of us to follow. If we follow his path, we will not only learn something about most aspects of biodiversity, but also find branching points (references) to enable us to strike out on our own paths into areas which a short primer cannot touch.

The future of biodiversity on this planet depends on us following these paths, recognizing the beauty of biodiversity, and becoming activists for its right to coexist with humanity.

Dr. David Duthie

United Nations Environment Programme, Nairobi, Kenya.

August 2002

Preface

“Clear writing brings a grave danger. People may begin to understand you! Then they will probably disagree with you.”
Rosenzweig (1995)

There is an increasingly growing literature on biodiversity and it seems that everything worth mentioning was already done, at least for now. Nevertheless, I will try in this book to carve myself a small niche, focusing on aspects related to species diversity. The concept of biodiversity is too broad in coverage and tends to become empty of content, difficult to perceive and understand by most people. On the other hand, species diversity is clearly defined and I consider it to be the best approach for understanding the major topics related to biodiversity. Although not always referring to it, the ultimate goal is the conservation and sustainable use of the different components of biodiversity. Without this goal in mind everything would be futile.

It is extremely hard to compete with the excellent books already published on the topic, but within the variety of terms, concepts and contradicting views a rearrangement might prove useful. I am myself a newcomer in the field of biodiversity, attracted by a small component of it, amphibians (i.e. frogs, toads, salamanders and newts), to whom I dedicated most of my work until now. Because of my fondness for amphibians I deserted biochemistry for ecology and conservation and never regretted it, partly due to the fact that I was guided on this new path by several wonderful persons and scientists: Ion Fuhn, Petru Bănărescu and Nicolae Botnariuc. They played a major part in my formation, but should not be held responsible for my mistakes.

I tried in this book to introduce the reader to the concept of biodiversity the way I see and understand it at present. Biodiversity is extremely dynamic and I expect my own views and opinions to change in time. Nothing is perennial in this field.

This book was written and published within my position of Guest Professor for the Chair of International Biodiversity at the Faculty of Forestry of the University of Applied Sciences of Eberswalde in Germany. The position was based in the study program International Forest Ecosystem Management (Bachelor of Science) and took place from Fall 2001 to Spring 2002. It was part of a two-year program of different guest professors in the field of international biodiversity. Funding for the Chair of International Biodiversity was generously provided by the Deutscher Akademischer Austauschdienst (DAAD) (German Academic Exchange

Service) and the Ministerium für Wissenschaft, Forschung und Kultur (Ministry of Science, Research and Culture) of the State of Brandenburg.

I would like to thank Prof. Vahrson, President of the University of Applied Sciences of Eberswalde and Prof. Mussong for making my position of the Guest Professor for International Biodiversity possible. My colleagues and friends in Eberswalde made my stay extremely pleasant and helped me get over the difficult moments. Most of all I am grateful to Michael Mussong, Astrid Schilling, Oskar Dietterle and Thorsten Mrosek. My students at the University of Bucharest and at the University of Applied Sciences of Eberswalde provided the motivation needed for persisting in this field.

Many people helped me while writing this book, most of all David Duthie, without whom the book would be much worse than it is. Dorel Ruşti and Dana Ghioca also provided helpful comments on parts of the book, while Robert Whittaker, Fred Grassle, Manuela Zamfir, Alistair Crame, Alain Dubois, Dan Manoleli, Dorel Ruşti and Benjamin Piña provided part of the needed literature. I am grateful to them all.

Eberswalde and Bucharest, 2002

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1. Biodiversity – an introduction

