INTERNATIONAL MASTER IN SUSTAINABLE DEVELOPMENT

MODULE: SUSTAINABILITY ELEMENTS: ENVIRONMENTAL PROTECTION

SUBJECT: BIOLOGICAL RESOURCES

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Introduction

"Biodiversity," the term and concept, has been a remarkable event in recent cultural evolution: 15 years ago the word did not exist, except perhaps through occasional idiosyncratic use. Today it is one of the most commonly used expressions in the biological sciences and has become a household word. It was born "BioDiversity" (later to be cited with less than bibliographical accuracy by most authors as *Biodiversity),* during the National Forum on BioDiversity, held in Washington, D.C., on September 21-24, 1986, under the auspices of the National Academy of Sciences and the Smithsonian Institution. By the summer of 1992, as a key topic of the Rio environmental summit meeting, biodiversity had moved to center stage as one of the central issues of scientific and political concern world-wide.

So what is it? Biologists are inclined to agree that it is, in one sense, everything. Biodiversity is defined as all hereditarily based variation at all levels of organization, from the genes within a single local population or species, to the species composing all or part of a local community, and finally to the communities themselves that compose the living parts of the diverse ecosystems of the world. The key to the effective analysis of biodiversity is the precise definition of each level of organization when it is being addressed.

Even though the study of biodiversity can be traced back as far as Aristotle, what finally has given it such extraordinarily widespread attention is the realization that it is disappearing. In the late 1970s and through the 1980s, the first convincing estimates were made of the rate of tropical deforestation, which translates to the area loss of habitat where most of living diversity is concentrated. This information led to disturbingly high estimates of the rates of loss of species in these forests. The magnitude of erosion also drew attention to ongoing extinction in other habitats, from deserts to coral reefs, at all levels of biological organization from alleles to entire local ecosystems. It became clear that the decline of Earth's biodiversity was serious. Worse, unlike toxic pollution and ozone depletion, it cannot be reversed.

Scientists who once had devoted their careers to bits and pieces of biodiversity now became holists, or at least more approving of the holistic approach, and they were energized by a new sense of mission. For the good of society as a whole, they now realized that the classification of such organisms as braconid wasps and lauraceous shrubs mattered. Moreover, the ecologists also were included: the processes by which natural communities are assembled and their constituent species maintained have central importance in both science and the real world. The study of diversity considered old problems in systematics and ecology, and specialists in these and in related fields of biology began to talk in common language as never before. Just as significantly, physical scientists, social scientists, geographers, and artists were drawn into the dialogue. The subject consequently has begun to be reshaped into a new, often surprisingly eclectic field of inquiry. Today we now hear regularly of "biodiversity science" and "biodiversity studies."

Since the 1986 National Forum on BioDiversity, there has been an exponential rise in research and technical innovation. Scientists appreciate that only a tiny fraction of biodiversity on Earth has been explored, and that its origin and maintenance pose some of the most fundamental problems of the biological sciences. These problems are also among the least technically tractable. Those who have cut into the outer surface of ecology and evolution suspect that molecular and cell biology eventually will prove simple by comparison.

Some scientists and policy-makers have worried that the magnitude of the biodiversity we now know to be present in the world's habitats is so enormous, the cost of exploring and documenting it so overwhelming, and the number of biologists who can analyze and document it so small that the goal of understanding the diversity of the world's species is unattainable. The central message of this lecture is, to the contrary, that the potential benefits of knowing and conserving this biodiversity are too great and the costs of losing it are too high to take a path of least resistance. There is a cost-effective and feasible way of approaching the conservation of the world's biological resources. The key to a cost-effective solution to the biodiversity crisis lies in the collaboration of museums, research institutions, and universities; the pooling of human and financial resources; and the shared use of physical and institutional structures that are already present. Rather than building the knowledge, institutional, and physical infrastructure for documenting biodiversity from the ground up, we need to build upon the preexisting infrastructure and increase support for systematics, training, and museums. Furthermore, this collaboration represents the type of cooperation that will be necessary for us to understand and protect our natural resources.

1. STATUS AND TRENDS OF GLOBAL BIODIVERSITY

1.1 Basic concepts and definitions

Marion Island

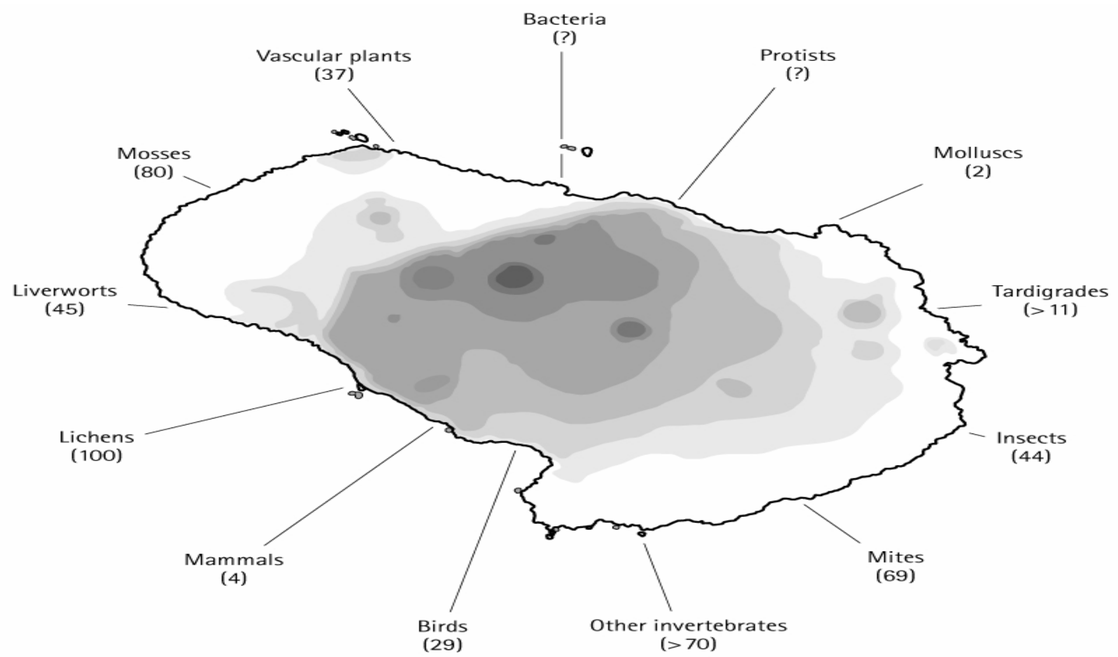

Fig. The breeding species of sub-Antarctic Marion Island, one of the two remote Prince Edward Islands. Grey scales indicate variation in elevation. (Data from a variety of sources, including Gremmen 1981; Hänel & Chown 1999; Gaston et al. 2001; Øvstedal & Gremmen 2001; S.L. Chown pers. comm.)

have associated parasites, but these also are mostly unknown. Indeed, there is a total of more than 500 species inhabiting Marion Island (Fig. below).

Each of these species embraces a diverse range of evolutionary history, genetics, morphology, physiology and ecology. Each typically also comprises many tens of thousands of individuals, sometimes considerably less, but sometimes orders of magnitude more. For the majority, rather few of these individuals actually occur on Marion Island itself (although there are some species that occur nowhere else), but are scattered over the land- or seascape across many hundreds of square kilometers. Most of these individuals will have a unique genetic make-up, and, if only in the fine details, a unique morphology, physiology and ecology.

Such variety is echoed time and again across the Earth. Indeed, although it is important because some species found there occur nowhere else, and because of the large breeding populations of birds and mammals, Marion Island would scarcely register on any league table of biological variation. It is by most standards a very disadvantaged place – as well as being small and remote, it is also cool (mean annual air temperature c. 5°C), wet (annual rainfall □2.5 m), windy (gale-force winds blow for at least 1 h on nearly a third of all days) and was extensively covered in ice during recent periods of glaciations, a combination that would not predispose it to 'Eden-like' tendencies. Many areas have many more species, individuals of which exhibit greater diversities of form and function. For example:

- 173 species of lichens have been recorded on a single tree in Papua New Guinea (Aptroot 1997);
- 814 species of trees have been recorded from a 50 ha study plot in Peninsular Malaysia (Manokaran et al. 1992);
- 850 species of invertebrates are estimated to occur at a sandy beach site in the North Sea (Armonies & Reise 2000);
- 1300 species of butterflies have been recorded on five field trips, averaging less than 3 weeks each, to an area of □4000 ha in Brazil (Robbins & Opler 1997);
- 245 resident species of birds have been recorded holding territories on a 97 ha plot in Peru (Terborgh et al. 1990);
- 200 species of mammals may occur at some sites in the Amazonian rain forest (Voss & Emmons 1996);
- 55–135 animal species have been recorded in individual 30 x 30 cm cores of ocean floor sediment from 2100 m depth (Grassle & Maciolek 1992).

What is biodiversity?

Most straightforwardly, biological diversity or biodiversity is 'the variety of life', and refers collectively to variation at all levels of biological organization. Thus, one can, for example, speak equally of the biodiversity of some small or large part of Marion Island, of the island as a whole, of the islands of the Southern Ocean, of a continent or an ocean basin, or of the entire Earth. Many more formal definitions of biological diversity or biodiversity (we shall use the two terms interchangeably) have been proposed, which develop this simple one (DeLong 1996 reviewed 85 such definitions!). Of these, perhaps the most important and far-reaching is that contained within the Convention on Biological Diversity (the definition is provided in Article 2). This landmark treaty was signed by more than 150 nations on 5th June 1992 at the United Nations Conference on Environment and Development, held in Rio de Janeiro, and came into force approximately 18 months later (we shall subsequently refer to it simply as 'the Convention', although elsewhere you will commonly find it referred to by its acronym, CBD).

The Convention states that:

'Biological diversity' means 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.

['*inter alia*' means 'among other things'.] Biodiversity is the variety of life, in all of its many manifestations. It encompasses all forms, levels and combinations of natural variation and thus serves as a broad unifying concept.

At present it does not obviously take into account the tremendous variety of biological life that occurred in the past, some of which is preserved in the fossil record.

The actual definition of biodiversity, as given above, is neutral with regard to any importance it may be perceived to have. The Convention is, in contrast, far from a neutral document, as amply revealed by its objectives (Article 1), which are:

. . . the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic

resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.

Likewise, much of the usage of the term 'biodiversity' is value laden. It carries with it connotations that biodiversity is per se a good thing, that its loss is bad, and that something should be done to maintain it. Consequently, it is important to recognize that there is rather more to use of the term than a formal definition in the Convention, or for that matter elsewhere, and its application often reveals just as much about the values of the person using it. This should always be borne in mind when interpreting what is being said about biodiversity, particularly now that the term has become a familiar feature of news programs and papers, and importance is attached to it by environmental groups, political decision-makers, economists and ordinary citizens alike. Many users assume everyone shares the same intuitive definition, but this is not necessarily the case.

Elements of biodiversity

The variety of life is expressed in a multiplicity of ways. Some sense of this variety can begin to be made by distinguishing between different key elements. These are the basic building blocks of biodiversity. They can be divided into three groups: (i) genetic diversity; (ii) organism or species diversity; and (iii) ecological diversity (see table below). Genetic diversity encompasses the components of the genetic coding that structures organisms (nucleotides, genes, chromosomes) and variation in the genetic make-up between individuals within a population and between populations. Organism diversity encompasses the taxonomic hierarchy and its components, from individuals upwards to species, genera and beyond. Ecological diversity encompasses the scales of ecological differences from populations, through niches and habitats, on up to biomes. Although presented separately, the groups are intimately linked, and in some cases share elements in common (e.g. populations appear in all three).

Some of these elements are more readily, and more consistently, defined than are others. When we consider genetic diversity, nucleotides, genes and chromosomes are discrete, readily recognizable, and comparative units. Things are not quite so straightforward and neat when we move up to individuals and populations, with complications being introduced by, for example, the existence of clonal organisms and difficulties in identifying the spatial limits to populations. When we come to organism diversity most of the elements are perhaps best viewed foremost simply as convenient human constructs for grouping evolutionarily related sets of individuals (although they do not always manage to do so). For instance, debate persists over exactly how many

taxonomic kingdoms of organisms there should be, with a three domain natural classification being increasingly widely accepted (Bacteria and Archaea (prokaryotes), and Eukarya (eukaryotes)). When we refer to orders, families, genera or species of different groups we are not necessarily comparing like with like, although within a group

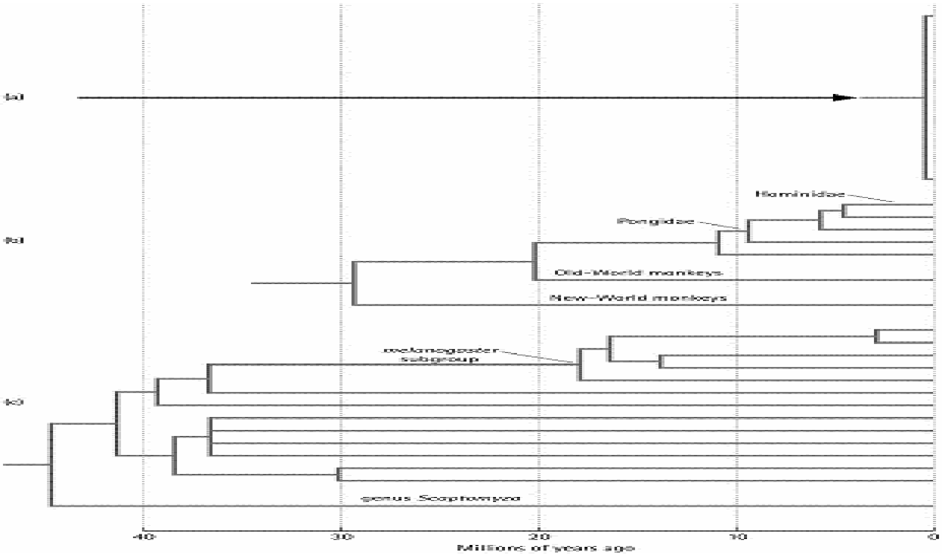

Fig. Examples of disparities of taxonomic assignments in classifications of representatives of: (a) cichlid fish in Lake Victoria (14 species in nine genera); (b) anthropoid primates (seven species of several families); and (c) the genus *Drosophila* (13 species). (From Avise & Johns 1999.)

examples of a given taxonomic level (e.g. different genera) may be broadly comparable. Thus, some species placed in different genera of cichlid fishes last shared common ancestors within the last few thousand years, some species placed in different families of primates diverged within the last few million years, and some species in the genus *Drosophila* diverged more than 40 million years ago (Fig. Below).

Even the reality and recognition of species, for long considered one of the few biologically meaningful elements, has been a recurrent theme of debate for many decades, and a broad range of opinions and viewpoints have been voiced. Finally, and perhaps most problematic, is exactly how we define the various elements of ecological diversity. In most cases these elements constitute useful ways of breaking up continua of phenomena. However, they are difficult to distinguish without recourse to what ultimately constitute some essentially arbitrary rules. For example, whilst it is helpful to be able to label different habitat types, it is not always obvious precisely where one should end and another begin, because no such beginnings and endings really exist.

While many of the elements of biodiversity may be difficult to define rigorously, and in some cases may have no strict biological reality, they remain useful and important tools for thinking about and studying biodiversity. Thus, the elements of biodiversity, however defined, are not independent. Within each of the three groups of genetic, organismal and ecological diversity, the elements of biodiversity can be viewed as forming nested hierarchies (see table below)

Table. Elements of biodiversity. (Adapted from Heywood & Baste 1995.)

Ecological diversity		**Organism diversity**
Biomes		Domains or Kingdoms
Bioregions		Phyla
Landscapes		Families
Ecosystems		Genera
Habitats		Species
Niches	**Genetic diversity**	Subspecies
Populations	Populations	Populations
	Individuals	Individuals
	Chromosomes	
	Genes	
	Nucleotides	

which serves also to render the complexity of biodiversity more tractable. For example, within genetic diversity, populations are constituted of individuals, each individual has a complement of chromosomes, these chromosomes comprise numbers of genes, and genes are constructed from nucleotides. Likewise, within organism diversity kingdoms, phyla, families, genera, species, subspecies, populations and individuals form a nested sequence, in which all elements at lower levels belong to one example of each of the elements at higher levels. Along with the evolutionary process, this hierarchical organization of biodiversity reflects one of the central organizing principles of modern biology.

Whether any one element of biodiversity, from each or all of the three groups, can be regarded in some way as the most fundamental, essential or even natural is a contentious issue. For some, genes are the basic unit of life. However, in practice, it is often the species that is treated as the most fundamental element of biodiversity.

Table (a) Species concepts; and (b) their strengths and weaknesses. (from Bisby 1995.)

(a)

Species concept	Definition
Biological species	A group of interbreeding natural populations that do not successfully mate or reproduce with other such groups (and, some would add, which occupy a specific niche)
Cohesion species	The smallest group of cohesive individuals that share intrinsic cohesive mechanisms (e.g. interbreeding ability, niche)
Ecological species	A lineage which occupies an adaptive zone different in some way from that of any other lineage in its range and which evolves separately from all lineages outside its range
Evolutionary species	A single lineage of ancestor–descendant populations which is distinct from other such lineages and which has its own evolutionary tendencies and historical fate
Morphological species	The smallest natural populations permanently separated from each other by a distinct discontinuity in heritable characteristics (e.g. morphology, behavior, biochemistry)
Phylogenetic species	The smallest group of organisms that is diagnostically distinct from other such clusters and within which there is parental pattern of ancestry and descent
Recognition species	A group of organisms that recognize each other for the purpose of mating and fertilization

(b)

Species concept,	Practical application	Strengths/weaknesses
Biological	Difficult	Popular, irrelevant to asexual organisms, complicated by natural hybridization, polyploidy, etc.
Cohesion	Difficult	Cohesion is difficult to recognize
Ecological	Difficult	Adaptive zones difficult to define, assumes two species cannot occupy same niche for even a short period
Evolutionary	Difficult	Criteria vague and difficult to observe
Morphological	Common	Morphological criteria may not reflect actual links that hold organisms together into a natural unit

Phylogenetic	Increasing	Will give rise to recognition of many more species than more traditional concepts
Recognition	Difficult	Determining if a feature is used to recognize potential mates is difficult or impossible in many populations

Measuring biodiversity

Number and difference

For many purposes the concept of biodiversity is useful in its own right, as it can provide a valuable shorthand expression for what is a very complex phenomenon. However, for more general applicability, one needs to be able to measure biodiversity, to quantify it in some way. Only then can one address such fundamental questions as how biodiversity has changed through time, where it occurs, and how it can be maintained.

From the definition alone, it is clear that no single measure of biodiversity will be adequate. Indeed, given its great complexity, it would be foolish to believe that the variety of life in an area, however small or large that area might be, could be captured in a single number. Measures of diversity in general, and not solely of biodiversity, are commonly found in basic ecological texts. Essentially, many of these measures have two components: (i) the number of entities; and (ii) the degree of difference (dissimilarity) between those entities. For example, species richness (the number of species) places emphasis on the number of elements. But, weighting each of these species by, say, the numbers of individuals, would be one way of incorporating a metric of the differences between them into a measure (Fig. Below). In the case of biodiversity the entities are one of its elements.

In measuring biodiversity, the breadth of ways in which differences can be expressed is potentially infinite. Think, for example, of the ways in which one could discriminate between just two species. These might include facets of their biochemistry, biogeography, evolutionary history, genetics, morphology or physiology, or perhaps the ecological role they play in a particular community (shredder, decomposer, predator, etc.). As a result of the variety of elements of biodiversity, and of differences between them, there is no single all-embracing measure of biodiversity – nor will there ever be one! This means that it is impossible to state categorically what is

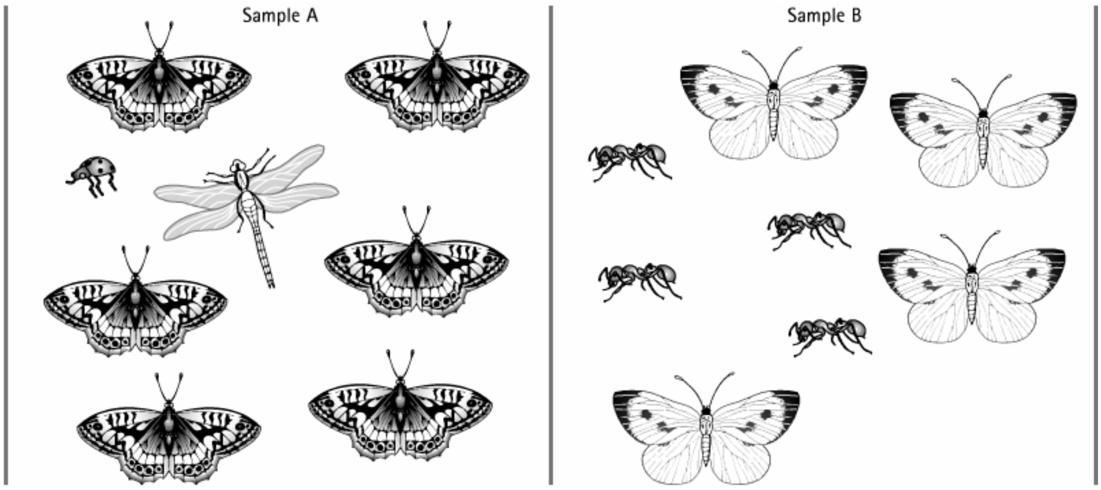

Fig. Two samples of insects from different locations, illustrating two of the many different measures of biodiversity: species richness and species evenness. Sample A could be described as being the more diverse as it contains three species to sample B's two. However, in sample B there is less chance than in sample A that two randomly chosen individuals will be of the same species. (From Purvis & Hector 2000.)

the biodiversity of an area or of a group of organisms. Instead, only measures of certain components can be obtained, and even then such measures are only appropriate for restricted purposes.