1.1 Origins of the concept

Our society is facing huge problems at an unprecedented scale: poverty, depletion of vital resources, extensive environmental destruction, emergence of new diseases, wars and famine. These major challenges to our well-being and even survival, despite being apparently unrelated, are all the result of our unfair, unsustainable approach. History offers many examples of human societies that made major changes in their environment. They have had to adapt to the changes they made by altering the patterns of their societies, or disappear. This has happened in every historical period and in every part of the inhabited Earth (Hughes, 2001). At present, we are facing the challenge of adapting at a global scale. A new, different approach in the way we perceive and exploit the natural resources provided by nature and the way we share these between us is required. This adaptive process is extremely complex and needs a radical change in our life-style and beliefs. The Western view of humanity's place in nature is dominated by a dualistic opposition between nature and culture (Haila, 2000). Most religions made us believe that we are a superior species, with special privileges (e.g. "So God created man in his own image", Old Testament, Genesis 1:27). Even Darwinism supports the idea that humans are the result of a long process of selection that allowed only the survival of the fittest. These ideas have been most often (mis)understood as giving us special rights and power over the rest of the species inhabiting the planet. We must realize that we are just part of a larger, life-supporting system, the ecosphere, and that we cannot survive outside it. A sustainable use of natural resources, a development that will not be harmful anymore to the environment is the only possible solution. In our quest for reaching a sustainable way of development, biodiversity management and conservation developed in one of the major issues for reaching this goal.

Biodiversity made up headlines during most of last decade, developing into a matter of high concern in most of the world. From a subject with little impact, of interest only to environmentalists and to parts of the scientific community, it rose to a high publicity issue. So what does biodiversity mean? Most people, especially biologists, are inclined to agree that it is, in one sense, everything. But since 'everything' is a bit too abstract, difficult to measure and to quantify, let's try to see how it can be defined and described in a measurable way.

The word biodiversity is a contraction of biological diversity. It was first used during the National Forum on BioDiversity held in Washington in 1986. The proceedings of the forum were published two years later under the title BioDiversity, and were later cited, most often inaccurately, as Biodiversity (Wilson, 1997). By 1992, at the United Nations Conference on Environment and Development in Rio de Janeiro, biodiversity became a major issue of concern worldwide, with the Convention on Biological Diversity (CBD) being signed by 168 countries. Presently there are over 180 Parties through ratification after signature or accession (i.e. ratification without signature). It is over 10 years now since the signing of the CBD and almost 10 years after entry into force (December 1993), and biodiversity is still a 'hot topic', drawing the attention not only of ecologists and biologists, but also economists, lawyers and politicians. This huge, unexpected 'success' of the term biodiversity could be explained as a result of our failure to manage and preserve our natural resources, most often focused only on species diversity. Biodiversity was the political response to this problem, bringing a more comprehensive approach in dealing with conservation problems. Perhaps the most important contribution made by 'biodiversity', is that it provides a basis for influencing the political process, and encourages those involved in conservation to look more seriously at the major aspects of concern (McNeely, 1998).

In policy discussions, biodiversity covers a huge and heterogeneous array of topics, scales and questions. Diversity is a concept that refers to the range of variation or differences among some set of entities, being a measure of its heterogeneity. Biological diversity is the result of evolutionary processes during geological periods that generated the entire variety of biological and ecological systems, allowing the existence of life in a multitude of forms. It includes the variety of components of the ecosphere, of the entire hierarchy of the biological and ecological systems. Since biodiversity includes entities with varying degrees of complexity and different time-space scales it has a hierarchical structure (Figure 1.1).