Whilst one may feel uncomfortable with this notion, it is important to realize that it also applies, though perhaps not so obviously, in making many other concepts operational. For example, the topic of complex systems is attracting wide interest across a spectrum of fields of research (including physics), but there is no single measure of complexity (or simplicity for that matter). Instead there are many measures, none necessarily any more correct than the others, and which quantify rather different components of complexity. To take an example closer to home, the concept of body size is utilized widely in biology. For example, one can recognize that relationships exist between body size and latitude (the biggest butterflies are found in the tropics) or between body size and abundance (elephants are rarer than many species of mice). And yet there is no such thing as the body size of an organism. Rather, size can be (and is) expressed in a variety of ways, none of which has any obvious logical precedence. Consider two individuals similar in body mass, but differing in linear dimensions. Which is the larger?

Value

Measures of biodiversity are commonly used as bases for making decisions about conservation action, or for planning more generally. It should now be clear that the choice of measure employed might not be neutral with regard to the outcome of such decisions. Different measures of biodiversity may suggest different answers. Moreover, it is important to remember that concentration on a particular element of biodiversity essentially places differential value on that facet of the variety of life. Both what you are measuring and how you are measuring it reveal something about what you most value. For example, if we use measures of ecological diversity as a basis for decision-making this implies that this is the dimension of biodiversity that is of most importance to us.

Genetic diversity as a critical component

Few would disagree that genetic diversity is a critical component of biodiversity. This can be measured both directly (identifying and cataloguing variation in nucleotides, genes and chromosomes; see Table) or indirectly (quantifying variation in phenotypic features shown – or often just assumed – to have a genetic basis). Genes are constructed from strings of nucleotides (DNA). The total number, position and identity (there are four different types) of the nucleotides are all critical in the coding of biological information. Thus, determining nucleotide sequences is arguably one of the strongest measures of genetic diversity, although a large number of other techniques involving DNA analysis are also prevalent (restriction fragment length polymorphism (RFLP), DNA fingerprinting, random amplified polymorphic DNAs (RAPDs), microsatellite variation), their usage being dependent on the precise question being addressed.

Huge variation is encountered in the size and composition of the small, but steadily increasing, number of genomes sequenced to date (Fig. Below).

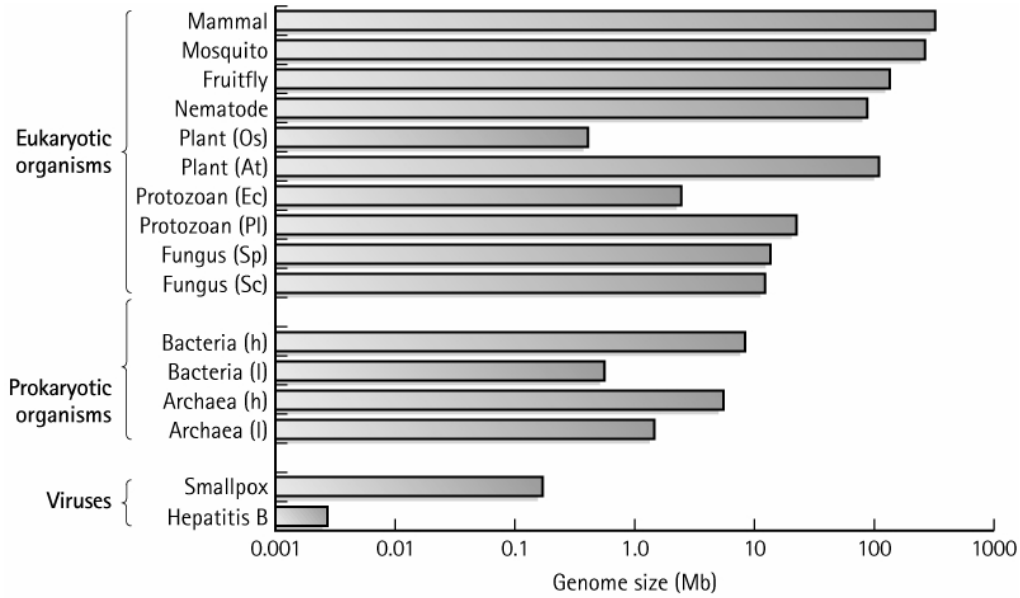

Fig. Genome size for a range of organisms and viruses for which there are complete sequences (data derived from Genome Monitoring Table at http://www2.ebi.ac.uk/genomes/mot and Genomes online database at http://wit.integratedgenomics.com/GOLD). Abbreviations: l, lowest value for the grouping; h, highest value for the grouping; Os, *Oryza sativa*; At, *Arabidopsis thaliana*; Ec, *Encephalitozoon cuniculi*; Pl, *Plasmodium falciparum*; Sp, *Schizosaccharomyces pombe*;

Generally, multicellular organisms tend to have more DNA than single celled organisms but there are exceptions. Similarly, although there appears to be an overall trend of increasing genome size with increasing morphological complexity, this is not invariant. For example, the lung- fish (which still has not been fully sequenced) seems to have approximately 40 times more DNA than the mammal example in Fig. 1.4. This said, many of these discrepancies can be accounted for if comparison is limited to functional portions of DNA, those that encode for functional RNA and proteins. The species with the greatest amount of DNA has about 100,000 times as much as that with the least, but the species with the largest number of genes has only 20 times as many genes as that found in many bacteria. In other words, much of the variation in genomes is attributable not to differences in the number of functional genes, but in the amounts of non-coding DNA. One of the most striking findings from comparative genomics is that there are many 'universal' gene segments (e.g. those that code for ATP-binding sites), suggesting the existence of an ancient minimal set of DNA sequences that all cells must have. There is some evidence that nucleotide sequence divergence increases with increasing taxonomic diversity.

Nucleotide variation may give rise to changes in the character of the actual protein coded for. Until recently allelic variation determined in this way was one of the most commonly used (and cheapest) measures of genetic diversity. It was assessed using allozyme electrophoresis that identifies protein alleles, as different forms of a protein migrate at different rates on a gel. Allozyme electrophoresis has revealed an enormous amount of variation at all hierarchical levels.

Genes are located on chromosomes. All eukaryotic cells contain chromosomes, and their number, size and shape in an individual is referred to as the karyotype. Variation in karyotype has been investigated in detail mainly within species of plants, insects, amphibians and mammals. Most eukaryotes possess between 10 and 50 chromosomes, but there is huge variation both within and between groupings, with the overall range being from one to more than 200 (Fig. below).

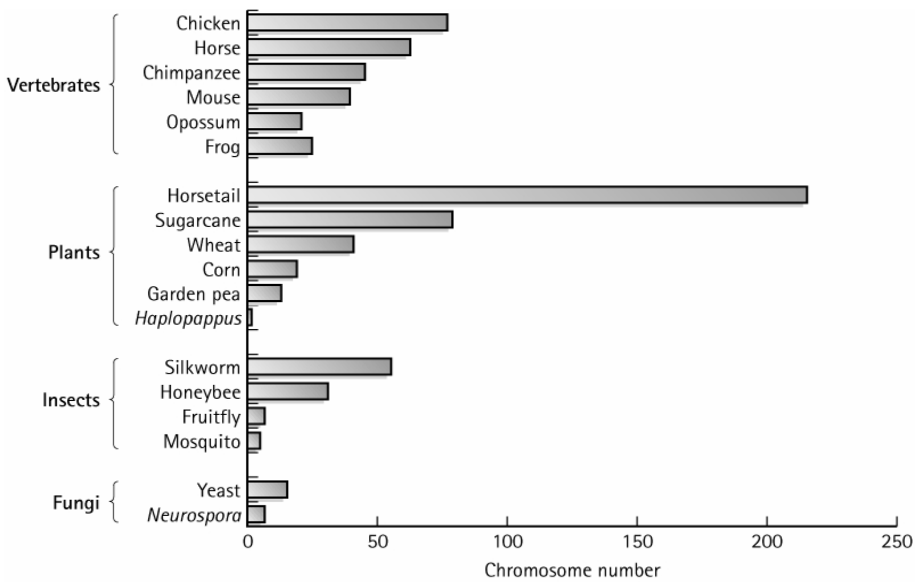

Fig. Chromosome number for a range of organisms. (Data from various sources.)

There is no obvious relationship between chromosome number and any other measure of genetic diversity.

It is difficult to see at present how the various measures of genetic diversity discussed above map onto, or relate to, other measures of biodiversity, and how they could be employed as the primary measures of biodiversity. In the former case, much of the difficulty lies in the limited understanding of how genetic diversity matches up with the results of its expression, phenotypic diversity, although great strides are being made in this area. In the latter case, the difficulty rests in the limited amount of data that are available on genetic diversity through time and space, although the quantity is growing rapidly and the means of obtaining it are becoming more rapid.

Species richness as a common currency

Whilst biodiversity can be measured in a host of ways, in practice it tends most commonly to be measured in terms of species richness, the number of species. There are several reasons why this is so.

1. *Practical application.* Species richness has proven to be measurable in practice, at least to the point where different workers will provide much the same estimation of the number of species of a given status (e.g. present, breeding, wintering) in a given taxon in a given area at a given time.

2. *Existing information*. A substantial amount of information already exists on patterns in species richness, and this has been made available in the scientific literature. Moreover, further information on this can readily be extracted from existing museum collections (which globally comprise many millions of biological specimens) and their associated literature (many millions of volumes), particularly as greater efforts are made to catalogue these collections in computerized databases that are accessible from remote locations.

3. *Surrogacy*. Species richness acts as a surrogate (substitute) measure for many other kinds of variation in biodiversity. In general, as long as the numbers involved are at least moderate, greater numbers of species tend to embody more genetic diversity (in the form of a greater diversity of genes through to populations), more organismal diversity (in the form of greater numbers of individuals through to higher taxa), and greater ecological diversity (from representatives of more niches and habitats through to more biomes) (Fig. Below).

4. *Wide application.* The species unit is commonly seen as the unit of practical management, of legislation, of political discourse, and of tradition (folk taxonomies

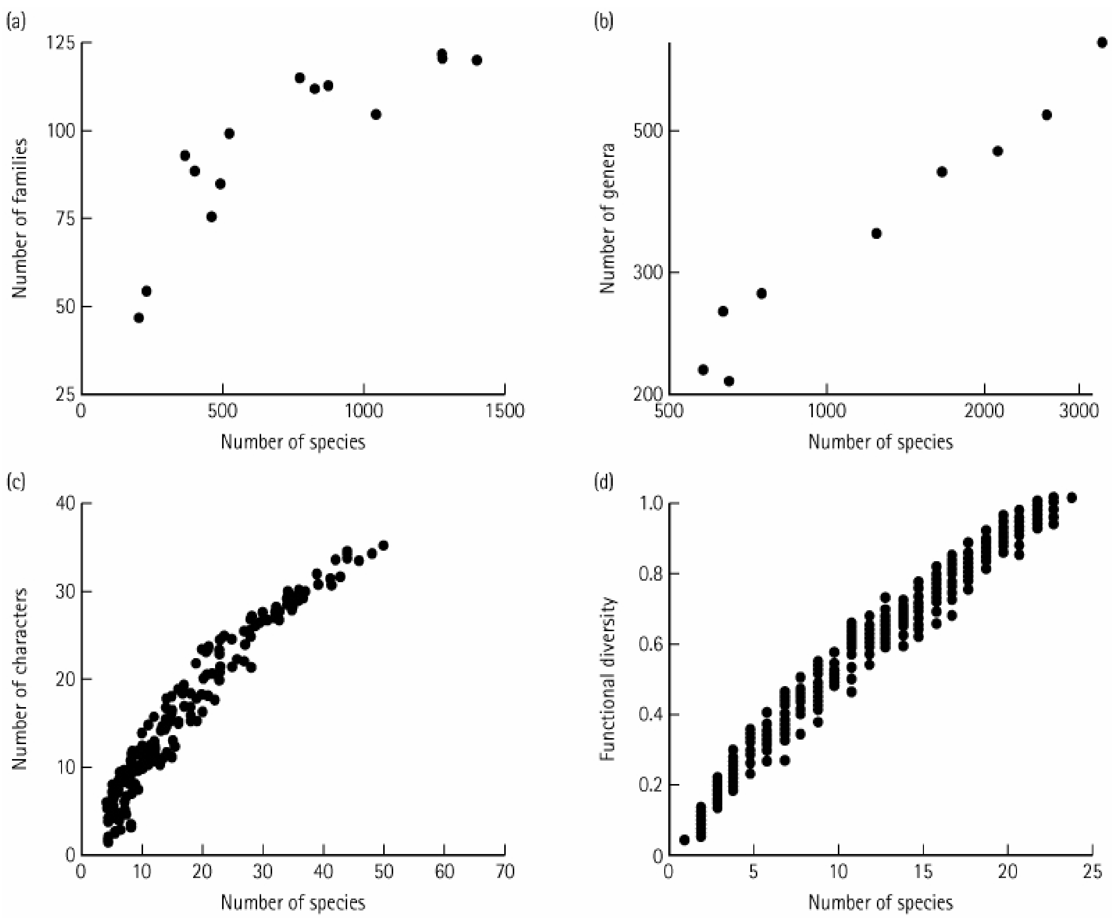

Fig. Relationships between species richness and: (a) family richness for eastern Pacific benthic mollusks in different latitudinal bands; (b) generic richness for macromycete fungi for areas of the UK; (c) character richness for bumblebees among 611,000 km2 grid cells; and (d) functional diversity (a measure of the extent of functional differences amongst a set of species) for Patagonian forbs. (a, From Roy et al. 1996; b, from Balmford et al. 2000; c, from Williams & Humphries 1996; d, from Petchey & Gaston 2002.)

have frequently been found to conform closely to modern ones). For a wide range of people, variation in biodiversity is pictured as variation in species richness.

The above said, the measurement of biodiversity in terms of species richness does have some significant limitations:

• *Definition of species.* The foremost difficulty is the lack of agreement as to precisely what constitutes a species. In major part this results because species can to a large extent be regarded as hypotheses, opinions or concepts, as much as real robust entities. There are at least seven major species concepts, each with their own strengths and weaknesses, from either theoretical or practical perspectives. The application of these different concepts can lead to the recognition of different numbers of species. For example, populations of seemingly coherent morphospecies (species separated on the basis of distinct discontinuities in one or more heritable characteristics, such as morphological features) may actually exhibit levels of genetic divergence typical of different species identified on this alternative basis, and thus constitute so-called cryptic species. Likewise, using a biological species concept, 40–42 species of birds-of-paradise (Paradisaeidae) have been distinguished in Australasia, but using a phylogenetic species concept pushes this figure up to 90 . In practice, such problems are, however, commonly not as severe as this might seem to imply. As the vast majority of groups of organisms have been, and are still being, described based on collections of preserved specimens using differences in morphological characteristics, references to species richness more often than not concern 'morphological' species richness or are very close to estimates based on such a species concept (with some particular level of morphological difference being regarded as sufficient to confer species status). Fortunately, this method of defining a species continues to be relatively effective for most needs (although it may be woefully inadequate for groups such as prokaryotes). There is general consensus amongst appropriate specialists as to the overall numbers of species in a reasonably well-studied group occurring in an area or globally, and radical shifts in the number of species recognized do not tend to occur.

• *Different kinds of diversity.* An additional limitation of species richness as a measure of biodiversity has frequently been illustrated with reference to the issue of whether an assemblage of a small number of closely related species, say two species of mouse, is more or less biodiverse than an equivalent sized assemblage of more distantly related species, say a species of mouse and a species of shrimp. While the latter assemblage would, intuitively, seem to be the more diverse (in terms of morphological variation, differences in evolutionary history, etc.), in terms of species richness the assemblages are equally diverse. The extent to which this is a weakness of using species richness as a measure of biodiversity depends, however, perhaps less on the outcomes of such simple scenarios than on scenarios more typical of studies of biodiversity, which commonly involve assemblages numbering at least tens, if not hundreds or thousands, of species. Here, it seems that species richness is often strongly positively correlated with many other measures of biodiversity; i.e. it is a good surrogate (substitute)(Gaston 1996a).

Species richness has become, in some sense, the common currency of much of the study of biodiversity. If one wishes to explore and discuss the origin, patterns and maintenance of biodiversity, such a currency certainly makes the task manageable. Although we will also have recourse to some other measures, we will essentially treat species richness as equivalent to biodiversity, notwithstanding the facts that it remains only one among many measures, and retains some significant and important limitations. In so doing, we do not wish to imply that the problems associated with using this one measure are either trivial or unimportant. However, progress can be made using it, provided one remains alert to its limitations.

Summary

1 Biodiversity is the variety of life, in all its manifestations.

2 Key elements of this variety can be recognized, comprising three nested hierarchies of genetic, organism and ecological diversity.

3 Because the variety of life can be expressed in a multiplicity of ways, there is no single overall measure of biodiversity, rather there are multiple measures of different facets.

4 The measure of biodiversity chosen may influence the findings of a particular study, and may reveal something about the values placed on a particular facet of the variety of life by an investigator.

5 Whilst it has some significant limitations, species richness has become the common currency of much of the study of biodiversity, and has proven valuable for many heuristic and practical purposes.

1.2 Does biodiversity matter? The value of Biodiversity

Introduction

The variety of life is manifestly complex, has changed dramatically through time and is unevenly distributed through space. For some these observations may be interesting in their own right, and the study of biodiversity may be largely a heuristic exercise. Certainly, exploring such issue has attracted the attentions of generations of natural historians, palaeobiologists and ecologists. But this ignores a fundamental question that demands both as intellectual and a practical response. Does biodiversity matter? In this section we address this issue. We discuss the sorts of things that might be valued about biodiversity and why. In so doing, we use 'value' in the broadest sense and not simply as a shorthand for monetary worth. The values of biodiversity can be divided into two broad and largely self-explanatory groups: use values and non-use values. These categories are not always clear-cut, but they are still helpful as long as one is mindful of their limitations. We begin by considering the use value of biodiversity, taking in turn its two major components of direct-use and indirect-use value and the relationships between biodiversity and ecosystem function. We then move on to address non-use values, including option bequest, existence and intrinsic values.

The sequence in which these values are presented is not indicative of our perceptions of their relative importance. Nor are observations that will be made on the form and level of some kinds of use intended to imply any endorsement of their appropriateness. Plainly, some of the examples of the exploitation of biodiversity that we will discuss are distressingly unsustainable at present levels and others would be regarded by some, and perhaps a substantial proportion, of the human population as unethical.

USE VALUE

<u>Direct-use value</u>

Direct-use value derives from the direct role of biological resources in consumption or production. It essentially concerns marketable commodities. The scale of the direct-use exploitation of biodiversity is enormous and extremely multifaceted. To date it has eluded comprehensive evaluation. Under some broad headings, selected types of the direct-use value of biodiversity are for food, medicine, biological control, industrial materials, recreational harvesting and ecotourism. We will address each of these in turn.

Food

Biodiversity provides food for humans, and hence is the foundation of all our food industries and related services. This food takes forms that include vegetables, fruit, nuts, meat, and adjuncts to food in the form of food colorants, flavoring and preservatives. These may derive from wild or cultivated sources, but for the bulk of the human population the latter are, of course, predominant (in 1997, global agriculture provided 95% of all plant and animal protein and 99% of energy consumed by humans; United Nations Development Program et al. 2000). The development of and subsequent improvements in agriculture enabled the continued expansion of the human population, from a global total of perhaps 4 million hunter-gatherers to the present 6 billion people (Cohen 1995). Current agricultural technology enables one person to be fed from the food grown on < 2000 m^2, although inequities mean that some of the human population is obese, and much is malnourished or at or below the level of starvation.

Of the 300,000 or more species of flowering plants, about 12,500 are considered to be edible to humans, although occasional use may embrace a much larger number (Rapoport & Drausal 2001). Around 200 plant species have been domesticated for food. However, at present more than 75% of the food supply (in terms of energy intake) of the human population is obtained, directly or indirectly, from just 12 kinds of plants (bananas/plantains, beans, cassava, maize, millet, potatoes, rice, sorghum, soybean, sugar cane, sweet potatoes, wheat). Average global annual production of major food crops in 1996-98 totaled 2.7 billion tones (2.07 billion tones of cereals and 0.64 billion tones of roots and tubers; United Nations Development

Program et al. 2000). The total number of wheat stalks alone grown in 1994 exceeded 450 trillion, probably a record at that time (Myers 1997).

The diversity of animals that are exploited for food is more difficult to enumerate, although again whilst a wide range of species is consumed or provides products for consumption (e.g. milk), most consumption is concentrated on just a small proportion of these species. Animals of which use is made directly or indirectly include groups of insects (moths, beetles, wasps and bees), crustaceans (lobsters, crabs, shrimp), mollusks (bivalves, gastropods, squid), echinoderms (sea urchins, sea cucumbers) and vertebrates (fish, amphibians, reptiles, birds, mammals). The vast scale of the exploitation is readily apparent from just a few figures: (i) 3.39 billion livestock are maintained worldwide (1996.98) (1.33 billion cattle, 1.76 billion sheep and goats, 0.12 billion equines, 0.18 billion buffaloes and camels; United Nations Development Program et al. 2000); (ii) average global annual meat production for 1996-98 was 215 million tones (United Nations Development Program et al. 2000); and (iii) global fisheries land more than 80 million tones per year.