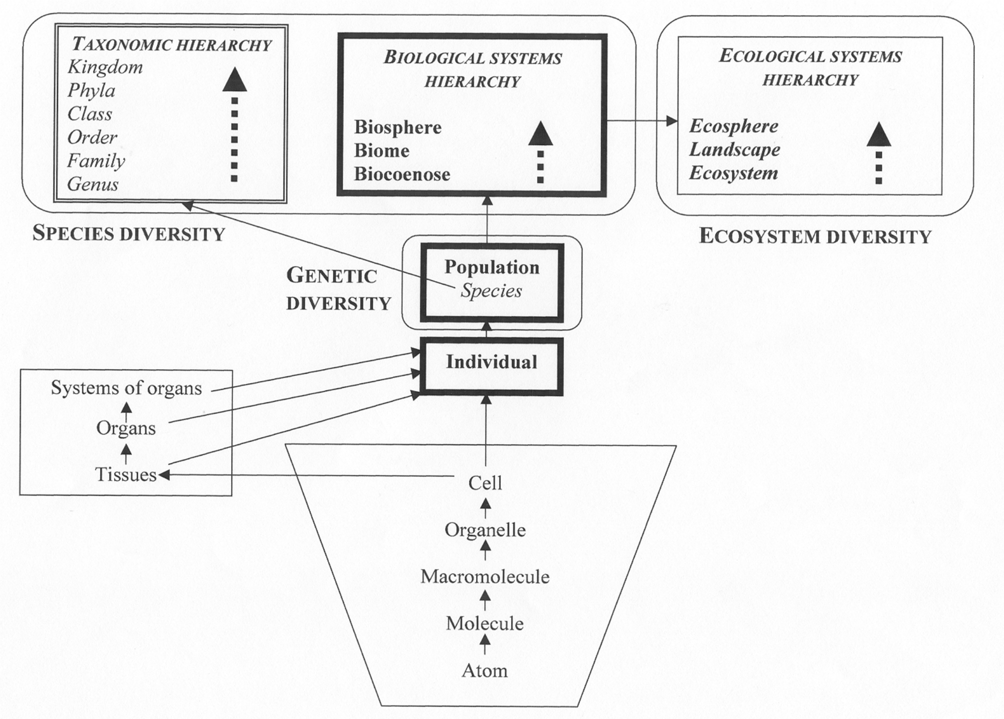

Figure 1.1 The hierarchical structure of the different components of biodiversity (adapted from Botnariuc, 1992).

1.2 Components of biodiversity

The most often cited and used definition of biodiversity is that given in the Convention on Biological Diversity (Article 2): 'Biological diversity' means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Three main components are thus defined: genetic diversity (within species), species diversity, and ecosystem diversity. A fourth component is sometimes added, the ethno-cultural or human diversity. Several dozen definitions are in use (Table 1.1). The topic is further complicated since there is a variety of other terms referring to biological diversity that appear in the scientific literature, most of them as synonyms or measures of the three major components. For example, genetic diversity is sometimes measured or quantified as biochemical diversity. Species diversity is often estimated at higher taxonomic levels as taxic diversity, defined as a measure of both the number of species, of their taxonomic position and the different contributions that species make. It can also be measured as the diversity of species within trophic levels (referred as trophic diversity), taxonomic groups, or even according to size or growth form. Another frequently used measure of species diversity is taxonomic or phyletic diversity, which is a measure of the diversity of higher taxa within a group of species. An interesting method to measure phyletic diversity of a subset of taxa was proposed by Faith (1995), as the sum of the lengths of the branches found along the path down the tree connecting all taxa in the subset, which assesses the amount of evolution preserved. Another measure of species diversity, focused not on sheer number (structure) but on the functions performed is functional diversity, which is defined in two different ways, either as the diversity of the ecological functions performed by different species, or as the diversity of species performing a given ecological function. Last, ecosystem diversity is sometimes referred to as system diversity, ecological diversity or habitat diversity (van der Maarel, 1997).

A biodiversity approach not only links species conservation with habitat and genetic conservation, but also addresses the political, social and economic factors involved. Due to its wide coverage biodiversity cannot be directly studied as a whole, only at different levels of complexity (genes, species, ecosystems). Species are the most useful component in the study of biodiversity, since they represent its best reflection, are discrete entities, and at least there is a relative consensus regarding their definition and identification. Also the number of species can be (at least in theory) estimated at different spatial scales. Species are also good indicators of environmental stress, some of them provide key roles in the provision of ecological services and last, but not least, individual species are the units of interest to people. There are also several major drawbacks when focusing on species diversity: there is still no universal definition of species and the criteria used for describing species vary between higher taxa. Despite these, species diversity remains the major component of biodiversity on which focus most scientific, public and political issues.

Table 1.1 The diversity of definitions of biodiversity.