Whether of plants or animals, the diversity of organisms exploited for food remains rather narrow when compared with their overall diversity leaving significant potential for further exploitation (although the characteristics necessary for domestication may be exhibited by a surprisingly small proportion of species; Diamond 2002). This gap is chiefly being closed indirectly, through the use of wild species and varieties to supply genes for the improvement of cultivated and domesticated species (increasing yields, tolerance, vigor and disease resistance); industrial-scale agriculture led to the loss of much of the previous local genetic variation in crops and livestock and their replacement by uniform varieties over often vast areas. Indeed, broadening the genetic base of some food species may perhaps be the only way in which our heavy reliance upon them can be maintained. Some of the most valuable genetic material may reside in particular wild populations of species that are exploited for food, or in their close relatives.

Medicine

As well as providing sustenance, biodiversity plays other vital direct roles in maintaining the health of the human population. Natural products have long been recognized as an important source of therapeutically effective medicines, and more than 60% of the world's human population relies almost entirely on plant medicine for primary health care (Harvey 2000). Of 520 new drugs approved between 1983 and 1994, 39% were natural products or were derived from them. Moreover, of the 20 best-selling non-protein drugs in 1999, nine were derived, directly or indirectly, from natural products, with combined annual sales of more than US$16 billion (simvastatin, lovastatin, enarlapril, pravesastatin, atorvastatin, augmentin, ciprofloxacin, clarinthromycin, cyclosporine; Harvey 2000). Plant species that have proven of medical importance includes willow trees (from which salicylic acid was originally obtained, and of which aspirin is a simple derivative), foxglove (digitoxin), belladonna (atropine) and poppy (codeine).

Animals also are extensively used in traditional remedies (with international trade in association with Oriental and other customary forms of medicine being substantial), as a source of a range of products in modern medicine (e.g. anticoagulants, coagulants, vasodilatory agents) and for models on which to test potentially useful drugs or techniques.

The proportion of species that have been investigated for the potential derivation of drugs is quite small. For example, as of 1995, whilst about 37,500 species of plants had been studied phytochemically, only about 14,000 had been studied for at least one type of biological activity (Verpoorte 1998), and the number studied in detail for their medicinal properties is at best in the low thousands (Dobson 1995).

Perhaps the most efficient way to find new drugs is to exploit the millions of generations of trial and error by natural selection that have given other creatures the means to healthy lives (Beattie &Ehrlich 2001). It has been suggested that one out of every 125 plant species studied has produced a major drug, whilst for synthesized chemicals the potential for finding major new drugs is of the order of one in 10,000 compounds tested (Dobson 1995). Thus, the search for useful compounds from biological material goes on (perhaps the most conspicuous example of what has come to be known as **bioprospecting**).

Clues to solutions to other medical problems faced by humans may also lie in other species. Thus, for example, new ways of preventing and treating osteoporosis may perhaps be found in bears, which are the only mammals in which the problem is thought not to occur. During the 3-7 months that black bears *Ursus americanus* den, they do not eat, drink, urinate or defecate, and yet they can deliver and nurse young, maintain their bone density and lean body mass, and do not become ketotic or uraemic.

Biological control

The use of natural enemies to control species regarded as problems is increasingly widespread and is often seen as an environmentally friendly alternative to the use of pesticides. Biocontrol programs have been attempted against several hundred species of plants and insects, with approximately 30% of weed biocontrol and 40% of insect biocontrol programs being successful . Biological control has included introductions of agents to control populations of pests in or on crops, populations of disease vectors (e.g. mosquitoes) and populations of invasive species.

The economic returns of biological control programs can be huge, with the monetary values of annual gains in food or other crop production perhaps exceeding by many times the entire investment in control programs. For example, the cost-benefit ratio for the control of cassava mealybug *Phenacoccus manihoti* by the encryrtid wasp *Epidinocarsis lopezi* in Africa was estimated to be 1 to 149 with annual savings as high as US$250 million.

Industrial materials

A wide range of industrial materials, or templates for the production of such materials, have been derived directly from biological resources. These include building materials, fibers, dyes, resins, gums, adhesives, rubber, oils and waxes, agricultural chemicals (including pesticides) and perfumes. For wood alone, in 1989 the total worldwide value of exports was estimated to be US$6 billion (World Conservation Monitoring Center 1992), and more than 3.8 billion cubic meters are estimated to be harvested annually worldwide, for fuel, timber and pulp (Kunin & Lawton1996). Including agriculture, food processing, industrial chemical and pollution control sectors, the bio technology industry made sales of US$10-12 billion in 1993 in the USA alone (these are projected to reach US$100 billion by 2035; Colwell 1997).

Biological materials have provided the models (biomimicry) for many industrial materials and structures. Thus, inspiration for the dome of the Crystal Palace in London came from the Amazonian water lily *Victoria amazonica*, for air-conditioning systems from the mounds constructed by termites, for Velcro fasteners from the seeds of burdock Arctium spp., for the echo-sounder from bats, and for infrared sensors from the thermosensitive pit organ of the rattlesnake (Beattie & Ehrlich 2001; Mateo et al.2001). As is the case for food and medicine, the scope for exploitation of a far greater diversity of organisms for industrial materials is vast. Plants and other animals have already solved many of the problems and challenges facing humankind, often in what appear to us to be ingenious ways. The reasons that the potential for exploitation is so much greater than presently realized probably have as much to do with cultural factors (the devil you know) as they do with ignorance of natural products.

Recreational harvesting

Examples of recreational harvesting are multifarious but include hunting and fishing, the harvesting of animals (e.g. fish, reptiles, birds, mammals) for display and as pets, and the harvesting of plants for personal and private gardens.

Thus, for example, in the British Isles alone, 25,000 plant species are grown in botanic in botanic gardens, and some 65,000 named plant taxa are sold for horticulture, of which 14,000 represent distinct species grown out of doors (Crawley et al. 1996). Likewise, an estimated 14-30 million fish may be traded each year for aquaria, about two-thirds of the species of which are from coral reefs (Groombridge & Jenkins 2002).

The global international legal net trade in wildlife and wildlife products reported by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1997 included 26,000 live primates, 235,000 live parrots, 76,000 live tortoises, 948,500 live lizards, 259,000 live snakes, 344,000 wild orchids, 22,000 cat skins, 850,000 crocodile skins, 1,638,000 lizard skins and 1,458,000 snake skins (United Nations Development Programme et al. 2000). Species traded legally within national borders and illegal trade are not included in these figures, but run to billions of dollars annually. Recreational harvesting is of huge commercial value, both because of the scale of the trade, and because individual specimens of rare and otherwise sought after species can attract large sums (with the value often increasing as the species become progressively rarer). The illegal trade in wildlife has been argued to rank second in value only to the clandestine arms and drugs markets (Juniper 2002). In the late 1990s an illegally smuggled pair of Lear's macaws *Andorhynchus leari* were gram for gram more valuable than heroin, fetching c. US$75,000 (Juniper 2002).

Ecotourism

Ecotourism is by definition founded on biodiversity, and has developed into a massive industry. Indeed, tourism as a whole is one of the fastest growing industries in the world. In 1988 an estimated 157-236 million people took part in international ecotourism (i.e. in countries of which they were not nationals), contributing between US$93 and US$233 billion to national incomes (Filion et al. 1994). However, international tourism is also estimated to account for perhaps only 9% of global tourism receipts (the rest is domestic), suggesting that these figures represent only a fraction of the scale and economic impact of ecotourism (Filion et al. 1994). In 1998, an estimated 9 million people went whale-watching alone with expenditures on just this activity of US$1 billion (Hoyt 2000).

At regional and local scale, ecotourism can be of economic significance. For example: (i) in Britain, at least US$7.5. billion is spent each year by urban visitors to the countryside in the course of more than 650 million day-visits (Pretty 1998); (ii) bird-watching contributes more than US$1500 million per annum to the economy of South Africa (Turpie & Ryan 1999); and (iii) marine wildlife tourism contributes US$14 million per year to the Scottish Highlands and Islands (Everett 1998).

Indirect-use value

The biota annually cycles gigatonnes (10^{15}g) of elements such as carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur, and teragrams (10^{12}g) of aerosols and particles among the atmosphere, hydrosphere (the waters) and lithosphere (the solid matter forming the Earth's crust; Naeem 2002). Such biochemical cycling modifies physical and chemical conditions, creating an environment that sustains life. Indeed, in the absence of life, Earth would be a very different place. In particular, it has been estimated that the atmospheric gas composition would be radically altered, and surface temperatures and pressures dramatically heightened.

The indirect-use value of biodiversity derives from the many functions that it performs in providing services that are crucial to human wellbeing (Westman 1997; Ehrlich & Ehrlich 1992; Chapin et al. 1997; Daily1997).

Table. Some **ecosystem services** provided by biodiversity.

Atmospheric regulation
Climatic regulation
Hydrological regulation
Nutrient cycling
Pest control
Photosynthesis
Pollination
Soil formation and maintenance

These services can in some sense be regarded as being 'free', in that they tend not to be subject of direct trading in the marketplace, although such a perception has proven detrimental to their maintenance. Alongside those that are perhaps more readily recognized, such as nutrient cycling and soil formation, there are numerous other ecosystem services. For example, many non-commercial species of marine mollusks and crustaceans may not be used directly themselves, but may nonetheless constitute an essential food source for many economically important fish species. The value of these invertebrates is indirect as they derive their value (in an economic sense) from the fish. Likewise, declines in the diversity and numbers of wild bees in many areas (often as a product of habitat destruction) have drawn attention to their agricultural significance as pollinators, and to the adverse effects on crop yields of these losses (O'Toole 1993).

Some natural environments have both a direct and an indirect value. Take, for example, a tropical forest. This may provide a number of direct-use values, including those of timber, medicinal plants, other forest products, hunting and fishing, recreation and tourism. It may also provide indirect-use values including soil conservation and soil productivity, and watershed protection (with consequences for water supply and storage, flood control climate, and carbon sequestration). The value of the forest for its indirect uses tends, however, vastly to exceed that for direct uses, giving it greater global than local value, and tending to make it more vulnerable to clearance by local people. In practice, of course, ecosystem services are essential for the maintenance of all direct-use values.

Indirect- use values are more difficult to quantify or cost than direct-use values and in some cases it may be difficult to recognize, let alone explain, them. There have nonetheless been some, inevitable extremely contentious, attempts to estimate the aggregated annual value of nature's services. These suggest figures similar in magnitude to, larger than, or a large proportion of, the global total annual gross national product, albeit there is nowhere one could purchase a replacement ser of such services. The overall benefit : cost ratio of an effective program for the conservation of remaining natural ecosystems has been estimated at, at least, 100:1.

A high proportion of humans live in cities. These draw on ecosystem services over large areas. Thus, the 29 largest cities in the Baltic Sea region have been estimated to draw ecosystem support services from areas at least 500-1000 times larger than the areas of the cities themselves (Folke et al. 1997). Average residents of North America, Europe, Japan and Australia require the biophysical output (an 'ecological footprint') of 5-10 ha of biophysically productive land and water each to support their consumer lifestyles (Rees 2001).

NON-USE VALUE

Non-use value is that associated with biological resources even if they are not directly or indirectly exploited. Non-use value can be divided into at least four components: option value, bequest value, existence value and intrinsic value.

Option value

In addition to the necessity that biodiversity be maintained for its current direct and indirect-use value, one might equally argue that it should be retained for the options for future use or non-use that it provides. There is, for example, huge unexploited potential for the use of biodiversity, particularly with the possible medicinal and industrial uses of much of the variety of life remaining unexplored. This potential should be valued, and may be vital as the problems faced by humanity change in nature and magnitude. Options value may include the knowledge (of practical or heuristic significance) embodied in organisms, in as much as the loss of a species represents the loss of information.

Bequest value

Closely related, but distinct from option value, is bequest value. This is the value of passing on a resource, in this case biodiversity, intact (or as near as possible) to future generations (Krutilla 1967). The philosopher John Locke suggested that each generation should bequeath enough and as good for others' to future generations not just because they should, but because justice demands it. The modern version of this is the slightly more elaborated "justice as opportunity" view that says we should compensate our children in the future for the loss of wealth, production or ecosystem services for which the present generation is responsible. This notion is embodied in the final section of the Preamble to the Convention on Biological Diversity, which states that contracting parties are "determined to conserve and sustainably use biological diversity for the benefit of present and future generation".

Existence value

All the values of biodiversity considered thus far in this chapter have been based, in one way or another, on marketable commodities and non -market goods and services. They assume that value is expressed solely in terms of the wellbeing of humanity. However, biodiversity may equally be seen as having value to people irrespective of the uses to which it may or may not be put. That is, value may be placed simply on its existence. For example, the continued persistence in the wild of many species of large-bodied mammals, such as the giant panda Ailuropoda melanoleuca, tiger Panthera tigris and killer whale Orcinus orca, is valued by sectors of the human population, despite the fact that these species are unlikely ever actually to be seen by many of these individuals, Indeed, substantial sums of money are contributed by them towards maintaining populations of such species. Wilson (1984) believes that humankind recognizes and has empathy with other bearers of life (“biophilia”), and that this naturally predisposes them to an appropriate care of, and for, biodiversity in all Its multifaceted forms.

Intrinsic value

Direct- and indirect- use values, and option, bequest and existence non-use values rest on human judgments of worth. Whether from a philosophical perspective values can exist independently of such judgments is a contentious issue; however if they can, then biodiversity may be seen to have an intrinsic value. The view that such a value exists seems to be deeply rooted in many societies, cultures and faiths. Logically it leads to an absolute moral responsibility to protect other species, our only known living companions (deities aside) in the universe (Ehrlich & Wilson 1991). Indeed, the notion of an intrinsic value to biodiversity (or components thereof) is found in many regional and global treaties for conservation. The opening section of the Preamble to the Convention on Biological Diversity recognizes the “intrinsic value of biological diversity and of the (ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic) values of biological diversity and its components”.

To some, listing intrinsic value first is a true reflection of its significance. Placing it last in this chapter is not intended to convey the converse message.

Summary

1. Direct-use values of biodiversity are concerned with the consumption or production of marketable commodities. These include food, medicine, use in biological control, industrial raw materials, recreational harvesting and ecotourism. Many present patterns of exploitation are not sustainable.

2. Indirect-use values of biodiversity are more difficult to quantify, not being subject to direct trading in the marketplace, but are nonetheless real and important, embracing the services provided by biodiversity which are crucial for human wellbeing.

3. It is not currently possible to build artificial systems that could provide us with the life-supporting systems that natural systems provide us "for free".

4. Ecosystem functioning increases from assemblages of very small to small numbers of species, with the effect diminishing as species numbers increase further, suggesting some degree of ecological equivalency amongst species.

5. Higher species richness increases both species redundancy and temporal resilience of ecosystem functioning, thereby increasing the reliability of that functioning.

6. Apart from present-day use values, biodiversity may have a variety of non-use values, including option value (for future use or non-use),bequest value (in passing on a resource to future generations), existence value(value to people irrespective of use or non-use) and intrinsic value (inherent worth, independent of that placed upon it by people)

1.3 Causes of biodiversity loss: Human impact

Introduction

Although it is essential to humankind, brings innumerable benefits, and has other important values, humans have had strong negative impacts on biodiversity. Indeed, while over geological time the general trend has been towards an overall net increase in biodiversity, the late Quaternary has been a period of marked decline, as both a direct and indirect consequence of human activities. This decline comprises all those changes that are associated with reducing or simplifying biological heterogeneity, from genes to ecosystems.

In this section we consider the negative human impacts on biodiversity, concentrating particularly on the loss of species. First, (we address the level of those losses) . Second, we examine the four principal proximate causes of the losses, namely overexploitation, habitat loss and degradation, introduced species, and extinction cascades. Third, we consider the ultimate causes of the impacts of humans on biodiversity, namely the size of the human population, the growth in that population, and the scale of the human enterprise.

Species extinctions

The best-known and most widely discussed impact of human activities on biodiversity has been that of the extinction of species. The loss of species seems to capture the public imagination, perhaps because of its irreversibility and the extraordinary nature of some of those species that have met their collapse. In addition, species extinctions constitute the obvious, as well as a genuinely useful barometer of change in biodiversity when this is measured in terms of species richness.

Prehistoric times

The impacts of humankind on other species have lasted for a long time, probably for much of the 100,000 - 200,000 years for which anatomically modern humans have existed. Although there remains some important debate on the issue, early humans may well have contributed significantly to the extinction of many large-bodied species of birds and mammals, and perhaps other groups, during the late Pleistocene (by some 10,000 years before the present (BP), all the major land masses except Antarctica had been colonized, some for a considerable period, and humans were exerting significant environmental effects). Apparently, broadly coincident with the arrival of humans in different major land masses, much of the mega fauna disappeared, suggesting that they were either hunted to extinction (or perhaps close to the brink, with other factors finally tipping them over) or were brought to extinction by anthropogenic ecosystem disruption. Doubtless, these extinctions were accompanied by many others, of which we remain unaware because of the inadequacies of the subfossil record.

The effects of early human activities on the biota are perhaps most graphically demonstrated by the large numbers of avian (and some other) extinctions that followed the colonization of **tropical Pacific islands** by prehistoric peoples, an expansion that began perhaps 30,000 years BP and was almost complete by 1000 years BP. The combined effects of resource exploitation, deforestation and the introduction of alien species led to roughly half the land bird species on each island group being exterminated. The proportion of the avifauna on selected Pacific island groups that has recently become extinct, or is now endangered or in immediate danger of extinction, is less where human occupancy has been longest. This suggests that those areas colonized first have already lost most of the species that are sensitive to human activities, although the time-lapse between human arrival and major extinction events was highly variable on oceanic islands.

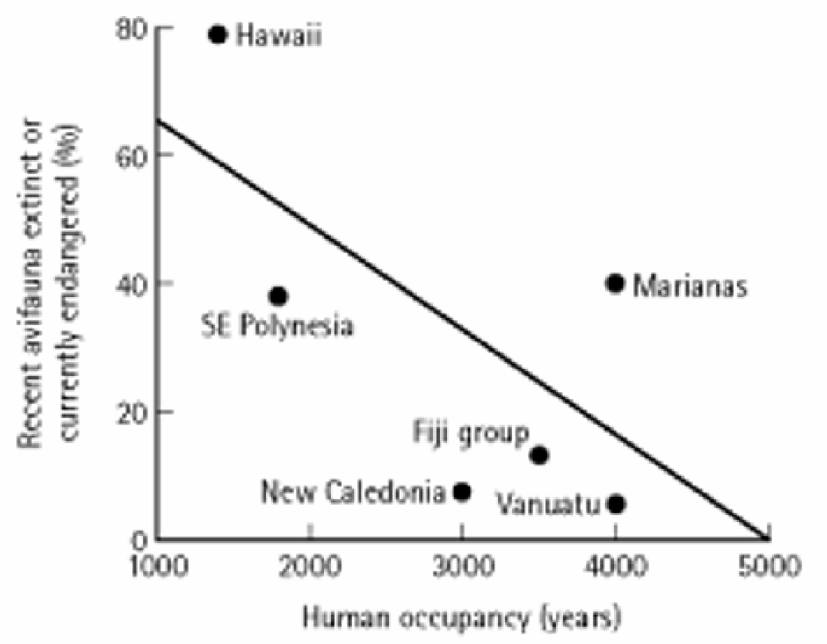

Fig. Relationship between the percentage of recent avifauna of Pacific islands that is extinct or currently endangered and the duration of human occupancy of those islands. The Marianas have an unusually high number of modern losses, as a result of recent colonization by the brown tree snake. (From Pimm et al. 1995b.)

A conservative estimate may be that an average of 10 sea-or land bird species or populations were lost from each of the approximately 800 islands of Oceania alone, giving an overall loss of 8,000 species or populations. With one to four endemic rail (spanish "*rascón*", ground breeding bird) species per island, 2,000 species of rails may have been lost alone, which contrast with the 133 extant (*present*) species, a number of which are regarded as being highly threatened. It is not difficult to conceive that globally, perhaps a half of all recent bird species have already been driven extinct, at least in part as a consequence of human activities.

1600 onwards

Species losses did not end when the primary phase of human colonization of the planet was largely complete. Since 1600 (a date after which the availability of contemporary information improves markedly) there have been over 1000 recorded extinctions of plant and animal species. Roughly a half of these took place in the last century. There has been a significant rise in the rate of recorded species extinctions for well-known groups of animals over the past 400 years, with a sharp increase in the 19th century coinciding with European colonial expansion.

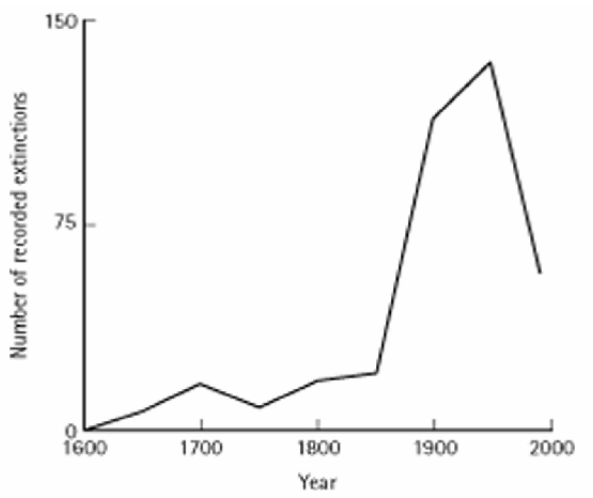

Fig. The number of recorded global extinctions of animal species since 1600, for which a date is known. (From Smith et al. 1993.)

A global decline in the recorded rate since about 1950 may perhaps in part reflect the growth of conservation activities, but more likely is due to the introduction of more severe criteria for deciding that a species is genuinely extinct (rather than that it has simply gone unrecorded). For example, the present IUCN (The World Conservation Union) criteria define a species as extinct when there is no reasonable doubt that the last individual has died and as extinct in the wild when the species is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed extinct in the wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual) throughout its historic range have failed to record an individual. Thus considerable time and effort is required to verify an extinction, particularly where the potential habitat for a species is extensive or difficult to access.

Interesting as the data on recorded extinctions may be, they undoubtedly underestimate the true levels of species losses. There are several reasons for believing this to be so.

1. Available information on extinctions is strongly biased (*inclined*) towards higher plants, birds and mammals, which have been better studied, and away from groups such as fungi, lower plants and invertebrates, which have been more poorly studied.
2. Available information on extinctions is strongly biased (*inclined*) towards islands and developed nations. In both cases this is in part because such extinctions have been easier to document, given the high levels of endemism commonly associated with islands and the longer period of formal study of the biotas of developed nations.
3. Available information on extinctions is strongly biased towards terrestrial and freshwater species, and away from marine ones.
4. It is almost invariably assumed that a described species is extant (*present*) unless sufficient evidence is accumulated to show that it is extinct.
5. Unless a species is known to science, then its extinction will pass unrecorded.

The future

Merely recording numbers of extinctions that have thus far occurred may underestimate the effects of past human activity on species losses, through a process known as extinction debt. Individuals of large-bodied species, for example, may persist after the populations to which they belong have ceased to be viable (they can no longer be self-sustaining), because they are long-lived. The species is effectively extinct; it just doesn't know it yet!

Information on the numbers of species that have been listed as being threatened with global extinction in the near future provides one of the bases for estimating the scale of imminent extinctions (although given the time required for sufficient evidence of extinction to accumulate, some of these species are certainly already extinct). The most recent figures for plant and animal are highly biased, and in much the same ways as are those of recorded extinctions. Only for birds and mammals has the threats status of virtually all extant species been evaluated. In the former case, more than 10% of species have been identified as at threat of global extinction; in the latter case, about 25% have been recognized as such. An estimate for plants has suggested that as many as a half of extant species may qualify as threatened with extinction were it possible to evaluate them.

The average life span of any species in the fossil record is estimated to be around 5-10 Myr. For birds and mammals, rates of documented extinction over the past century correspond to species life spans of around 10,000 years. Although the calculation are inevitably very rough and ready, projection of impending extinctions, if current trends continue, suggest a life span for bird and mammal species of 200-400 years! These figures may perhaps be regarded as representative of a broad range of organisms, in which case impending extinction rates are at least three to four orders of magnitude faster that background rates seen in the fossil record.

By comparison with most of those species that have been driven extinct or to the brink of extinction, Homo sapiens is rather recent addition to the earth. Species that have existed for millions of years are being erased by one that has existed for a fraction of that time.

Population, individuals and genetic diversity

The listing of a species as having a significant risk of extinction in the near future is commonly associated with it having suffered a decline in population or geographic range size. In other words, it has undergone a loss of local population, a decline in the numbers of individuals in remaining populations, or both. Such losses and declines are being experienced by huge numbers of species, whether these are sufficient for them to be listed as threatened by global extinction or not. For example, amphibian population declines are a global problem, with causes that may include ultraviolet radiation, predation, habitat modification, environmental acidity and toxicants, diseased, changes in climate or weather patterns, and interactions among these factors. Concerns have similarly been expressed about declines in the abundances of species in a wide range of groups, such as trees, sharks and birds.

There are estimations that in tropical forests, 1800 populations may be being destroyed per hour, 16 million annually. Land-use change alone may have caused the overall global bird population to decline by a fifth to a quarter from pre-agricultural levels.

The extinction of individual local populations and declines in species` local abundances both represent potentially dangerous forms of erosion of biodiversity. Population losses, in particular, will tend to reduce the taxonomic generic and functional diversity of sites, and perhaps the performance of ecosystems without initially necessarily contributing to the global species extinctions that attract the bulk of attention.

Threats to biodiversity

Species losses, and other declines in biodiversity, result from four main causes, namely: -direct exploitation; -habitat loss and degradation; - introduced species; and extinction cascades. These have been termed the evil quartet. Whilst reasonably well characterized, the patterns and rates at which these drivers are changing are less well understood.

Direct exploitation

The most obvious way in which humans can cause the extinction of species is by exploiting their populations, either down to the last individual or down to such numbers that they have a very high likelihood of becoming extinct by chance. The scale of human exploitation of some species is incredibly high, and is not sustainable. Here we give three examples:

1. *Bush meat*. Hunting of wildlife in tropical forests, principally for subsistence or commerce, is ubiquitous. Indeed, for many species it is difficult to ascertain what their natural abundances would be in the absence of such pressure, because places without the pressure do not exist. For example, 9.6-23.5 million reptiles, birds and mammals, or 67-165 thousand tones, have been estimated to be consumed per annum in the Brazilian Amazon. Demand is increasing as tropical

forests become more accessible to hunters, effective human population densities increase, people become more sedentary, traditional hunting practices change, the meat trade becomes more commercial, and demand increases from urban centers for wild meat. The use of mathematical models demonstrates that this harvest is not sustainable, particularly because of the low annual production rates of large mammals in tropical forests. It is estimated that the mammal production rates in the Congo Basin and the Amazon Basin are about 2.1 and 1.8 million tones per year, with extraction rates being 4.9 and 0.15 million tones per year respectively. This means that Congo basin mammals must annually produce 93% of their body mass to balance current extraction rates, whereas Amazonian mammals must produce only 4%.

2. *Fuel wood*. More than 2 billion people (about a third of the present total) are estimated to depend directly for their primary or sole source of energy on biomass fuels, including woodfuels (fuelwood, charcoal, etc.), agricultural residues, and animal wastes. Of these, fuelwood is the dominant form of biomass energy in many, predominantly developing, countries. Supplies have decreased significantly in many areas in recent decades, with members of some communities having to travel substantial distances to obtain material. Although globally, this has to some degree been offset by programs of tree planting, woodfuel demand by 2010 is forecast to be 2.4-4.3 billion m^3 compared with an estimated availability of 2.3-2.4 billion m^3 of fuelwood and charcoal combined.
3. *Marine fisheries*. The 1950s and 1960s saw a huge increase in global fishing effort, fuelled in large part by its industrialization, which gave rise to rapid increases in catches. The first major stock collapse was that of the Peruvian anchoveta Engraulis ringens in 1971-72, which was accompanied by declining catches elsewhere, which accelerated in the late 1980s and early 1990s when cod (*bacalao*) *Gadus morhua* stocks off New England and eastern Canada collapsed. Global fishing effort, nonetheless, continued to expand, such that by the mid-1990s a high proportion of stocks had collapsed or were being exploited beyond sustainability. Reported world fisheries landings have been declining slowly since the late 1980s by about 0.7 million tones per annum. Fisheries have increasingly been "fishing down marine food webs", as large long-lived predatory fish have been removed and those at lower trophic levels exploited. They have changed the evolutionary characteristics of populations through size-selective harvesting and

have placed the future persistence of some target species at risk. Evidence suggests that although the effects of overfishing may be reversible, the time for stocks to recover may be considerable. With declines of fisheries stock in shallow waters, increasing emphasis has been directed towards deep-water fisheries, which are even less robust to such impacts. In addition to those on the stocks of target species, fishing has wider impacts, through: - the wholesale reorganization of the structure of remaining species assemblages as trophic interactions are disturbed;- the huge amounts of by-catch of non-target species that are typically simply discarded (*worthless*) (by-catch is in excess of 25 million tons per annum); - the incidental capture and killing of other species (including sea-birds, turtles, sea snakes, marine mammals, many of which are particularly vulnerable because they are long-lived and have low reproductive rates); - the habitual destruction generated by some of the technique employed (e.g. bottom-trawling); - and the environmental consequences of fishing debris (*wastes*) (e.g. lost nets).

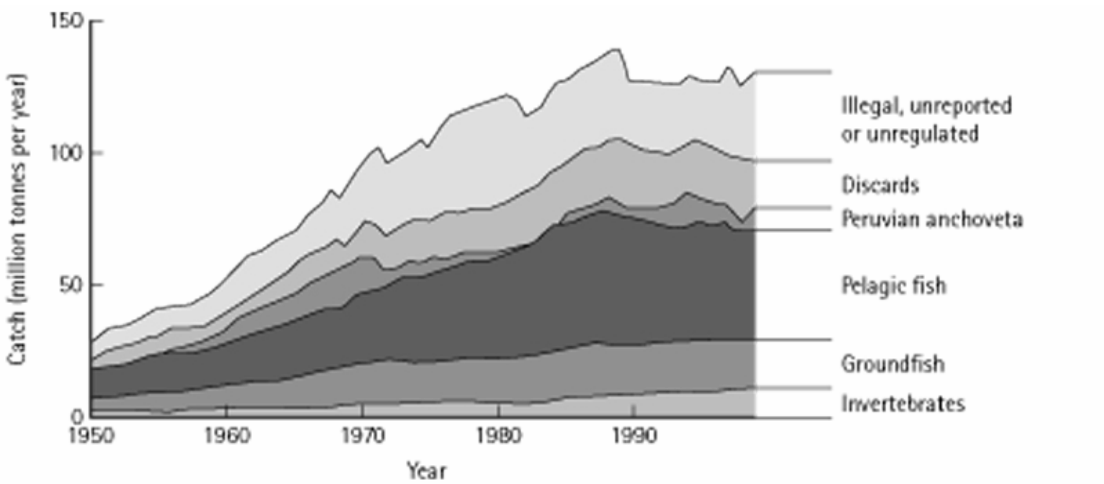

Fig. Estimated global fish landings for 1950-99. (Note that the estimates for illegal, unreported or unregulated fish landings are very tentative.) (From Pauly et al. 2002.)

Perhaps above all, the history of human exploitation of resources teaches us that the populations of even initially extremely abundant species can be reduced to low levels remarkably rapidly, and that the ease with which this can be achieved has grown with the march of technology. Unfortunately, in the short-term, from a strictly economic standpoint (knowing the cost of everything and the value of nothing?), non-sustainable use can in some cases still be regarded as a viable option. For example, from this perspective, the best harvesting strategy for biological populations with relatively low growth rates (e.g. whales) may be to exploit them to extinction. The revenue generated by this harvest when invested could conceivably yield a greater cash return than that generated by the sustainable harvest from the population. Of course, this ignores both the direct- and indirect- use value (which may both be vital to sustain human populations) and the non-use value of biological resources, both in the short- and the long- term (we cannot conceive of the value that the continued existence of particular species may have in the future).

Habitat loss, fragmentation and degradation

Dramatic reshaping of the distribution of habitats or vegetation types has been a feature of much of the history of humankind, which habitat change as a consequence of the activities of prehistoric populations having been reported on numerous occasions. Indeed, it has repeatedly been discovered that what had been held to be “natural” landscapes had actually been much transformed by earlier human activities.

At a broad scale, compared with an estimation of their extent before significant human disturbance, forest/woodland has declined in area by 29%, steppe/savannah/grassland by 49%, shrub land by 74%, and tundra/hot desert/ice desert by 14%. Cropland now covers 11% of the land surface, and pasture 23%. Human disturbance is evident in every biome on Earth, and in terrestrial systems is most marked in temperate broadleaf and evergreen sclerophyllous forests (Mediterranean forests areas where the climate is characterized by warm, wet winters and hot, dry summers as for the olive (*Olea europaea*) and cork oak (*Quercus suber*) and the holm oak (Quercus ilex). Perhaps some of the most graphic evidence of such changes comes from contrasting the extent of the most speciose terrestrial environment, tropical forest, at different times, in particular areas of the world. Most such forest clearance arises from pressures that are external to the ecosystem, particularly an undervaluing of the forest resource that encourages liquidation of the natural capital it provides and its replacement with agricultural systems that yield quicker returns. This situation is acute in regions where immediate needs predominate, and future income is discounted at a high rate.

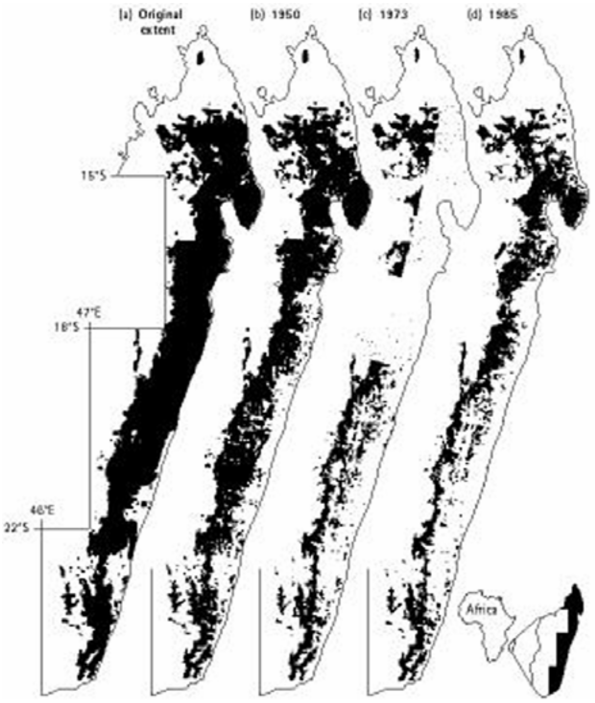

Fig. Maps of the distribution of wet tropical forest in eastern Madagascar through time (extensive cloud cover permitted only partial mapping in 1973). The original cover of 11.2 million ha was reduced to 7.6 million ha by 1950, and to 3.8 million ha by 1985 (34% of the original). (From Green & Sussman 1990.)

As predicted from species-area relationships, land- use changes have brought about the loss of many species, and are the primary cause of species being listed as at high risk of extinction in the near future. Thus, globally 71% of freshwater fish species (excluding Lake Victoria cichlids, because of the complexity of their situation) that have recently become extinct have apparently done so for this reason, and 85% of bird and 47% of mammals species (not including most of the small mammals, because of insufficient data) are listed as being at risk on the same grounds. More than 100 species of birds are at threat as a result, at least in part, of each of 13 causes of habitat loss: selective logging (forest exploitation) /cutting, smallholder farming, plantations, clear-felling (*talar*), arable farming/horticulture, livestock farming, infrastructure development, human settlement, grazing, shifting agriculture, deforestation with unknown causes, timber (firewood), and mining (Birdlife International 2000).

Substantial land-use change is predicted to continue in the future, not simply as a consequence of direct human activities, but also as a consequence of anthropogenic global **climate change**. The global average surface temperature has increased by approximately 0.6ºC over the past 100 years, with most of the warming occurring during two periods, 1919-45 and 1976-2000. This temperature is projected to increase by from 1.4ºC to 5.8ºC over the period 1990-2100, based on a number of climate models, a rate much higher than observed during the 20th century and likely to be without precedent during at least the last 10,000 years.

In large part, these changes result because human activities add carbon dioxide (CO_2) to the atmosphere by mining and burning fossil fuels, and by converting forests and grasslands to agricultural and other low biomass ecosystems. Carbon dioxide is the principal "greenhouse gas", although others make a contribution, including methane (CH_4), the chlorofluorocarbons (CFCs), ozone (O_3), and nitrous oxide (N_2O). Analysis of air bubbles extracted form ice cores from Antarctica and Greenland reveal that the atmospheric concentration of CO_2 was more or less stable for thousands of years, until about 1800, since when it has increased exponentially.

The distributions of a large number of species currently seem to be shifting in response to climate change. Other responses to climate change are also being documented. Thus, although there is regional variation, common shifts in phenology (*external expression of genes*) in Europe and North America include earlier breeding or first singing of birds, earlier arrival of migrant birds, earlier appearance of butterflies, earlier choruses and spawning in amphibians, and earlier shooting and flowering in plants.

Many of the changes that humans are making to the landscape involve not simply the reduction of the areas of some vegetation types and the expansion of others, but also the **fragmentation** of vegetation. This generates a landscape consisting of (often small) remnant areas of native vegetation embedded in a matrix of agricultural and developed land. Fragmentation results consequence in change in the physical environment within patches (e.g. in fluxes of radiation, water and nutrients), in part because the size of areas of vegetation influences local climate, and because of the greater ratio of edge to area for smaller patches of vegetation which increases the potential for penetration by, and influence from, events and processes in the surrounding landscape. Changes in edge to area ratios may also increase pressure from invasive species, and other direct (e.g. hunting) and indirect (e.g. pollution) consequences of human activities. In addition, fragmentation causes biogeographic changes (e.g. in isolation and connectivity), which like its other consequences may be important influences in the size and composition of the biota of the remnant patches.

As well as changes in the pattern of coverage of different vegetation types, those areas that remain may for other reasons be degraded in terms of their capacity to support populations of naturally occurring species. That **degradation** may take many forms, including changes in the frequency and abundance of many materials. For example, human activity has markedly altered the global nitrogen cycle, by fixing N_2 (combining it with carbon, hydrogen or oxygen), either deliberately (for fertilizer) or as a by-product of other actions (fossil fuel combustion). Now this activity adds at least as much fixed N to terrestrial ecosystems as do all natural sources combined. The consequences include increasing atmospheric concentrations of the greenhouse gas N_2O, increasing fluxes of reactive N gases, contribution to acid rain and photochemical smog, increases in productivity of ecosystems where fixed N was in short supply resulting in losses of N and cations from soil, eutrophication (Organic material increase and O_2 reduction) of aquatic systems, and loss of biodiversity.

The sheer pervasiveness of such influences is well illustrated by the spread of materials that do not occur naturally. For example, brominated flame retardants are used in electronic equipment, such as computers and television sets, in textiles, cars and many other applications. They have been found to be present in sperm whales *Physeter macrocephalus* that normally stay and feed in deep water, suggesting that these compounds have reached these locations (de Boer et al. 1998).

Introduced species

Since prehistoric times, human actions have served, intentionally or accidentally, to introduce non-domesticated species to areas in which they would not naturally have occurred, breaking many natural barriers to their dispersal. Ignoring domesticated species, the earliest known instance involves the introduction of a marsupial, the gray cuscus *Phalanger orientalis,* to New Ireland about 19,000 years ago. Perhaps some 400,000 species have now been introduced. Often these constitute a high proportion of the species that occur in a given area, and they continue to grow in number. Introduced species are now widespread even in many nature reserves.

Such movements of species have been brought about by a multiplicity of routes, including intentional introduction for cultivation or sport, the transport of soil and ballas (Spanish "*lastre*"), the connection of waterways through canals, and the release or escape of pets. They reflect our choices as consumers, travelers, gardeners, and so on. Frequently, the numbers of introduced species in an area increase with the size of the human population, the duration of human occupation, and the numbers of visitors, all of which tend to increase the levels of such activities, and hence the likelihood and frequency with which individuals of given species arrive. The numbers of introduced species in an area tend also commonly to be positively related to the number of native species, probably because the successful establishment of species of both groups responds to similar factors.

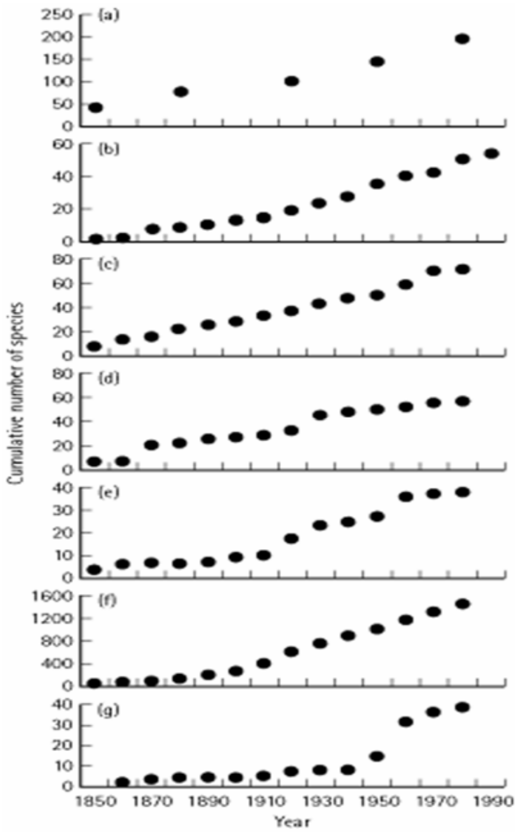

Fig. Cumulative numbers of introduced species by decade of introduction for: (a) Illinois plants; (b) Great Lakes animals; (c) Great Lakes plants; (d) San Francisco Bay invertebrates; (e) Hawaiian birds; (f) North American insects; and (g) USA fish. (From Ruesink et al. 1995.)