Definition	Source
Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes, and their relative abundance.	OTA, 1987
Biodiversity is the variety of the world's organisms, including their genetic diversity and the assemblages they form. It is the blanket term for the natural biological wealth that undergirds human life and well-being. The breadths of the concept reflect the interrelatedness of genes, species and ecosystems.	Reid and Miller, 1989
Biological diversity encompasses all species of plants, animals and microorganisms and the ecosystems and ecological processes of which they are part. It is an umbrella term for the degree of nature's variety, including both the number and frequency of ecosystems, species or genes in a given assemblage.	McNeely et al., 1990
The genetic, taxonomic and ecosystem variety in living organisms of a given area, environment, ecosystem or the whole planet.	McAllister, 1991
Biological diversity refers to the full range of variety and variability within and among living organisms, their associations and habitat-oriented ecological complexes. The term encompasses ecosystem, species and landscape, as well as intraspecific (genetic) levels of diversity.	Fiedler and Jain, 1992
The structural and functional variety of life forms at genetic, population, species, community and ecosystem levels.	Sandlund et al., 1992
The variety of living organisms considered at all levels, from genetics through species, to higher taxonomic levels, and including the variety of habitats and ecosystems.	Meffe and Carroll, 1994
Biodiversity is a state or attribute of a site or area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans. Biodiversity can be measured in terms of genetic diversity and the identity and number of different types of species, assemblages of species, biotic communities and biotic processes and the amount (e.g., abundance, biomass, cover, rate) and structure of each. It can be observed and measured at any spatial scale ranging from microsites and habitat patches to the entire biosphere.	DeLong, 1996
Biodiversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.	EPA, 1997
The variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels; includes the variety of ecosystems, which comprise both the communities of organisms within particular habitats and the physical conditions under which they live.	Wilson, 2001
Biodiversity refers to species, genetic, and ecosystem diversity in an area, sometimes including associated abiotic components such as landscape features, drainage systems, and climate.	Swingland, 2001
Biodiversity is synonymous with species richness and relative species abundance in space and time. Species richness is simply the total number of species in a defined space at a given time, and relative species abundance refers to their commonness or rarity.	Hubbell, 2001

1.3 What is a species?

Species are the basic units of classification, consisting of a population or series of populations of closely related and similar individuals (see chapter 2.2). For organisms reproducing sexually, the Biological Species Concept defines a species as a population or series of populations that freely interbreed with one another in natural conditions, but not with members of other species (Mayr, 1942). Species also have a historical continuity, they have existed in the past and, unless they become extinct, will continue to exist in the future. They can be viewed as a channel transmitting genetic information in time through the component individuals.

Species are real, well-defined biological systems but nevertheless they are paradoxical entities. They are torn apart between the need for preserving their identity and travel through time without alteration (conservative), and the permanent changes due to mutations and recombinations (evolution), which cancel their initial identity (Botnariuc, 1992). There are several mechanisms and processes that operate at different levels of complexity and allow for their dual nature. At genetic level the redundancy of genetic information (double strand of DNA, double number of chromosomes in most species, complete genetic information within each cell of metazoans), the various DNA reparatory systems, and the semi-conservative mechanisms of multiplication/replication converge to the unaltered transfer in time of the genetic information. The opposing processes are mutations and recombinations, induced by a variety of factors that affect all levels of complexity (codon, gene, chromosome, and genome). At populational level, panmixia (i.e. the random breeding among individuals within a population) is mitigated by a wide variety of mostly behavioral, reproductive barriers that limit its importance. Dispersal, as a process that maintains cohesion among the populations belonging to a species, is often limited. Thus, species appear to be contradicting, unstable systems navigating between metastable phases.

1.4 Time-space scales in the study of biodiversity

Species are historical units, the result of continuous selective and adaptive processes. The footprint of this historical evolution is stored in the genotype. Species are not only following certain patterns of distribution in time but also in space, occupying ranges that vary in size between tens of square meters to millions of square km. Present day biodiversity is the result of almost four billion years of dynamic evolution, during which the Earth suffered major changes, with entire continents rising and disappearing and billions of species that appeared and then became extinct in time. Natural changes are still taking place, but human influences are becoming dominant in major parts of the world. It is difficult to study and understand the complex patterns and mechanisms behind these dynamic processes, but certain general rules must be followed. Perhaps the first and most important is a correct scaling of the domain of interest, in both time and space.

Biodiversity has a many-fold importance for us, from local to global scales. Different processes operate at different time-space scales. It is therefore extremely important, when attempting to study and understand the dynamic changes within the different components of biodiversity, to confine to a certain time-space domain.