Property Some introductions have enriched human existence and most invaders have minor consequences; Williamson suggests that as a useful rule of thumb, 10% of introduced invaders become established, and 10% of those established become pets. Unfortunately, the negative effects can be very large, and introductions have been described as constituting “one of the great historical convulsions in the world’s fauna and flora”. Introduced species can alter nutrient regimes, fire regimes, hydrology, or energy budgets, change vegetation or habitat, and drive changes in the abundance and distribution of native species, ultimately to extinction. Drawn from a wide diversity of groups, they have thus become major agents of global change. Nearly a half of the threatened species of the USA, for example, are at risk at least in part because of the effects of alien species.

Introduced species have most frequently caused species extinctions through predation/parasitism. Perhaps some of the best-documented examples have concerned the introduction of exotic predators to lakes and islands and the consequent extinction of plants and animals that had evolved no defenses against them. Thus, numbers of species of fish, many endemic, from the lakes of the East African Rift Valley may be extinct as a result of the intentional introduction of the Nile perch *Laes niloticus*, a voracious predator (although other factors have also contributed). Likewise, the accidental introduction of the brown tree snake Boiga irregularis to the island of Guam around 1950 resulted, directly or indirectly, in the loss of perhaps 12 species of an original fauna of 22 native birds (tree pelagic species and perhaps nine forest ones, some endemic to the island), the reduction of most of the remaining forest species to small remnant populations, and the loss of 3-5 species of an original fauna of 10-12 reptiles. In both cases, the tastes of the generalist predators involved has been important, enabling them to maintain high abundances even when one of their prey species has been driven scarce.

The potential for introduced species to predate native species high-lights the need for great caution in employing biological control of pest species. Whilst this can be exceedingly beneficial in economic terms, potential biological control agents need to be very carefully screened to ensure that they will not have negative impacts on other species. A growing number of cases have been documented in which sufficient caution has not been exercised.

Introduced species may also cause species extinctions, at least locally through competition. Thus, the introduction of some ant species, such as the red fire ant *Solenopsis invicta*, the Argentine ant *Linepithema humile*, and the big-headed ant *Pheidole megacephala*, has often caused dramatic reductions in native and assemblages through aggressive interactions. Likewise, the tropical alga *Caulerpa taxifolia* spread dramatically around the coastline of the Mediterranean , carpeting large areas and excluding many other species.

The economic costs of introductions may be vast. Pimentel et al. Estimate that the approximately 50,000 non-indigenous species in the USA alone result in economic damage and control estimated at US$137 billion per annum.

The net effect of species extinctions and of the introduction of species into areas in which they would not naturally occur is to homogenize biotas across the globe, making them more similar to one another; in the extreme we would be left with biota comprising pests and weeds.

Extinction cascades

The extinction of one species may lead to the extinction of others. Indeed, this is inevitable where this species provides critical resources for others, such as specialist herbivores, parasites or predators, or perhaps itself acts as a specialist pollinator or dispersal agent. Thus, for example, in New Zeland, the giant eagle *Harpagornis moorei* almost certainly preyed on the large flightless bird moas, and its extinction likely resulted when these declined in numbers as a result of the hunting by the Maori that led to their disappearance. More complex sets of interactions may also result in cascades of extinctions, as evidenced by the dramatic, and often extensive, changes in floral and faunal composition that can result from changes in the abundance and occurrence of key species (e.g. large-bodied predators and herbivores). For example, the loss of large-bodied predator species may be accompanied by meso-predator release, in which somewhat smaller predators escape the populations controls that were previously imposed on them, and as a result they exert increased predation pressure on their prey species, reducing their abundance and perhaps driving them locally or even globally extinct.

The scale of the human enterprise

In some sense all of the above causes of species extinction and threat to biodiversity are proximate. The ultimate causes concern the size of the human population, growth in that population, and what has been termed the scale of the human enterprise. The facts are simple:

1. *Population size and growth.* The world's human population is estimated to have reached a total of about 6.1 billion individuals in mid-2000. This compares to figures for the other great apes, our closest relatives, of 10,000-25,000 for the bonobo *Pan paniscus*, 100,000-150,000 for the chimpanzee *Pan troglodytes*, 40,000-65,000 for the gorilla *Gorilla gorilla*, and about 38,500 for the orangutan *Pongo pygmaeus*.

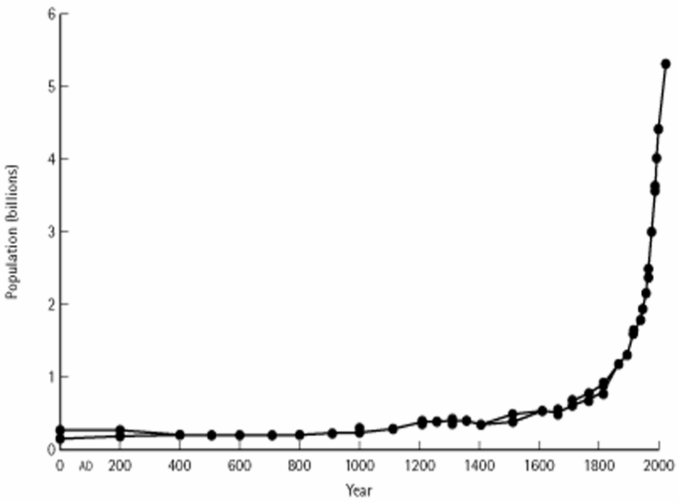

Fig. Estimated human population from AD 1 to the present. Different lines represent estimates from different sources. (From Cohen 1995.)

a) Generally, at a crude spatial resolution, there seems to be a marked positive correlation between the numbers of species found in an area and human density. It seems to occur because both species numbers and numbers of people show similar relationships with primary productivity, finding similar kinds of areas good for multiplication. Indeed, the human population is distributed such that more than 1.1 billion individuals live within the 25 global biodiversity hotspots, which constitute some of the most important and threatened areas for other forms of life. The density of people in these hotspots is about 73 per km^2, compared with a global average of 42 per km^2

b) Levels of habitat loss in areas are commonly correlated with the number of people, even at relatively coarse (*common*) spatial resolutions but the conflict between people and biodiversity becomes more obvious at finer spatial resolutions (here, of course, positive relationship between numbers of people and species richness tend rapidly to break down (highly urbanized areas may have few native species). Thus, the number of previously native scarce plant species that have not been recorded from areas of Britain since 1970 is an increasing function of the human population density of those areas, and the occurrence and persistence of a number of large-bodied vertebrate species declines with human population density, even when these species are in protected areas and this density is measured in the surrounding areas.

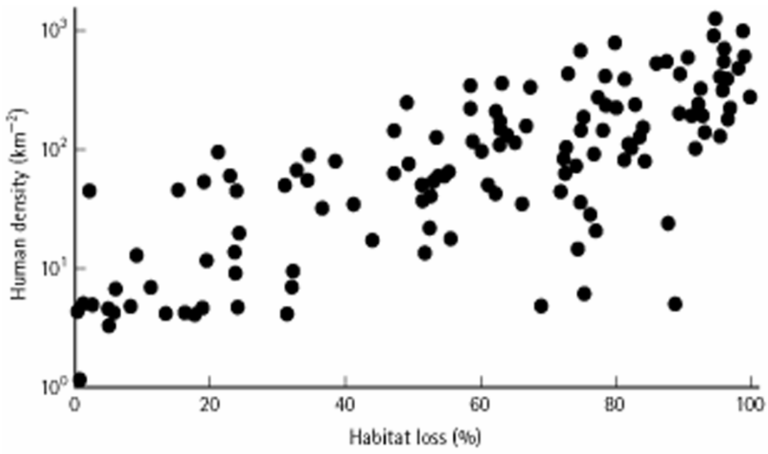

Fig. Relationship between human population density and habitat loss for forest ecoregions of the Indo-Pacific. (From Wikramanayake et al. 2002)

The extent of such conflicts will, of course, almost inevitably grow. The human population is currently increasing at an annual rate of 1.2% (about 80 million people annually, or nearly a quarter of a million people each day), and by 2050 is expected to be between 7,9 billion and 10,9 billion, with a medium variant of predictions of 9,3 billion (United Nations 2001). Population growth has been slow for most of human existence but over the past 200 years the rate has increased dramatically. In 19 of the global biodiversity hotspots, the human population is growing more rapidly than it is globally, and in most of the hotspots located in developing countries it is projected to grow for several more decades.

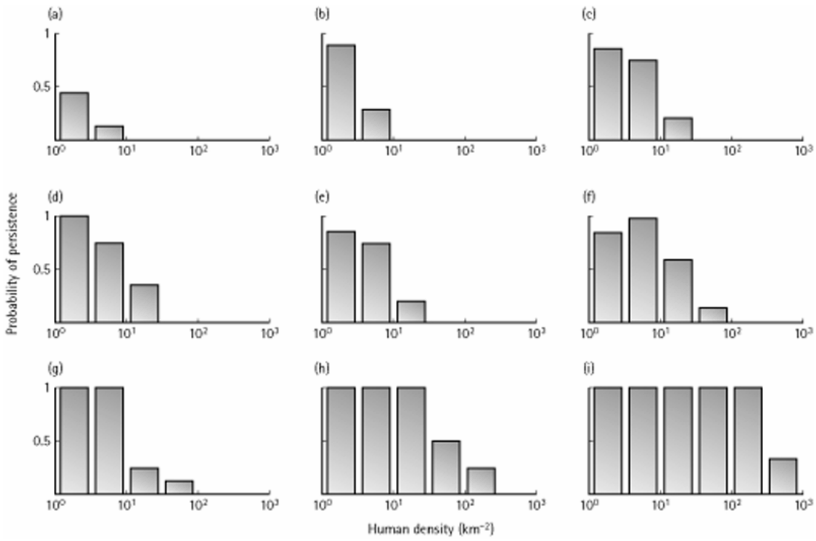

Fig. Relationships between human density and probability of persistence for: (a) African wild dog in Southern Africa; (b) grizzly bear in USA; (c) African wild dog in Kenya; (d) mountain lion in USA; (E) wolf in USA; (f) cheetah in Kenya; (g) jaguar in Brazil; (h) spotted hyaena in Kenya; and (i) leopard in Kenya. (From Woodroffe 2000.)

The interaction between human population growth and species extinction may perhaps be illustrated by silphion *Ferula historica*, a herb in the carrot family. It once grew in abundance in the hills near Cyrene on the coast of what is now Libya, and was apparently highly valued as an antifertility drug in the classical world, in effect an oral contraceptive. It became one of the principal commodities of Cyrene´s trade, and became very valuable. Indeed, coupled with the failure of attempts to cultivate the plant, its value was such that it was overharvested, and in the 2nd or 3rd centuries AD, it disappeared.

2. *Primary production*. Human use or destroy approximately 35-40% of all potential terrestrial net primary productivity (the net accumulation of organic carbon resulting from the surplus of fixation over respiration. The equivalent figure for aquatic systems is 8% of primary production, but with the proportion for near shore and freshwater systems being much higher and close to that for terrestrial systems.

3. *Energy use*. Ehrlich (19995) estimates that from before the agricultural revolution to the present time, total power consumption by humanity multiplied roughly 7000-13000-fold, from 0.001-0.002 terawatts (1 TW=10^{12} watts) to 13 TW. Global

commercial energy production in 1993 reached 338 exajoules (1 exajoule = 10^{18} joules, or about 163 million barrels of oil), 40% greater than in 1973. Total energy consumption rose to 326 exajoules, 49% greater that 20 years before (World Resources Institute 1996).

4. *Water*. Humanity uses more than a quarter of the 69,600 $km^3\ yr^{-1}$ of terrestrial evapotranspiration and more than a half of the 12,500 $km^3\ yr^{-1}$ of runoff that is geographically and temporally accessible. Of global water use, 42% is attributable to agriculture and 14% to industry. Freshwater is scarce in many regions, increasing ecological degradation, limiting production of agriculture and industry, impacting on human health, and increasing international tensions.

5. *Global economy.* For many decades, global increases in consumption have outpaced increases in the human population. For 1980-97, the global economy nearly tripled to some US$29 trillion, although over the same period the population only increased by a third (United Nations Development Program et al. 2000). Per capita consumption levels are rising in many nations as their economics develop.

It is out of the question that an enterprise of this scale will have major detrimental impacts on biodiversity.

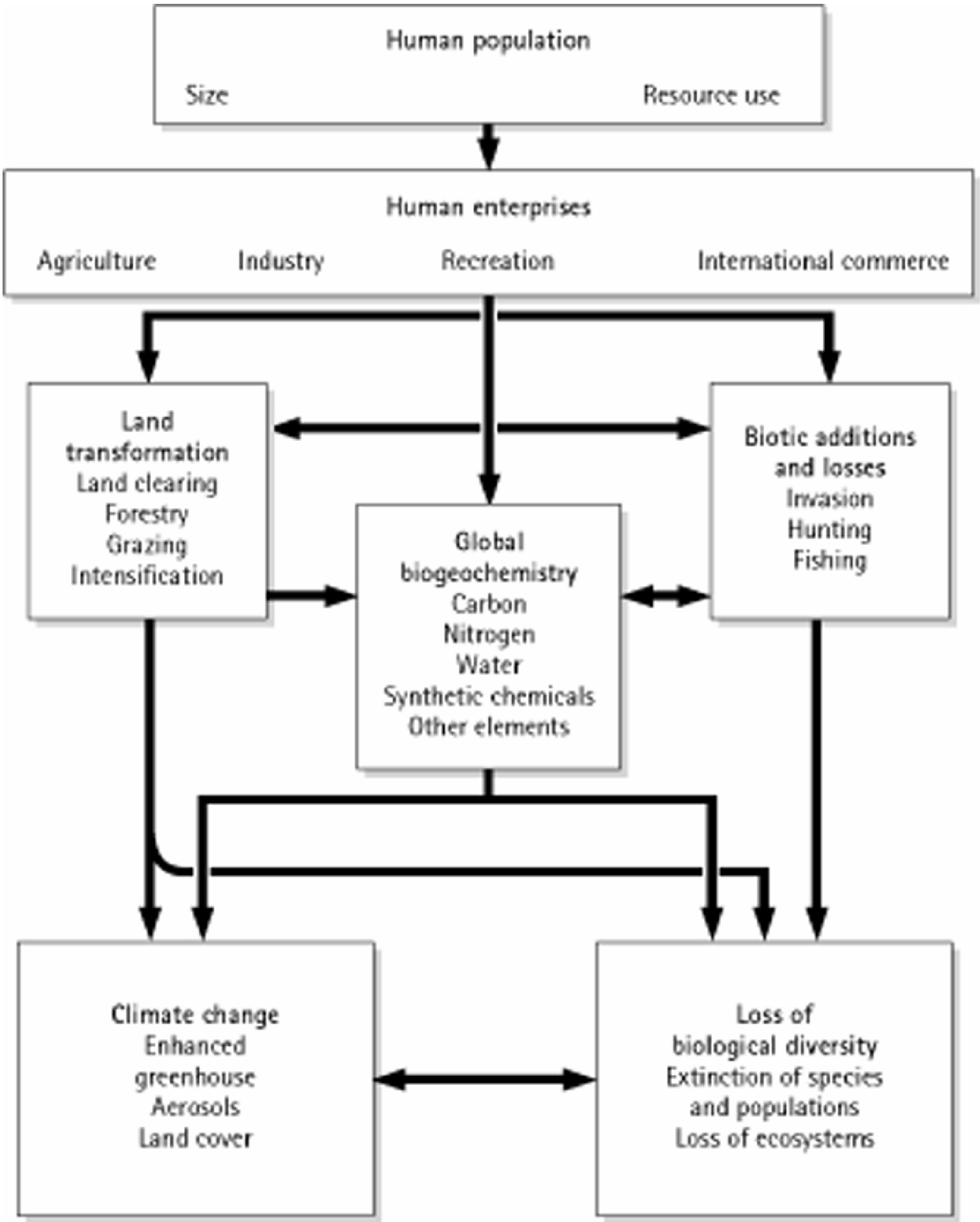

Fig. A conceptual model illustrated humanity's direct and indirect effects on the Earth system (From Vitousek et al. 1997a.)

Summary

1. Biodiversity loss, as shown by species extinctions, has been taking place as a consequence of human activities for a long time, initially associated with the colonization of some areas of the world by prehistoric peoples.
2. Since 1600 there have been over 1000 recorded extinctions of plant and animal species.
3. Imminent extinction rates are estimated to be orders of magnitude greater than the background rates seen in the fossil record.
4. The principal proximate causes of biodiversity loss are: Direct exploitation; habitat loss, degradation and fragmentation; the effects of introduced species; and extinction cascades.
5. The ultimate causes of biodiversity loss concern the size of the human population, the rate of human population growth and the scale of the human enterprise.

1. SOLUTIONS FOR THE PROTECTION AND PRESERVATION OF BIODIVERSITY

2.1 Political, Social and Economic related solutions

Political:

a) The Convention on Biological Diversity: Common framework for debate

b) The integration of Biod. concerns in sectorial policies:

Transport policies: Roads.

Agriculture: Pesticides, monoculture

Dev. Cooperation: Env. concerns on projects

Fisheries, forestry, energy, tourism.

c) EIA for projects, programmes and policies: feedback

d) Public Tenders: Biodiversity-friendly criteria for selection of projects

e) Long term biodiversity management plans

f) Create and Protect Natural Areas: Natura 2000

g) Law enforcement: Customs control alien sp, pollution.

h) Partnerships with private companies/NGOs

i) Economical/Taxes incentives to private companies

Social:

Public awareness

NGOs role

Consumers power: organic food production

Economic:

a) Incorporating benefits from biodiversity in decision making:
long term vs priority short term benefits. Difficult
Private gain priority vs benefits to society

b) Private companies certifications: Legal timber origin

c) Private companies financial support for conservation projects

d) Put a value on biodiversity

2.2 The Challenge: The Convention and preservation of Biodiversity

The Convention on Biological Diversity is the first convention to provide a comprehensive approach to the conservation and sustainable use of biodiversity. It is an ambitious international framework for reversing the losses of global biodiversity, upon which many development opportunities depend. agree

Introduction

Use of the term “biodiversity” arose in the context of, and has remained firmly wedded to, concerns over the loss of the natural environment and its contents. The importance of this connection cannot be overstated. In defining biodiversity, we have relied heavily on the Convention on Biological Diversity. This was not solely as a matter of convenience. It underscores our belief that, for better or for worse, and with its many flaws, this remains perhaps the single most important international step towards the long-term maintenance of biodiversity. The Convention constituted an historic commitment by nations of the world (though sadly not all of them, including the USA, have ratified or even signed). It was the first time that biodiversity was comprehensively addressed in a binding global treaty, the first time that genetic diversity was specifically covered, and the first time that the conservation of biodiversity was recognized as the common concern of humankind. So, having examined the main features and patterns of biodiversity, the value placed on it, and the threats that it faces, we now turn to the relevant Articles contained in the Convention to provide a useful framework in which to discuss its maintenance into the future (as well as providing a valuable lesson in how such treaties are formulated). Whether or not one regards the Convention as having major significance, this provides a much broader canvas than that obtained by simply focusing on issues traditionally associated with the field of conservation biology. It draws attention to the fact that the maintenance of biodiversity touches on many facets of human activities, and concerns much more than how to prevent individual species from becoming extinct, or the provision of nature reserves and other protected areas for conservation.

The Convention is comprised of 42 Articles, concerning issues ranging from its objectives, the practical obligations of each signatory, the policies to be followed, and the use of terms. Below we take various Articles in turn, and use these as a starting point to discuss the relationship of particular issues to the maintenance of biodiversity. Each of the Articles chosen is reproduced in full, followed by some commentary. We would encourage readers not to be deterred by the legal language (with its multiple caveats and sub-clauses) of the sections of the attempt to maintain biodiversity in a broader societal context; the obfuscation was necessary to achieve a document that so many countries could sign up to. Although at times rather formidable, the underlying ideas remain simple to understand and are amplified in the accompanying text.

Objectives of the Convention

The objectives of the Convention (Article 1) are threefold:

The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.

(To avoid possible confusion, **“**sustainable use” is defined (in Article 2) as “ the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations" – to many minds, this is unhelpfully vague.)

This is the heart of the Convention, establishing the framework and context for the subsequent Articles, and its overall sense of direction. Indeed, right at the outset the Convention recognizes some of the main strands that must be involved in the future interaction of humanity with biodiversity. Biodiversity must be maintained, if only because to fail to do so would be to put in danger human existence through the consequences for direct and indirect use. This can only be achieved through sustainable use, and only if the benefits arising form the use are fairly and equitably distributed. This reflects a general acceptance that there are social contexts to conservation actions.

The emphasis on equitable sharing of benefits arising from the utilization of genetic resources reflects concerns that in the past such resources belonging to one nation have been exploited by one or more others, with no recompense. Although examples usually relate to the exploitation of the genetic resources of developing nations by developed ones, where its consequences are at their most severe, the problem is more widespread. Thus, for instance, Svarstad et al. (2000) relate how the hyphomycete fungus *Tolypocladium inflatum* was collected in soil samples by a biologist during his holiday in Norway in 1969, within an open access regime. Best-selling medicines based on cyclosporine A (an immunosuppressant, and essential in the transplant of human organs), a biochemical produced by the fungus, were subsequently developed by a pharmaceutical company. Two per cent royalties on sales might have been a reasonable claim if these had been benefit-sharing with the source country (although the fungus has subsequently been found to be distributed across many countries), and in 1997 alone these would have amounted to US$24.3 million.

General measures for conservation and sustainable use

This, Article 6, is perhaps one of the most far-reaching and significant Articles in the Convention, and reads as follows:

Each Contracting Party shall, in accordance with its particular conditions and capabilities:

(a) Develop national strategies, plans or programs for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programs which shall reflect, inter alia, *the measures set out in this Convention relevant to the Contracting Party concerned; and*
(b) Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programs and policies.

In short, the conservation and sustainable use of biodiversity are not expected to emerge fortuitously in each nation. Indeed they will not do so, as the recent history of biodiversity testifies. Biodiversity is under great pressure from human activities, with many species being threatened with extinction, and much of the use being unsustainable.

The Convention obliges nations to establish mechanisms for bringing about the conservation and sustainable use of biodiversity, or for developing these mechanisms if they already exists. Strategies, plans and programs can be seen as a chronological series of steps whereby specific recommendations are turned into methods of achieving those ends and thence into action on the ground. They will inevitably have to be dynamic, and under continual refinement and development, in order to respond to the changing circumstances of biodiversity in a particular nation. If they are to be effective, then these national strategies, plans and programs will not be easy to formulate, as they will have to touch on multiple (perhaps even most) human activities. They will thus have to be integrated with policies in fields as diverse as agriculture, education, employment, energy, health, industry and transport. If they are to be truly effective, then the strategies, plans and programs for conserving and sustainably using a nation's biological diversity will have to become central to the way in which that nation's affairs are conducted.

A striking example of the ways in which this is not presently occurring concerns so-called perverse subsidies. These are subsidies that are adverse in the long run to both the economy and the environment, and include support for: (i) agriculture. May cause overloading of croplands, leading to soil erosion, pollution from synthetic fertilizers and pesticides, and release of greenhouse gases; (ii) fossil fuels and nuclear energy- may increase pollution, smog and global warming, and creates waste-disposal problems; (iii) road transport- promotes pollution, excessive road-building and resultant habitat loss; (iv) water- encourages greater use and misuse of supplies; and (v) fisheries- support overharvesting. The scale of perverse subsidies is vast, totaling perhaps US$1450 billion per annum, and often exceeding the value in the market-place of the goods that are generated form a given industrial sector. For example, global subsidies to marine fisheries exceed the market value of the fish that are landed.

In accordance with Article 6, a number of countries have developed national Biodiversity Strategies (general instruments to identify strategic needs) or Action Plans (practical documents that identify what is to be done and who is to do what). At their best, such documents can identify how the ways in which societies operate will be restructured, so as to bring about the conservation and sustainable use of biodiversity. More frequently, they reflect aspirations with little indication of how these will be met, and fail to recognize the fundamental nature of what needs to be done.

Table: The goal, principles and objectives of the UK Action Plan (Anon, 1994)

Overall goal
To conserve and enhance biological diversity within the UK and contribute to the conservation of global biodiversity through all appropriate mechanisms.

Underlying principles

1. Where biological resources are used, such use should be sustainable
2. Wise use should be ensured for non-renewable resources
3. The conservation of biodiversity requires the care and involvement of individuals and communities as well as Governmental processes
4. Conservation of biodiversity should be an integral part of Government programs, policy and action
5. Conservation practice and policy should be based upon a sound knowledge-base
6. The precautionary principle should guide decisions

Objectives for conserving biodiversity

1. To conserve and where practicable to enhance:
    a) the overall populations and natural ranges of native species and the quality and range of wildlife habitats and ecosystems;
    b) internationally important and threatened species, habitats and ecosystems;
    c) species, habitats and natural managed ecosystems that are characteristic of local areas;
    d) the biodiversity of natural and semi-natural habitats where this has been diminished over recent past decades
2. To increase public awareness of, and involvement in, conserving biodiversity
3. To contribute to the conservation of biodiversity on a European and global scale

Identification and monitoring

In order to know whether strategies, programs and plans for conservation and sustainable use are appropriate and are working effectively, it will be necessary to gather suitable information. Article 7 places such an obligation on signatories to the Convention:

Each Contracting Party shall, as far as possible and as appropriate, in particular for the purposes of Articles 8 to 10:

(a) Identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex I;
(b) Monitor, through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;
(c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and
(d) Maintain and organize, by any mechanism data, derived from identification and monitoring activities pursuant to subparagraphs (a), (b) and (c) above.

The combination of the scarcity of knowledge of biodiversity and the extraordinary magnitude of the variety of life make it impossible to identify or monitor all of the components of biodiversity that lie within a nation's borders. The Article and its associated Annex therefore concentrate these undertakings in two directions: first on those components that are considered to be important for the conservation and sustainable use of biodiversity; and second on those activities which are likely to have the most substantial impacts on this conservation and use. Much of this will require the acquisition of entirely new information, while it will be possible to use some existing data, perhaps freshly collateral. Combined, this will have benefits far beyond the Convention, serving to improve overall understanding of biodiversity. This will be facilitated by the final clause of this Article.

The ease with which nations can begin to fulfill the requirements of this Article will vary dramatically, on the basis of existing knowledge alone. However, it is important that attempts to improve knowledge are not used as an excuse for failing to undertake action in other spheres of activity. This has been a frequent problem in the fields of conservation and sustainable use.

In-situ conservation:

Article 8 embodies the principal obligations for the conservation of biological diversity. Although it is one of the longer Articles in the Convention, and thus may appear especially daunting, it is so important that we must consider all of it. However, to make the task a little less onerous we will divide it into manageable sections.

Each Contracting Party shall, as far as possible and as appropriate:
(a) Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity;
(b) Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity;

Protected area systems or networks are required to be established as a central point of a national strategy for conserving biodiversity. More than 20,000 existing protected areas, spread amongst virtually all countries in the world, are recognized by the IUCN (The World Conservation Union) Commission on Parks and Protected Areas, covering an estimated13.2 million km^2 (Fig. below); marine reserves cover about 1.3. million km^2 of this total. However, this network suffers from a number of severe limitations.

1. Most protected areas are extremely small (Fig. below), typically of a size that is far below that required to maintain viable populations of large vertebrates. The severity of this size constraint may be reduced if protected areas are linked by corridors, but in practice with a few notable exceptions this has not happened, and there are both pros and cons to the creation of corridors. Potential benefits include increased immigration rates, and the provisions of increased or alternative refugia; potential disadvantages include facilitated transmission of fire, disease and predators, and reduction in between-population genetic variation. The overall number of protected areas continues to increase, but the average size of those declared in any given period has tended to decline through time.

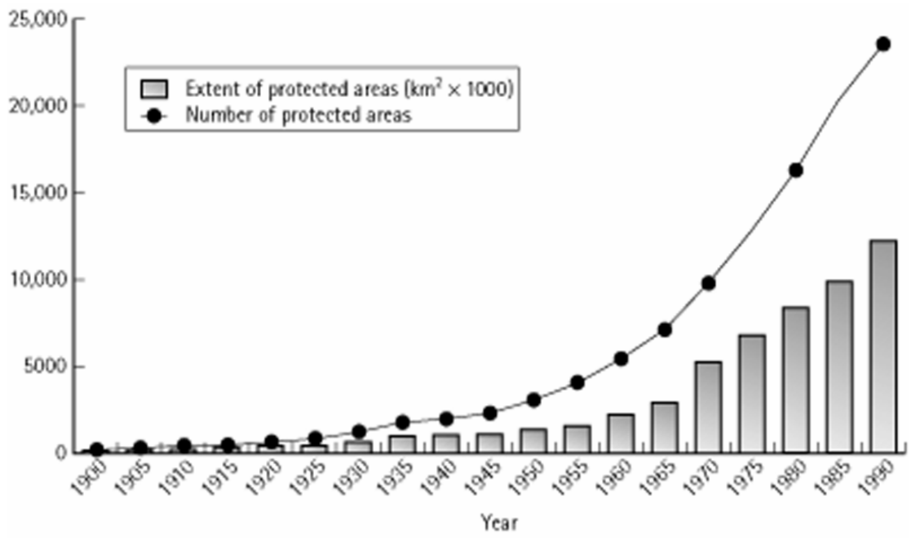

Fig. Cumulative growth in the number and extent of protected areas (1900-94). (From Green & Paine 1997.)

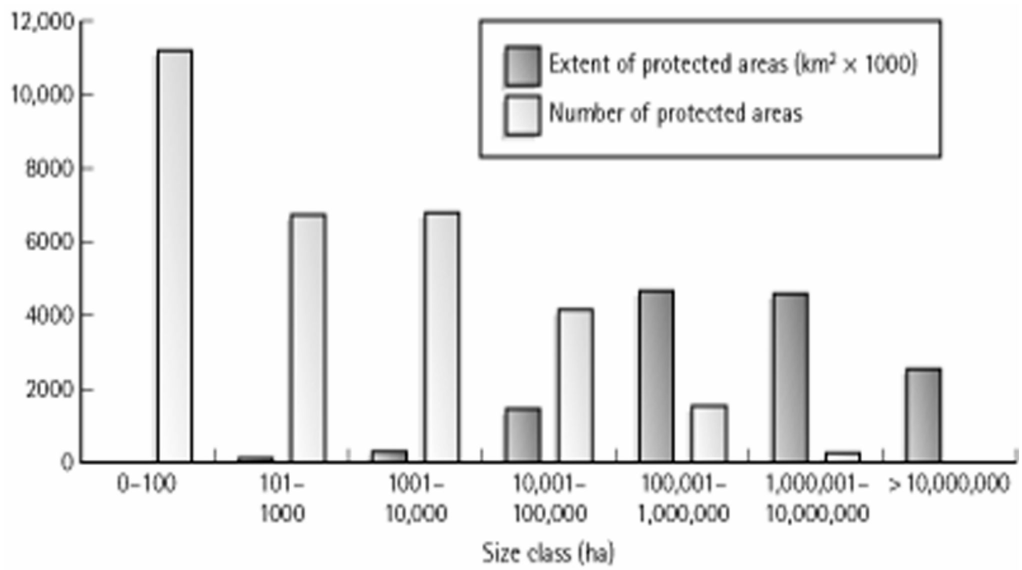

Fig. Frequency distribution of protected area sizes (From Green & Paine 1997.)

2. Protected areas tend to be biased towards lands of low economic value, experiencing less competition from alternative forms of land use, and towards the limits of geopolitical units where they may serve as buffer zones. In consequence, they do not adequately represent patterns of natural vegetation or species occurrences. Models of the changes in the distributions of species that are likely to result reveal that this situation is likely to be further exacerbated by climate change.

3. Many areas that have been formally designated for conservation in practice receive no, little or limited protection (and have often been termed "paper parks"). Thus, for example, Gronne Ejland in Greenland was declared a Ramsar site (a protected area designated under the Ramsar Convention on Wetlands of International Importance) in 1987, with special reference to the presence of the world's largest colony of Artic terns *Sterna paradisaea* (c.1950 estimates suggested 50,000 – 80,000 breeding pairs). This designation never had any practical significance, and in the summer of 2000 not a single breeding pair of terns was recorded as remaining. The effectiveness of many other protected areas has been much debated. Ultimately, this will often depend on the level of management activities (e.g. enforcement of park boundaries, anti-poaching patrols). Funds for this are insufficient in much of the world. US$6 billion is presently spent globally on protected areas for conservation. This compares with US$2.1 billion for the cost of a replacement space shuttle in 1991, US$6 billion spent to resolve property damage following Hurricane Floyd in 1999, US$15 billion agreed in 2002 for a single order of fighter aircraft by the UK government, and US$50 billion spent each year globally on methods of dieting.

4. The overall extent of the existing conservation network is too small. IUCN (1993) encourages that at least 10% of the land area of each nation be set aside for conservation. The expansion of the global network of protected areas to meet a target of 15% has been estimated to carry a global price-tag of US$20 billion-28 billion per annum. In practice, even a network covering 15% of different regions is likely to be inadequate to represent all species, especially in the tropics. Substantially larger percentages may be required for ecosystems or nations with higher levels of species richness and/or endemism. The proportion of the land area set aside for conservation may be too small, but the proportion of the marine environment set aside for these purposes is much lower (c. 0.5% of ocean area). Nonetheless, existing evidence strongly supports the notion that designating protected areas of ocean has enormous benefits both for biodiversity within and without those areas, and hence for exploitation of the latter. Estimates suggest that an initiative to generate a globally effective network covering 30% of the area of the oceans would cost c. US$23 billion per annum in recurrent costs, plus c. US$6 billion per annum (over 30 years) in start-up costs.

5. The existing conservation network has been conceived along rather static lines, and is not well equipped to cope with the changes in the distributions of species that are being brought about by global climate changes. These changes would normally cause shifts in the distributions of species, typically with expansions along some range boundaries and contractions along others. However, as protected areas become progressively more like islands of natural vegetation in a matrix of modified environments, often isolated from one another by considerable distances, the possibility for species to respond by such movements becomes increasingly constrained.

There have been a number of attempts to identify priority areas for conservation, to guide thinking in the location of future protected areas and the exercise of other conservation measures. These are based on the principles that biodiversity is unevenly distributed across the planet, that it is under more immediate threat in some areas than others, and that resources for conservation action are limiting. They include approaches based on hotspots of biodiversity, endemism and threat, and on the most outstanding examples of different habitat types, such as Birdlife International's Endemic Bird Areas, Conservation International's Hotspots, etc. Particularly at regional scales, increasing attention is being paid to maximizing the complementarity between different areas (including the largest number of species in a network of a given total extent, cost, etc.).

A key issue in identifying priority areas for conservation is the extent to which areas chosen on the basis of one taxonomic group are also appropriate for the maintenance of the biodiversity of others in a region (this is related to, although not the same as, the issue of how well the patterns of species richness of different groups are correlated). Whilst there are some important similarities, there are also significant differences, which caution against assuming that planning based on those groups that we know well will suffice for those we do not.

(c) Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to ensuring their conservation and sustainable use;
(d) Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings;
(e) Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas;

Of course, whether on land or in the ocean, protected areas, whilst vital, are not sufficient in themselves for the conservation of biodiversity. First, they are not isolated from events beyond their boundaries, and the more degraded conditions become outside, the greater the reduction of population viability within. Second, they are often vulnerable to threats and accidents emanating from outside, such as resource exploitation and chemical contamination. Thus, for example, extinction rates of large mammals in protected areas in West Africa have been shown to increase with human density in the surrounding areas, presumably reflecting the increased hunting pressures that they face. Third, much biodiversity will not be contained within protected areas. For example, an unknown but doubtless large proportion of species is unrepresented within protected areas, and large numbers of some flagships species occur outside their boundaries; 80% of Africa's elephants live outside protected areas. Fourth, many fundamental processes, such as migration and population replenishment (especially in marine systems), occur at scales much larger than those protected areas can reasonably attain. Fifth, climate change may make conditions within the boundaries of existing protected areas untenable for some of the species they were intended to conserve. These paragraphs of Article 8 therefore require the management of biological resources both within protected areas and outside of them (i.e. the general protection of ecosystems and populations wherever they occur), and so ensure that development in areas adjacent to protected areas does not undermine the capacity of those protected areas to conserve biodiversity.

Some attempt has been made to estimate what might be the cost of protecting biodiversity in the matrix of landscapes beyond reserves. Thus, it has been suggested that biodiversity remediation costs might be US$34 billion per annum for the forestry sector, US$1 billion for freshwater and US$14 billion for coastal and marine systems (United Nations 1993). Biodiversity conservation in the farming sector would cost far more, with one estimate of US$240 billion per annum, giving an overall annual total of about US$290 billion. This is a fraction of the sums presently spent on perverse subsidies.

(f) Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, inter alia*, through the development and implementation of plans or other management strategies;*

The conservation of biodiversity is not simply about maintaining things the way they presently are: few (if any) areas are pristine and touched, directly or indirectly, by human hand, and many are severely degraded. A creative approach to restoration is thus required, which can reverse the slide of lands from wild to degrade (Fig. below).

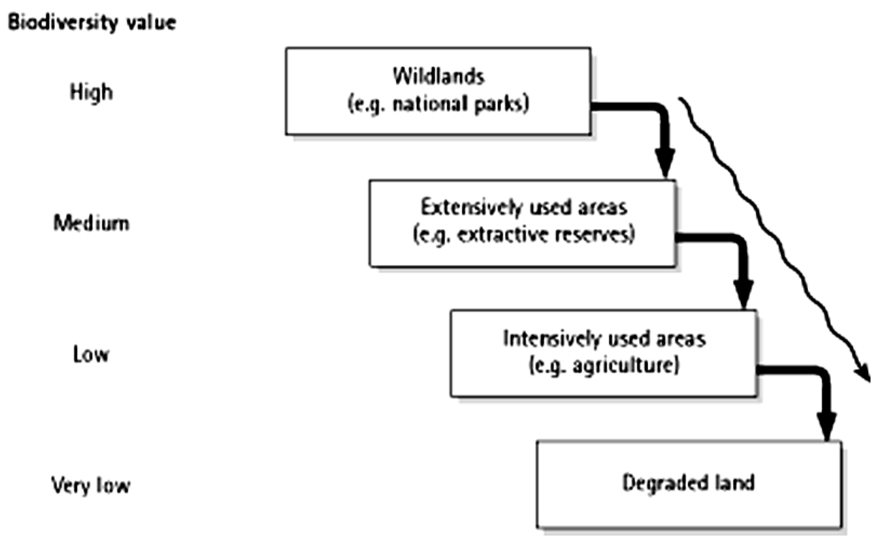

Fig. The land-use cascade. (From Terborgh 1999.)

This has given rise to the emergence of the science of restoration ecology. Many innovative and cost-effective approaches to restoration have been developed, which harness natural ecosystems processes. Agricultural and industrial development, whilst it may be curtailed, cannot be stopped, so restoration provides a means of reducing the time for which habitat remains in a degraded state.

(g) Establish or maintain means to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, taking also into account the risks to human health;
(h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species;

The impacts on biodiversity and the environment associated with the introduction of alien species have already been mentioned and, plainly, actions to ameliorate these effects are a necessary part of an effective conservation strategy. Prevention of invasions is much less costly than is their control once they become established, and so effective quarantine measures are vital, although presently adopted by very few nations. Eradication of established introductions is sometimes possible, particularly from islands and small areas, where action can be taken early in the invasive process, where measures can be persistently applied often over long periods (temptations to reduce efforts in response to initial success in reducing numbers must be resisted), and where there is public support for such campaigns. In some cases the, often high, costs associated with eradication may be more economic than the ongoing year-on-year expenses associated with control programs that serve solely to contain the distribution or reduce the abundance of an alien species. However, in most cases the latter steps are the only ones that are practical, and may require a great deal of commitment and diligence.

The need to combat the possible risks associated with the intentional use and release of living 'modified' organisms (which include genetically modified organisms) has been particularly highlighted in this Article. There is, of course, vigorous debate as to how severe these risks are.

(i) Endeavor to provide the conditions needed for compatibility between present uses and the conservation of biological diversity and the sustainable use of its components;
(j) Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices;

Intuitively, support for the conservation of biological diversity will be less when necessary changes conflict with present uses. The first of these paragraphs requests that Parties to the Convention should minimize theses conflicts, although plainly this will often be difficult and, at times, impossible. This issue begs the question of whether it is better to exploit smaller areas intensively, or to exploit less intensively over larger areas. Conventionally, the latter has been viewed as being better for the maintenance of biodiversity. However, evidence from studies both of forestry and fisheries suggests the converse may well be the case. The long-term sustainability and environmental consequences of intensive agriculture are, however, of great concern. Locally, intensification of agricultural systems can increase erosion, lower soil fertility, and reduce biodiversity; regionally, it may pollute ground waters and cause eutrophication of rivers and lakes; globally, it may change the atmosphere and climate.

The second paragraph of this part of the Article recognizes that the knowledge, innovations and practices of indigenous and local communities may be pertinent to the conservation and sustainable use of biodiversity, and that this cultural relevance should be promoted, to the benefit of its custodians.

(k) Develop or maintain necessary legislation and/or other regulatory provisions for the protection of threatened species and populations;
(l) Where a significant adverse effect on biological diversity has been determined pursuant to Article 7, regulate or manage the relevant processes and categories of activities; and
(m) Cooperate in providing financial and other support for in-situ *conservation outlined in subparagraphs (a) to (l) above, particularly to developing countries.*

These paragraphs all concern mechanisms for conserving biodiversity, including the development of appropriate legislation, the regulation and management of processes and activities which from the gathering of suitable information (as outlined in Article 7) have been found to be detrimental to biodiversity, and the provision of financial and other support to developing countries. The final paragraph reflects a recurrent theme of the Convention, in recognizing that the resources available for the conservation and sustainable use of biodiversity are not evenly distributed, and that the poorer countries will require support from the richer if these ends are to be achieved.