The rising of the concept of scale in ecology has received increasing attention lately. Schneider (2001) reviews how the concept of scale became a central concern in ecology. The problem of scale arose because the major, pressing problems in ecology take place at scales of tens and hundreds of years, on areas large sometimes of millions of square kilometers, but we measure variables on small areas, during short periods of time. Patterns measured at small spatial and temporal scales are often not valid at larger scales, nor do processes dominant at small scales necessarily prevail at larger scales. We are trying to address problems at larger scales by studying them locally, and frequently we are getting wrong or biased answers when up-scaling. To cope with the present biodiversity crisis we have to understand the time-space scale and the different patterns and processes operating within each domain (Table 1.2). With a correct understanding of scaling we can start asking pertinent questions and limit the usefulness of the answers obtained within their range of applicability.

Table 1.2 The major time-space domains within biodiversity studies. Note that there is a certain degree of overlapping among the different domains.

Hierarchical units (biological/ ecological)	Scale domain	Space scale range (m^2)	Time scale range (years)	Disturbance process	Biotic processes	Discipline
Population/ habitat	Local	10^1 - 10^7	10^{-2} – 10^3	Epidemics	Population demographics	Population biology
Community/ ecosystem	Local	10^5 - 10^7	10^1 – 10^3	Periodic abiotic disturbances (e.g. fire regime, floods)	Ecological succession/ genetic variation	Ecology
Biota/Landscape	Regional	10^7 - 10^{10}	10^3 – 10^5	Extreme abiotic disturbances	Speciation and extinction	Landscape ecology
Macrobiota/ Biogeographical province	Macro-regional	10^{10} - 10^{14}	10^4 – 10^8	Climate changes	Evolution of biotas	Evolutionary biology / Paleontology
Biosphere/ Ecosphere	Global	10^{15}	10^5 – 10^9	Plate tectonics	Macroevolution	Life sciences

1.5 Genesis of biodiversity

Before discussing the dynamic changes in biodiversity at different time and spatial scales, a brief outline of how life developed on Earth is needed. Present-day biodiversity is the result of almost four billion years of evolution marked by innovative solutions and rapid forward leaps followed by long periods of stagnation. It all started about 4.5 billion years ago with the formation of planet Earth, a part separated from the Sun, boiling at huge temperatures. In time it started to cool, allowing the formation of the atmosphere, then the lithosphere (the solid surface crust) and, when the temperature dropped below 100^0C, of the hydrosphere. At that time everything was different from present, the oceans were very acid and the atmosphere consisted mainly of carbon dioxide. The first living organisms appeared in the ocean about

3.5-4.0 billion years ago. They were bacteria like, lacking organelles and nucleus (prokaryotes), feeding on the organic compounds dissolved in water. Soon, i.e. more than 3 billion years ago, there was not enough food for all of them. Some organisms turned towards a better source of energy, plentiful and unending, the solar radiation, and started transforming and storing it as chemical energy through photosynthesis. Photosynthesis allowed the organisms to thrive on this huge source of energy, but also had a side effect that in time completely restructured the planet. During photosynthesis water molecules are decomposed to use the hydrogen and the dangerous, extremely reactive compound previously bound to it, oxygen, is eliminated as gas. Due to its high chemical reactivity oxygen tends to combine with a variety of substances and disrupts vital processes within an organism not provided with defense mechanisms. In time oxygen started to accumulate in both water and air, and about 2 billion years ago, at less than 0.3% of its present concentration (Botnariuc, 1999), it was toxic enough and could not be ignored anymore. Instead of building further defenses against oxygen's toxicity, most living organisms started using its reactivity to further break down organic compounds and use more of the chemical energy stored, a process called respiration. A similar approach was used towards another highly toxic compound, widespread in the environment, calcium, which was bound and stored within the body in special formations. Organisms started to make better and better use of calcium by constructing elaborated exoskeletons and later on endoskeletons, which eventually provided for most of the fossil record.