This is particularly so because there is a complex set of interactions between poverty and the environment. First, the majority of biodiversity tends to occur towards low latitudes, and there is also a decline in the wealth of nations (as measured by per capita gross national product GNP) towards low latitudes (Fig. below),

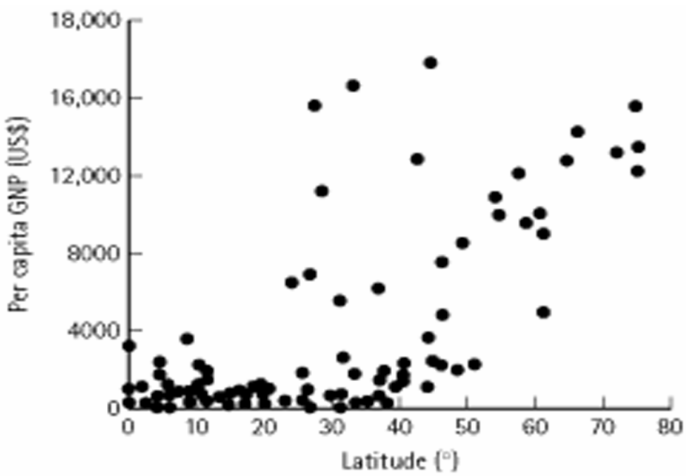

Fig. Latitudinal gradient in the per capita gross national product (GNP) of countries of the world in 1986. (From Huston 1994.)

which means that the majority of biodiversity occurs in those nations that have the least resources with which to conduct conservation and sustainable use. Second, damage to ecosystems often impacts most directly on the poor, who suffer the effects of polluted environments, the loss of productive lands, the collapse of fisheries, and the loss of traditional sources of food, fodder, fuel and fibre when forest are cut down. The poor do not have the financial resources with which to acquire the resources that they need (food, water, etc.) from elsewhere; the large ecological footprint of the rich reduces their vulnerability to local environmental degradation. Third, as a consequence, the relative impacts of factors affecting biodiversity are not the same in poorer and richer countries (Fig. below).

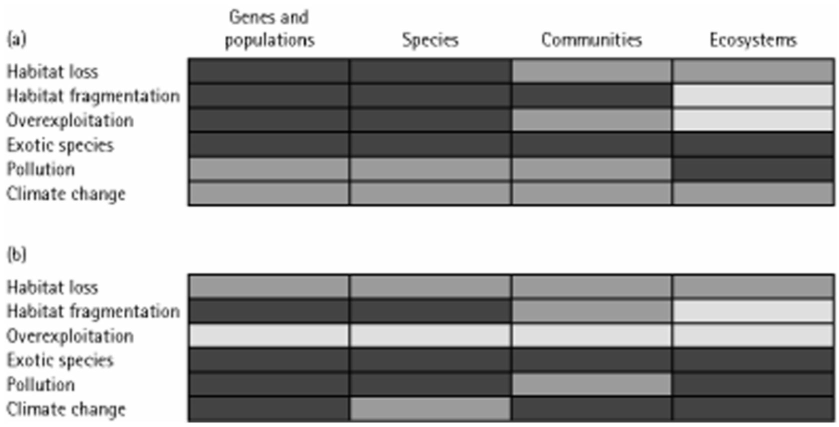

Fig. Relative impacts of factors affecting terrestrial biodiversity in: (a) poor; and (b) rich countries. Shading indicates intensity of impact, from black (highest) to light grey (lowest). (From Soulé 1991.)

Ex-situ **conservation**

Conservation actions have traditionally been divided into *in-situ* and *ex-situ*, and having dealt with the former in Article 8, the Convention moves on to the latter in Article 9.

Each Contracting Party shall, as far as possible and as appropriate, and predominantly for the purpose of complementing in-situ measures:
(a) Adopt measures for the ex-situ conservation of components of biological diversity, preferably in the country of origin of such components;
(b) Establish and maintain facilities for ex-situ conservation of and research on plants, animals and micro-organisms, preferably in the country of origin of genetic resources;
(c) Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions;
(d) Regulate and manage collection of biological resources from natural habitats for ex-situ conservation purposes so as not to threaten ecosystems and in-situ populations of species, except where special temporary ex-situ measures are required under subparagraph (c) above; and
(e) Cooperate in providing financial and other support for ex-situ conservation outlined in subparagraphs (a) to (d) above and in the establishment and maintenance of ex-situ conservation facilities in developing countries.

Ex-situ conservation measures may include seed banks, sperm and ova banks, culture collections (e.g. of plant tissues), artificial propagation of plants and captive breeding of animals. In a growing number of instances, more individuals of given species are held in such facilities than occur in the wild. The relative costs and benefits of *ex-situ* conservation have been much debated. This is particularly true with regard to large-bodied vertebrates (such as primates, big cats and cetaceans). Key issues here include the ethics of keeping individuals in captivity, whether the resources so used could practically be deployed in other ways (e.g. for *in-situ* conservation), the short- and long-term viability of both captive and wild populations, the relationship between the two (including the use and efficacy of reintroductions of species into areas in which they have become extinct, and to bolster declining natural populations), and other potential benefits of captive populations (e.g. in education of urban human populations). Whatever one's position on these matters, *ex-situ* activities should play only a very secondary role to *in-situ* conservation.

Sustainable use of components of biological diversity:

The sustainable use of biological diversity is one of the objectives of the Convention (Article 1). Article 10 embodies the obligations for attaining this goal.

Each Contracting Party shall, as far as possible and as appropriate:
(a) Integrate consideration of the conservation and sustainable use of biological resources into national decision-making;
(b) Adopt measures relating to the use of biological resources to avoid or minimize adverse impacts on biological diversity;
(c) Protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements;
(d) Support local populations to develop and implement remedial action in degraded areas where biological diversity has been reduced; and
(e) Encourage cooperation between its governmental authorities and its private sector in developing methods for sustainable use of biological resources.

To live sustainably, the human population must do so within the biosphere's regenerative capacity, drawing on its natural capital without depleting the capital stock. Evidence suggests that since the 1980s, human exploitation of the Earth's biological productivity may well have exceeded this capacity, such that the ecological footprint of the global population in 1999 was 1.2. times that of the entire Earth. Issues of sustainability thus extend far beyond the frequent media focus on trade in particular commodities of high economic value, such as wood from mahoganies, horn from rhinoceros, body parts from tigers and ivory from elephants. Put simply, most present use of biodiversity is not sustainable (management approaches have often focused on maximizing short-term yield and economic gain rather than long-term sustainability).

A major difficulty lies in controlling the level of use. Even where use may be reasonably sustainable at low levels, it may significantly impact at higher levels. This highlights the potential tradeoffs between levels of use, the spatial extent of that use (to obtain the same resource, low levels of use have to be spread over greater areas), and the impacts of use. Such considerations span the extraction of products from natural tropical forest to the planting of genetically modified crops.

In essence, the Convention proposes that sustainable use is to be achieved by its integration into national planning. How this can most effectively be done is a complex issue, with debate particularly centered on the most appropriate approach to trade (free-market, highly regulated, etc.)

Sustainable use requires the support of local peoples, and the protection and encouragement of customary use is one way in which to achieve this. However, it is important to distinguish those traditional uses that are compatible with conservation and sustainable use from those that are not. For example, the widespread belief that “primitive” peoples have no appreciable adverse impact on their environment is, expressed in such a generic fashion, simply a myth. Even when not based on distortions of history, appeals to traditional uses often reflect situations in which human densities were far lower and there was no commercial exploitation.

Incentive measures:

Biodiversity loss is driven in major part by economic forces. Article 11 is an attempt to harness these same forces to its conservation and sustainability.

Each Contracting Party shall, as far as possible and as appropriate, adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity.

Put simply, the obligation is to adopt measures that encourage conservation and sustainable use. In contrast, as exemplified by perverse subsidies, the converse is often the case.

The interactions between society and the environment are complex, requiring careful analysis to determine the full consequences of particular actions.

Responses to the Convention:

A number of Parties to the Convention have produced Biodiversity Strategies and Action Plans. This is, however, a rather easy step in responding to its contents, one which may attract significant media attention. Implementing the changes required to conserve biodiversity effectively and to exploit it in a sustainable fashion is much more difficult, and typically unpleasant to politicians with short-term goals (like re-election and personal financial gain). A number of nations have made small steps in the right direction, but substantial moves are largely wanting.

The obvious way forward, employed by other treaties and agreement, is to establish and agree targets for each party to achieve in fulfillment of the Convention, and protocols for reporting progress so that this can be carefully assessed. Un fortunately, such an approach has yet to be adopted, despite several Conferences of the Parties (CoPs) and summit meetings. Until significant progress is made in achieving the principles laid down in the Convention, whether by ensuring its application or by some other mechanism (individual nations could make much progress unilaterally), then biodiversity will continue to decline as a consequence of human activities. Whether ultimately this will threaten the existence of humanity is less significant than whether it will threaten the kind of existence people would like to enjoy. For us, it is already doing so.

SUMMARY

1. The Convention on Biological Diversity is one of the main global attempts to set an agenda for maintaining biodiversity and provides a useful framework for considering these issues.

2. The main objectives of the Convention are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from the utilization of genetic resources.

3. The conservation and sustainable use of biodiversity will not emerge fortuitously in each nation, but will require the establishment of explicit mechanisms.

4. In order to know whether strategies, programs and plants for conservation and sustainable use are appropriate and are working effectively, it will be necessary to gather suitable information.

5. Conservation of biodiversity will require a network of protected areas for *in-situ* protection, measures for its conservation in the wider land-scape, and perhaps also the use of *ex-situ* measures.

6. Sustainable use will only be attained by its integration into national planning, to minimize the adverse impacts of use on biodiversity.

7. Whilst there have been moves in the direction of the changes embodied in the Convention, as yet these are wholly inadequate.

Other International agreements

The conservation and sustainable use of biological diversity was first identified as a priority at the United Nations Conference on Human Environment in Stockholm in 1972, and since then a number of international legal instruments have been adopted.

The Ramsar Convention on Wetlands (1971) seeks to protect biologically-rich but undervalued wetland ecosystems.
(http://www.ramsar.org)

The Convention for the Protection of the World Cultural and Natural Heritage (abbreviated to World Heritage Convention, 1972) identifies sites of outstanding universal value, and provides support for their protection and management.
(http://www.unesco.org/whc)

The Convention on International Trade in Endangered Species (CITES, 1973) is a legally-binding international treaty, regulating trade in plant and animal species threatened with extinction.
(http://www.cites.org.)

The Convention on Migratory Species (alias The Bonn Convention, 1979) coordinates regional and global efforts to protect some 10,000 migratory species, including birds, dolphins, and marine turtles.
(http://www.wcmc.org.uk/cms)

The UN Framework Convention on Climate Change (1992) was negotiated in response to anticipated environmental damage, and aims to mitigate climate change impacts. *(http://www.unfccc.org)*

The UN Convention to Combat Desertification (1994) is a comprehensive approach to reducing desertification and drought. *(http://www.unccd.int)*

ANNEX 1

CONVENTION ON BIOLOGICAL DIVERSITY

5 JUNE 1992

Preamble

The Contracting Parties,

Conscious of the intrinsic value of biological diversity and of the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity and its components,
Conscious also of the importance of biological diversity for evolution and for maintaining life sustaining systems of the biosphere,
Affirming that the conservation of biological diversity is a common concern of humankind,
Reaffirming that States have sovereign rights over their own biological resources,
Reaffirming also that States are responsible for conserving their biological diversity and for using their biological resources in a sustainable manner,
Concerned that biological diversity is being significantly reduced by certain human activities,
Aware of the general lack of information and knowledge regarding biological diversity and of the urgent need to develop scientific, technical and institutional capacities to provide the basic understanding upon which to plan and implement appropriate measures,
Noting that it is vital to anticipate, prevent and attack the causes of significant reduction or loss of biological diversity at source,
Noting also that where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat,
Noting further that the fundamental requirement for the conservation of biological diversity is the *in-situ* conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings,
Noting further that *ex-situ* measures, preferably in the country of origin, also have an important role to play,
Recognizing the close and traditional dependence of many indigenous and local communities embodying traditional lifestyles on biological resources, and the desirability of sharing equitably benefits arising from the use of traditional knowledge, innovations and practices relevant to the conservation of biological diversity and the sustainable use of its components,
Recognizing also the vital role that women play in the conservation and sustainable use of biological diversity and affirming the need for the full participation of women at all levels of policymaking and implementation for biological diversity conservation,
Stressing the importance of, and the need to promote, international, regional and global cooperation among States and intergovernmental organizations and the non-governmental sector for the conservation of biological diversity and the sustainable use of its components,
Acknowledging that the provision of new and additional financial resources and appropriate access to relevant technologies can be expected to make a substantial difference in the world's ability to address the loss of biological diversity,
Acknowledging further that special provision is required to meet the needs of developing countries, including the provision of new and additional financial resources and appropriate access to relevant technologies,
Noting in this regard the special conditions of the least developed countries and small island States,

Acknowledging that substantial investments are required to conserve biological diversity and that there is the expectation of a broad range of environmental, economic and social benefits from those investments,
Recognizing that economic and social development and poverty eradication are the first and overriding priorities of developing countries,
Aware that conservation and sustainable use of biological diversity is of critical importance for meeting the food, health and other needs of the growing world population, for which purpose access to and sharing of both genetic resources and technologies are essential,
Noting that, ultimately, the conservation and sustainable use of biological diversity will strengthen friendly relations among States and contribute to peace for humankind,
Desiring to enhance and complement existing international arrangements for the conservation of biological diversity and sustainable use of its components, and
Determined to conserve and sustainably use biological diversity for the benefit of present and future generations,

Have agreed as follows:

Article 1. Objectives
The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.

Article 2. Use of Terms
For the purposes of this Convention:
"*Biological diversity*" means 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.
"*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.
"*Biotechnology*" means any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.
"*Country of origin of genetic resources*" means the country which possesses those genetic resources in *in-situ* conditions.
"*Country providing genetic resources*" means the country supplying genetic resources collected from *in-situ* sources, including populations of both wild and domesticated species, or taken from *ex-situ* sources, which may or may not have originated in that country.
"*Domesticated or cultivated species*" means species in which the evolutionary process has been influenced by humans to meet their needs.
"*Ecosystem*" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
"*Ex-situ conservation*" means the conservation of components of biological diversity outside their natural habitats.
"*Genetic material*" means any material of plant, animal, microbial or other origin containing functional units of heredity.
"*Genetic resources*" means genetic material of actual or potential value.
"*Habitat*" means the place or type of site where an organism or population naturally occurs.
"*In-situ conditions*" means conditions where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.
"*In-situ conservation*" means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in

the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.
"*Protected area*" means a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives.
"*Regional economic integration organization*" means an organization constituted by sovereign States of a given region, to which its member States have transferred competence in respect of matters governed by this Convention and which has been duly authorized, in accordance with its internal procedures, to sign, ratify, accept, approve or accede to it.
"*Sustainable use*" means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.
"*Technology*" includes biotechnology.

Article 3. Principle
States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

Article 4. Jurisdictional Scope
Subject to the rights of other States, and except as otherwise expressly provided in this Convention, the provisions of this Convention apply, in relation to each Contracting Party:
(a) In the case of components of biological diversity, in areas within the limits of its national jurisdiction; and
(b) In the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control, within the area of its national jurisdiction or beyond the limits of national jurisdiction.

Article 5. Cooperation
Each Contracting Party shall, as far as possible and as appropriate, cooperate with other Contracting Parties, directly or, where appropriate, through competent international organizations, in respect of areas beyond national jurisdiction and on other matters of mutual interest, for the conservation and sustainable use of biological diversity.

Article 6. General Measures for Conservation and Sustainable Use
Each Contracting Party shall, in accordance with its particular conditions and capabilities:
(a) Develop national strategies, plans or programs for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programs which shall reflect, *inter alia*, the measures set out in this Convention relevant to the Contracting Party concerned; and
(b) Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programs and policies.

Article 7. Identification and Monitoring
Each Contracting Party shall, as far as possible and as appropriate, in particular for the purposes of Articles 8 to 10:
(a) Identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex I;
(b) Monitor, through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;
(c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and

(d) Maintain and organize, by any mechanism data, derived from identification and monitoring activities pursuant to subparagraphs (a), (b) and (c) above.

Article 8. In-situ Conservation

Each Contracting Party shall, as far as possible and as appropriate:
(a) Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity;
(b) Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity;
(c) Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to ensuring their conservation and sustainable use;
(d) Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings;
(e) Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas;
(f) Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, *inter alia*, through the development and implementation of plans or other management strategies;
(g) Establish or maintain means to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, taking also into account the risks to human health;
(h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species;
(i) Endeavour to provide the conditions needed for compatibility between present uses and the conservation of biological diversity and the sustainable use of its components;
(j) Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices;
(k) Develop or maintain necessary legislation and/or other regulatory provisions for the protection of threatened species and populations;
(l) Where a significant adverse effect on biological diversity has been determined pursuant to Article 7, regulate or manage the relevant processes and categories of activities; and
(m) Cooperate in providing financial and other support for *insitu* conservation outlined in subparagraphs (a) to (l) above, particularly to developing countries.

Article 9. Ex-situ Conservation

Each Contracting Party shall, as far as possible and as appropriate, and predominantly for the purpose of complementing *in-situ* measures:
(a) Adopt measures for the *ex-situ* conservation of components of biological diversity, preferably in the country of origin of such components;
(b) Establish and maintain facilities for *ex-situ* conservation of and research on plants, animals and micro-organisms, preferably in the country of origin of genetic resources;
(c) Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions;
(d) Regulate and manage collection of biological resources from natural habitats for *ex-situ* conservation purposes so as not to threaten ecosystems and *in-situ* populations of species, except where special temporary *ex-situ* measures are required under subparagraph (c) above; and

(e) Cooperate in providing financial and other support for *exsitu* conservation outlined in subparagraphs (a) to (d) above and in the establishment and maintenance of *ex-situ* conservation facilities in developing countries.

Article 10. Sustainable Use of Components of Biological Diversity
Each Contracting Party shall, as far as possible and as appropriate:
(a) Integrate consideration of the conservation and sustainable use of biological resources into national decision-making;
(b) Adopt measures relating to the use of biological resources to avoid or minimize adverse impacts on biological diversity;
(c) Protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements;
(d) Support local populations to develop and implement remedial action in degraded areas where biological diversity has been reduced; and
(e) Encourage cooperation between its governmental authorities and its private sector in developing methods for sustainable use of biological resources.

Article 11. Incentive Measures
Each Contracting Party shall, as far as possible and as appropriate, adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity.

Article 12. Research and Training
The Contracting Parties, taking into account the special needs of developing countries, shall:
(a) Establish and maintain programmes for scientific and technical education and training in measures for the identification, conservation and sustainable use of biological diversity and its components and provide support for such education and training for the specific needs of developing countries;
(b) Promote and encourage research which contributes to the conservation and sustainable use of biological diversity, particularly in developing countries, *inter alia*, in accordance with decisions of the Conference of the Parties taken in consequence of recommendations of the Subsidiary Body on Scientific, Technical and Technological Advice; and
(c) In keeping with the provisions of Articles 16, 18 and 20, promote and cooperate in the use of scientific advances in biological diversity research in developing methods for conservation and sustainable use of biological resources.

Article 13. Public Education and Awareness
The Contracting Parties shall:
(a) Promote and encourage understanding of the importance of, and the measures required for, the conservation of biological diversity, as well as its propagation through media, and the inclusion of these topics in educational programmes; and
(b) Cooperate, as appropriate, with other States and international organizations in developing educational and public awareness programmes, with respect to conservation and sustainable use of biological diversity.

Article 14. Impact Assessment and Minimizing Adverse Impacts
1. Each Contracting Party, as far as possible and as appropriate, shall:
(a) Introduce appropriate procedures requiring environmental impact assessment of its proposed projects that are likely to have significant adverse effects on biological diversity with a view to avoiding or minimizing such effects and, where appropriate, allow for public participation in such procedures;
(b) Introduce appropriate arrangements to ensure that the environmental consequences of its programs and policies that are likely to have significant adverse impacts on biological diversity are duly taken into account;

(c) Promote, on the basis of reciprocity, notification, exchange of information and consultation on activities under their jurisdiction or control which are likely to significantly affect adversely the biological diversity of other States or areas beyond the limits of national jurisdiction, by encouraging the conclusion of bilateral, regional or multilateral arrangements, as appropriate;
(d) In the case of imminent or grave danger or damage, originating under its jurisdiction or control, to biological diversity within the area under jurisdiction of other States or in areas beyond the limits of national jurisdiction, notify immediately the potentially affected States of such danger or damage, as well as initiate action to prevent or minimize such danger or damage; and
(e) Promote national arrangements for emergency responses to activities or events, whether caused naturally or otherwise, which present a grave and imminent danger to biological diversity and encourage international cooperation to supplement such national efforts and, where appropriate and agreed by the States or regional economic integration organizations concerned, to establish joint contingency plans.
2. The Conference of the Parties shall examine, on the basis of studies to be carried out, the issue of liability and redress, including restoration and compensation, for damage to biological diversity, except where such liability is a purely internal matter.

Article 15. Access to Genetic Resources
1. Recognizing the sovereign rights of States over their natural resources, the authority to determine access to genetic resources rests with the national governments and is subject to national legislation.
2. Each Contracting Party shall endeavor to create conditions to facilitate access to genetic resources for environmentally sound uses by other Contracting Parties and not to impose restrictions that run counter to the objectives of this Convention.
3. For the purpose of this Convention, the genetic resources being provided by a Contracting Party, as referred to in this Article and Articles 16 and 19, are only those that are provided by Contracting Parties that are countries of origin of such resources or by the Parties that have acquired the genetic resources in accordance with this Convention.
4. Access, where granted, shall be on mutually agreed terms and subject to the provisions of this Article.
5. Access to genetic resources shall be subject to prior informed consent of the Contracting Party providing such resources, unless otherwise determined by that Party.
6. Each Contracting Party shall endeavor to develop and carry out scientific research based on genetic resources provided by other Contracting Parties with the full participation of, and where possible in, such Contracting Parties.
7. Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, and in accordance with Articles 16 and 19 and, where necessary, through the financial mechanism established by Articles 20 and 21 with the aim of sharing in a fair and equitable way the results of research and development and the benefits arising from the commercial and other utilization of genetic resources with the Contracting Party providing such resources. Such sharing shall be upon mutually agreed terms.