The more efficient oxygen-burning cells grew faster and, in time, started to include other cells within their own membrane, cells that became specialized either in photosynthesis (plastids), or respiration (mitochondria), a process named endosymbiosis. In this way the first eukaryotic organisms were formed about 1.8 billion years ago (Margulis, 1992). About 1.1 billion years ago the simple asexual reproductive strategies were replaced with a more complicated process, derived from the DNA repairing mechanisms, named sexuality (Margulis and Sagan, 1986). After a couple of hundred million years the first metazoans (i.e. multicellular) algae were recorded from the fossil record, followed around 600 million years ago by the first invertebrate metazoans (Schopf, 1994). Then a burst in speciation occurred, with new and innovative plans of organization arising, and with a huge diversity of phyla emerging. The most important and impressive burst of speciation occurred at the beginning of the Cambrian. This process can be divided in three different stages (Philippe and Adonette, 1996). The initial Precambrian fauna, most probably diploblastic, appeared about 570-555 million years ago, and by the early Cambrian, already most organisms were triploblasts (540 million years ago), followed by the explosive diversification of this fauna in the middle Cambrian (520 million years ago). Thus, it appears that the major diversification of metazoans into more than the 35 extant phyla, since several lineages were later eliminated, may have occurred in less than 20 million years. The first primitive fish, animals with internal skeletons, appeared about 500 million years ago. Then a huge increase in species diversity occurred by growing command of Earth's environment. Plants were already producing large amounts of oxygen, so its concentration in the atmosphere reached at that time a concentration similar to the present-day one. When at high altitude in the atmosphere, the oxygen molecule (O_2), consisting of two oxygen atoms, can be broken apart by the high-energy content of ultraviolet (UV) radiation. The resulting oxygen radicals are extremely reactive and can combine with an oxygen molecule generating a compound called ozone (O_3). Ozone can absorb UV radiation and in time, the large quantities of ozone accumulated in the higher strata of the atmosphere, tens of km above the surface, created a shield against the harmful effects of this radiation. Until then, life forms existed only in water, which could shield them from UV radiation. Land was a barren, scorched, desert-like structure, deprived of any life forms.

About 440 million years ago the first plants, followed by invertebrates and vertebrates, started colonizing the land. It was not an easy task since water is 775 times denser than air and aquatic organisms have adapted by having a specific gravity just slightly higher. They needed no supporting tissues or supporting organs, which are used, when present, only to assist in movement. Nevertheless, movement in water requires more energy than in air (Dobson and Frid, 1998). Also, life on land was controlled from the very beginning by a vital, limiting resource, which was water. Colonizing organisms, deserting the aquatic environment had to adapt and limit water losses by insulating their external parts, by developing storing formations and by reducing water needs and consumption. Plants had to develop huge skeletons consisting of cellulose and lignin to fight gravity, and had to adapt to the limited water supply at their lower end by building pumps that could send water, sometimes tens of meters high, against the gravity pull. The harsh terrestrial environment put a tremendous pressure on the organisms that attempted to colonize and adapt to it. Not all marine phyla attempted or succeeded in doing so. Although now there are more terrestrial than aquatic species, the complexity of life forms is lower on land. The most successful group that developed on land in an enormous variety of similar forms were the insects. The large amount of organic matter stored in woody structures were mostly unavailable to usual grazers and herbivores, and accumulated in enormous quantities, parts contributing to the formation of soils, while others in time transformed into coal. In this way huge amounts of carbon dioxide were pumped from the atmosphere and caused a decrease of the greenhouse effect, inducing the first biotic-driven climatic changes. At this stage, all the surface of the planet was already covered by life forms, generating the newest layer called the biosphere.

2. Species diversity

2.1 How big was Noah's Ark?

The enormous diversity of life forms has long intrigued humans, but few attempts to inventory it were done before the 18th century. The Swedish botanist Linné first proposed in 1758 the binary system of classification of living organisms that is still in use and since the number of species described has steadily increased (Figure 2.1). It is generally agreed that of the 1.7–1.8 million species described until now, only about 1.4 million are valid species (Figure 2.2), but estimates of the total number of species varies between a conservative figure of 3 million and over 100 millions (Table 2.1).

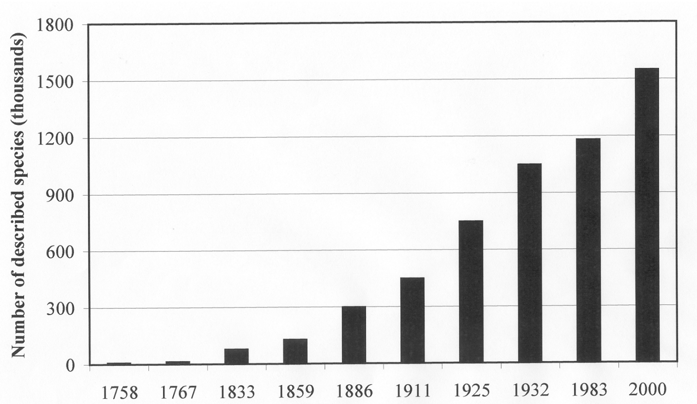

Figure 2.1 The increase in the number of species described starting with Linné (1758) until present (from Cogălniceanu, 1999).

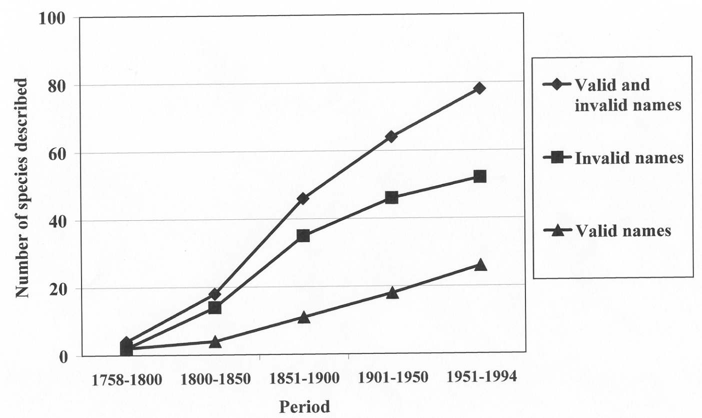

Figure 2.2. Valid and invalid (i.e. duplicates) scientific names published for frogs of the subgenus *Rana* (*Pelophylax*) from 1758 to 1994 (data from Table 1 in Dubois and Ohler, 1994).

Insects represent more than half of the known species so most of the estimates of the total number of species are based on this group. Perhaps the most cited, praised, and criticized estimate of the actual number of species at over 30 millions, is due to the American entomologist Erwin. He collected in Panama in the canopy of 19 trees belonging to a single species, *Luehea seemannii*, 7735 beetles (Coleoptera), belonging to 1143 species. He then attempted to estimate the number of host-specific species (Table 2.2). Based on this estimate it results that for each tree species there are 163 host-specific coleoptera (Erwin, 1982). He then proceeded with the following arguments:

1. Since there are 50,000 tree species in the world and if each has 163 host- specific coleoptera, then there are 50,000 x 163 = 8,150,000 coleopteran species associated with tree canopy.

2. Since the known species of coleoptera represent about 40% of the total number of arthropods, then there are 8,150,000 x 100/40 = 20,375,000 species of arthropods living in tree canopy.

3. If at ground level the number of species is half the one in the canopy, then the total number of arthropod species is 20,375,000 + 20,375,000/2 = 30,562,500.

The assumptions made by Erwin provided an agenda for research and subsequently all of these were tested. This extrapolation might be correct or not, and Erwin's assumptions were repeatedly criticized (e.g. Stork, 1997, Novotny et al., 2002), but the facts remain that 1143 species of beetles were collected from just 19 trees. More sampling might double, triple or even more increase Erwin's number of found species, but never reduce this number. This is hard data and an excellent proof of the huge diversity of life forms. Rosenzweig (1995) states that 'it is not really important if better estimates show that Erwin's estimate of 30 millions is off by a factor of five. Noah may have needed to know the exact truth, but the rest of us will simply have to admit that there are more insects than we can keep track off.' Erwin's estimate was repeatedly used to show how little we know the global species diversity, and also to indicate the threat of extinction due to forest loss. The figure of 30 million species has become a political tool, and until better estimates become available we should accept it despite its limits.

A recent study (Novotny et al., 2002) suggests that Erwin grossly overestimated arthropod diversity. After analyzing over 900 herbivorous insect species feeding on 51 plant species in New Guinea, a low host specificity was found. When inserting this lower value in Erwin's calculations, the global estimate of arthropod diversity becomes 4-6 million species. This new estimate is comparable to other similar studies and, even more important, is in agreement with estimates based on the analysis of regional faunas and the evaluation of museum collections by taxonomists, reconciling the disparate results of ecological and taxonomic approaches to the estimation of global species richness.

The gaps in the inventory of species richness exist because identifying and counting species is not an easy task. There are several major difficulties related to the study of species diversity (Bouchet, 2000):