Article 16. Access to and Transfer of Technology
1. Each Contracting Party, recognizing that technology includes biotechnology, and that both access to and transfer of technology among Contracting Parties are essential elements for the attainment of the objectives of this Convention, undertakes subject to the provisions of this Article to provide and/or facilitate access for and transfer to other Contracting Parties of technologies that are relevant to the conservation and sustainable use of biological diversity or make use of genetic resources and do not cause significant damage to the environment.
2. Access to and transfer of technology referred to in paragraph 1 above to developing countries shall be provided and/or facilitated under fair and most favorable terms, including on concessional and preferential terms where mutually agreed, and, where necessary, in accordance with the financial mechanism established by Articles 20 and 21. In the case of technology subject to patents and other intellectual property rights, such access and transfer

shall be provided on terms which recognize and are consistent with the adequate and effective protection of intellectual property rights. The application of this paragraph shall be consistent with paragraphs 3, 4 and 5 below.
3. Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, with the aim that Contracting Parties, in particular those that are developing countries, which provide genetic resources are provided access to and transfer of technology which makes use of those resources, on mutually agreed terms, including technology protected by patents and other intellectual property rights, where necessary, through the provisions of Articles 20 and 21 and in accordance with international law and consistent with paragraphs 4 and 5 below.
4. Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, with the aim that the private sector facilitates access to, joint development and transfer of technology referred to in paragraph 1 above for the benefit of both governmental institutions and the private sector of developing countries and in this regard shall abide by the obligations included in paragraphs 1, 2 and 3 above.
5. The Contracting Parties, recognizing that patents and other intellectual property rights may have an influence on the implementation of this Convention, shall cooperate in this regard subject to national legislation and international law in order to ensure that such rights are supportive of and do not run counter to its objectives.

Article 17. Exchange of Information
1. The Contracting Parties shall facilitate the exchange of information, from all publicly available sources, relevant to the conservation and sustainable use of biological diversity, taking into account the special needs of developing countries.
2. Such exchange of information shall include exchange of results of technical, scientific and socio-economic research, as well as information on training and surveying programs, specialized knowledge, indigenous and traditional knowledge as such and in combination with the technologies referred to in Article 16, paragraph 1. It shall also, where feasible, include repatriation of information.

Article 18. Technical and Scientific Cooperation
1. The Contracting Parties shall promote international technical and scientific cooperation in the field of conservation and sustainable use of biological diversity, where necessary, through the appropriate international and national institutions.
2. Each Contracting Party shall promote technical and scientific cooperation with other Contracting Parties, in particular developing countries, in implementing this Convention, *inter alia*, through the development and implementation of national policies. In promoting such cooperation, special attention should be given to the development and strengthening of national capabilities, by means of human resources development and institution building.
3. The Conference of the Parties, at its first meeting, shall determine how to establish a clearing-house mechanism to promote and facilitate technical and scientific cooperation.
4. The Contracting Parties shall, in accordance with national legislation and policies, encourage and develop methods of cooperation for the development and use of technologies, including indigenous and traditional technologies, in pursuance of the objectives of this Convention. For this purpose, the Contracting Parties shall also promote cooperation in the training of personnel and exchange of experts.
5. The Contracting Parties shall, subject to mutual agreement, promote the establishment of joint research programs and joint ventures for the development of technologies relevant to the objectives of this Convention.

Article 19. Handling of Biotechnology and Distribution of its Benefits
1. Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, to provide for the effective participation in biotechnological research activities by those Contracting Parties, especially developing countries, which provide the genetic resources for such research, and where feasible in such Contracting Parties.

2. Each Contracting Party shall take all practicable measures to promote and advance priority access on a fair and equitable basis by Contracting Parties, especially developing countries, to the results and benefits arising from biotechnologies based upon genetic resources provided by those Contracting Parties. Such access shall be on mutually agreed terms.
3. The Parties shall consider the need for and modalities of a protocol setting out appropriate procedures, including, in particular, advance informed agreement, in the field of the safe transfer, handling and use of any living modified organism resulting from biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity.
4. Each Contracting Party shall, directly or by requiring any natural or legal person under its jurisdiction providing the organisms referred to in paragraph 3 above, provide any available information about the use and safety regulations required by that Contracting Party in handling such organisms, as well as any available information on the potential adverse impact of the specific organisms concerned to the Contracting Party into which those organisms are to be introduced.

Article 20. Financial Resources
1. Each Contracting Party undertakes to provide, in accordance with its capabilities, financial support and incentives in respect of those national activities which are intended to achieve the objectives of this Convention, in accordance with its national plans, priorities and programs.
2. The developed country Parties shall provide new and additional financial resources to enable developing country Parties to meet the agreed full incremental costs to them of implementing measures which fulfill the obligations of this Convention and to benefit from its provisions and which costs are agreed between a developing country Party and the institutional structure referred to in Article 21, in accordance with policy, strategy, program priorities and eligibility criteria and an indicative list of incremental costs established by the Conference of the Parties. Other Parties, including countries undergoing the process of transition to a market economy, may voluntarily assume the obligations of the developed country Parties. For the purpose of this Article, the Conference of the Parties, shall at its first meeting establish a list of developed country Parties and other Parties which voluntarily assume the obligations of the developed country Parties. The Conference of the Parties shall periodically review and if necessary amend the list. Contributions from other countries and sources on a voluntary basis would also be encouraged. The implementation of these commitments shall take into account the need for adequacy, predictability and timely flow of funds and the importance of burden-sharing among the contributing Parties included in the list.
3. The developed country Parties may also provide, and developing country Parties avail themselves of, financial resources related to the implementation of this Convention through bilateral, regional and other multilateral channels.
4. The extent to which developing country Parties will effectively implement their commitments under this Convention will depend on the effective implementation by developed country Parties of their commitments under this Convention related to financial resources and transfer of technology and will take fully into account the fact that economic and social development and eradication of poverty are the first and overriding priorities of the developing country Parties.
5. The Parties shall take full account of the specific needs and special situation of least developed countries in their actions with regard to funding and transfer of technology.
6. The Contracting Parties shall also take into consideration the special conditions resulting from the dependence on, distribution and location of, biological diversity within developing country Parties, in particular small island States.
7. Consideration shall also be given to the special situation of developing countries, including those that are most environmentally vulnerable, such as those with arid and semi-arid zones, coastal and mountainous areas.

Article 21. Financial Mechanism
1. There shall be a mechanism for the provision of financial resources to developing country Parties for purposes of this Convention on a grant or concessional basis the essential elements of which are described in this Article. The mechanism shall function under the authority and

guidance of, and be accountable to, the Conference of the Parties for purposes of this Convention. The operations of the mechanism shall be carried out by such institutional structure as may be decided upon by the Conference of the Parties at its first meeting.
For purposes of this Convention, the Conference of the Parties shall determine the policy, strategy, program priorities and eligibility criteria relating to the access to and utilization of such resources. The contributions shall be such as to take into account the need for predictability, adequacy and timely flow of funds referred to in Article 20 in accordance with the amount of resources needed to be decided periodically by the Conference of the Parties and the importance of burden-sharing among the contributing Parties included in the list referred to in Article 20, paragraph 2. Voluntary contributions may also be made by the developed country Parties and by other countries and sources. The mechanism shall operate within a democratic and transparent system of governance.
2. Pursuant to the objectives of this Convention, the Conference of the Parties shall at its first meeting determine the policy, strategy and program priorities, as well as detailed criteria and guidelines for eligibility for access to and utilization of the financial resources including monitoring and evaluation on a regular basis of such utilization. The Conference of the Parties shall decide on the arrangements to give effect to paragraph 1 above after consultation with the institutional structure entrusted with the operation of the financial mechanism.
3. The Conference of the Parties shall review the effectiveness of the mechanism established under this Article, including the criteria and guidelines referred to in paragraph 2 above, not less than two years after the entry into force of this Convention and thereafter on a regular basis. Based on such review, it shall take appropriate action to improve the effectiveness of the mechanism if necessary.
4. The Contracting Parties shall consider strengthening existing financial institutions to provide financial resources for the conservation and sustainable use of biological diversity.

Article 22. Relationship with Other International Conventions
1. The provisions of this Convention shall not affect the rights and obligations of any Contracting Party deriving from any existing international agreement, except where the exercise of those rights and obligations would cause a serious damage or threat to biological diversity.
2. Contracting Parties shall implement this Convention with respect to the marine environment consistently with the rights and obligations of States under the law of the sea.

Article 23. Conference of the Parties
1. A Conference of the Parties is hereby established. The first meeting of the Conference of the Parties shall be convened by the Executive Director of the United Nations Environment Programme not later than one year after the entry into force of this Convention. Thereafter, ordinary meetings of the Conference of the Parties shall be held at regular intervals to be determined by the Conference at its first meeting.
2. Extraordinary meetings of the Conference of the Parties shall be held at such other times as may be deemed necessary by the Conference, or at the written request of any Party, provided that, within six months of the request being communicated to them by the Secretariat, it is supported by at least one third of the Parties.
3. The Conference of the Parties shall by consensus agree upon and adopt rules of procedure for itself and for any subsidiary body it may establish, as well as financial rules governing the funding of the Secretariat. At each ordinary meeting, it shall adopt a budget for the financial period until the next ordinary meeting.
4. The Conference of the Parties shall keep under review the implementation of this Convention, and, for this purpose, shall:
(a) Establish the form and the intervals for transmitting the information to be submitted in accordance with Article 26 and consider such information as well as reports submitted by any subsidiary body;
(b) Review scientific, technical and technological advice on biological diversity provided in accordance with Article 25;
(c) Consider and adopt, as required, protocols in accordance with Article 28;

(d) Consider and adopt, as required, in accordance with Articles 29 and 30, amendments to this Convention and its annexes;
(e) Consider amendments to any protocol, as well as to any annexes thereto, and, if so decided, recommend their adoption to the parties to the protocol concerned;
(f) Consider and adopt, as required, in accordance with Article 30, additional annexes to this Convention;
(g) Establish such subsidiary bodies, particularly to provide scientific and technical advice, as are deemed necessary for the implementation of this Convention;
(h) Contact, through the Secretariat, the executive bodies of conventions dealing with matters covered by this Convention with a view to establishing appropriate forms of cooperation with them; and
(i) Consider and undertake any additional action that may be required for the achievement of the purposes of this Convention in the light of experience gained in its operation.
5. The United Nations, its specialized agencies and the International Atomic Energy Agency, as well as any State not Party to this Convention, may be represented as observers at meetings of the Conference of the Parties. Any other body or agency, whether governmental or non-governmental, qualified in fields relating to conservation and sustainable use of biological diversity, which has informed the Secretariat of its wish to be represented as an observer at a meeting of the Conference of the Parties, may be admitted unless at least one third of the Parties present object. The admission and participation of observers shall be subject to the rules of procedure adopted by the Conference of the Parties.

Article 24. Secretariat
1. A secretariat is hereby established. Its functions shall be:
(a) To arrange for and service meetings of the Conference of the Parties provided for in Article 23;
(b) To perform the functions assigned to it by any protocol;
(c) To prepare reports on the execution of its functions under this Convention and present them to the Conference of the Parties;
(d) To coordinate with other relevant international bodies and, in particular to enter into such administrative and contractual arrangements as may be required for the effective discharge of its functions; and
(e) To perform such other functions as may be determined by the Conference of the Parties.
2. At its first ordinary meeting, the Conference of the Parties shall designate the secretariat from amongst those existing competent international organizations which have signified their willingness to carry out the secretariat functions under this Convention.

Article 25. Subsidiary Body on Scientific, Technical and Technological Advice
1. A subsidiary body for the provision of scientific, technical and technological advice is hereby established to provide the Conference of the Parties and, as appropriate, its other subsidiary bodies with timely advice relating to the implementation of this Convention. This body shall be open to participation by all Parties and shall be multidisciplinary. It shall comprise government representatives competent in the relevant field of expertise. It shall report regularly to the Conference of the Parties on all aspects of its work.
2. Under the authority of and in accordance with guidelines laid down by the Conference of the Parties, and upon its request, this body shall:
(a) Provide scientific and technical assessments of the status of biological diversity;
(b) Prepare scientific and technical assessments of the effects of types of measures taken in accordance with the provisions of this Convention;
(c) Identify innovative, efficient and state-of-the-art technologies and know-how relating to the conservation and sustainable use of biological diversity and advise on the ways and means of promoting development and/or transferring such technologies;
(d) Provide advice on scientific programs and international cooperation in research and development related to conservation and sustainable use of biological diversity; and

(e) Respond to scientific, technical, technological and methodological questions that the Conference of the Parties and its subsidiary bodies may put to the body.
3. The functions, terms of reference, organization and operation of this body may be further elaborated by the Conference of the Parties.

Article 26. Reports
Each Contracting Party shall, at intervals to be determined by the Conference of the Parties, present to the Conference of the Parties, reports on measures which it has taken for the implementation of the provisions of this Convention and their effectiveness in meeting the objectives of this Convention.

Article 27. Settlement of Disputes
1. In the event of a dispute between Contracting Parties concerning the interpretation or application of this Convention, the parties concerned shall seek solution by negotiation.
2. If the parties concerned cannot reach agreement by negotiation, they may jointly seek the good offices of, or request mediation by, a third party.
3. When ratifying, accepting, approving or acceding to this Convention, or at any time thereafter, a State or regional economic integration organization may declare in writing to the Depositary that for a dispute not resolved in accordance with paragraph 1 or paragraph
2 above, it accepts one or both of the following means of dispute settlement as compulsory:
(a) Arbitration in accordance with the procedure laid down in Part 1 of Annex II;
(b) Submission of the dispute to the International Court of Justice.
4. If the parties to the dispute have not, in accordance with paragraph 3 above, accepted the same or any procedure, the dispute shall be submitted to conciliation in accordance with Part 2 of Annex II unless the parties otherwise agree.
5. The provisions of this Article shall apply with respect to any protocol except as otherwise provided in the protocol concerned.

Article 28. Adoption of Protocols
1. The Contracting Parties shall cooperate in the formulation and adoption of protocols to this Convention.
2. Protocols shall be adopted at a meeting of the Conference of the Parties.
3. The text of any proposed protocol shall be communicated to the Contracting Parties by the Secretariat at least six months before such a meeting.

Article 29. Amendment of the Convention or Protocols
1. Amendments to this Convention may be proposed by any Contracting Party. Amendments to any protocol may be proposed by any Party to that protocol.
2. Amendments to this Convention shall be adopted at a meeting of the Conference of the Parties. Amendments to any protocol shall be adopted at a meeting of the Parties to the Protocol in question. The text of any proposed amendment to this Convention or to any protocol, except as may otherwise be provided in such protocol, shall be communicated to the Parties to the instrument in question by the secretariat at least six months before the meeting at which it is proposed for adoption. The secretariat shall also communicate proposed amendments to the signatories to this Convention for information.
3. The Parties shall make every effort to reach agreement on any proposed amendment to this Convention or to any protocol by consensus. If all efforts at consensus have been exhausted, and no agreement reached, the amendment shall as a last resort be adopted by a two-third majority vote of the Parties to the instrument in question present and voting at the meeting, and shall be submitted by the Depositary to all Parties for ratification, acceptance or approval.
4. Ratification, acceptance or approval of amendments shall be notified to the Depositary in writing. Amendments adopted in accordance with paragraph 3 above shall enter into force among Parties having accepted them on the ninetieth day after the deposit of instruments of ratification, acceptance or approval by at least two thirds of the Contracting Parties to this Convention or of the Parties to the protocol concerned, except as may otherwise be provided in

such protocol. Thereafter the amendments shall enter into force for any other Party on the ninetieth day after that Party deposits its instrument of ratification, acceptance or approval of the amendments.
5. For the purposes of this Article, "Parties present and voting" means Parties present and casting an affirmative or negative vote.

Article 30. Adoption and Amendment of Annexes
1. The annexes to this Convention or to any protocol shall form an integral part of the Convention or of such protocol, as the case may be, and, unless expressly provided otherwise, a reference to this Convention or its protocols constitutes at the same time a reference to any annexes thereto. Such annexes shall be restricted to procedural, scientific, technical and administrative matters.
2. Except as may be otherwise provided in any protocol with respect to its annexes, the following procedure shall apply to the proposal, adoption and entry into force of additional annexes to this Convention or of annexes to any protocol:
(a) Annexes to this Convention or to any protocol shall be proposed and adopted according to the procedure laid down in Article 29;
(b) Any Party that is unable to approve an additional annex to this Convention or an annex to any protocol to which it is Party shall so notify the Depositary, in writing, within one year from the date of the communication of the adoption by the Depositary. The Depositary shall without delay notify all Parties of any such notification received. A Party may at any time withdraw a previous declaration of objection and the annexes shall thereupon enter into force for that Party subject to subparagraph (c) below;
(c) On the expiry of one year from the date of the communication of the adoption by the Depositary, the annex shall enter into force for all Parties to this Convention or to any protocol concerned which have not submitted a notification in accordance with the provisions of subparagraph (b) above.
3. The proposal, adoption and entry into force of amendments to annexes to this Convention or to any protocol shall be subject to the same procedure as for the proposal, adoption and entry into force of annexes to the Convention or annexes to any protocol.
4. If an additional annex or an amendment to an annex is related to an amendment to this Convention or to any protocol, the additional annex or amendment shall not enter into force until such time as the amendment to the Convention or to the protocol concerned enters into force.

Article 31. Right to Vote
1. Except as provided for in paragraph 2 below, each Contracting Party to this Convention or to any protocol shall have one vote.
2. Regional economic integration organizations, in matters within their competence, shall exercise their right to vote with a number of votes equal to the number of their member States which are Contracting Parties to this Convention or the relevant protocol. Such organizations shall not exercise their right to vote if their member States exercise theirs, and vice versa.

Article 32. Relationship between this Convention and Its Protocols
1. A State or a regional economic integration organization may not become a Party to a protocol unless it is, or becomes at the same time, a Contracting Party to this Convention.
2. Decisions under any protocol shall be taken only by the Parties to the protocol concerned. Any Contracting Party that has not ratified, accepted or approved a protocol may participate as an observer in any meeting of the parties to that protocol.

Article 33. Signature
This Convention shall be open for signature at Rio de Janeiro by all States and any regional economic integration organization from 5 June 1992 until 14 June 1992, and at the United Nations Headquarters in New York from 15 June 1992 to 4 June 1993.

Article 34. Ratification, Acceptance or Approval

1. This Convention and any protocol shall be subject to ratification, acceptance or approval by States and by regional economic integration organizations. Instruments of ratification, acceptance or approval shall be deposited with the Depositary.
2. Any organization referred to in paragraph 1 above which becomes a Contracting Party to this Convention or any protocol without any of its member States being a Contracting Party shall be bound by all the obligations under the Convention or the protocol, as the case may be. In the case of such organizations, one or more of whose member States is a Contracting Party to this Convention or relevant protocol, the organization and its member States shall decide on their respective responsibilities for the performance of their obligations under the Convention or protocol, as the case may be. In such cases, the organization and the member States shall not be entitled to exercise rights under the Convention or relevant protocol concurrently.
3. In their instruments of ratification, acceptance or approval, the organizations referred to in paragraph 1 above shall declare the extent of their competence with respect to the matters governed by the Convention or the relevant protocol. These organizations shall also inform the Depositary of any relevant modification in the extent of their competence.

Article 35. Accession
1. This Convention and any protocol shall be open for accession by States and by regional economic integration organizations from the date on which the Convention or the protocol concerned is closed for signature. The instruments of accession shall be deposited with the Depositary.
2. In their instruments of accession, the organizations referred to in paragraph 1 above shall declare the extent of their competence with respect to the matters governed by the Convention or the relevant protocol. These organizations shall also inform the Depositary of any relevant modification in the extent of their competence.
3. The provisions of Article 34, paragraph 2, shall apply to regional economic integration organizations which accede to this Convention or any protocol.

Article 36. Entry Into Force
1. This Convention shall enter into force on the ninetieth day after the date of deposit of the thirtieth instrument of ratification, acceptance, approval or accession.
2. Any protocol shall enter into force on the ninetieth day after the date of deposit of the number of instruments of ratification, acceptance, approval or accession, specified in that protocol, has been deposited.
3. For each Contracting Party which ratifies, accepts or approves this Convention or accedes thereto after the deposit of the thirtieth instrument of ratification, acceptance, approval or accession, it shall enter into force on the ninetieth day after the date of deposit by such Contracting Party of its instrument of ratification, acceptance, approval or accession.
4. Any protocol, except as otherwise provided in such protocol, shall enter into force for a Contracting Party that ratifies, accepts or approves that protocol or accedes thereto after its entry into force pursuant to paragraph 2 above, on the ninetieth day after the date on which that Contracting Party deposits its instrument of ratification, acceptance, approval or accession, or on the date on which this Convention enters into force for that Contracting Party, whichever shall be the later.
5. For the purposes of paragraphs 1 and 2 above, any instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by member States of such organization.

Article 37. Reservations
No reservations may be made to this Convention.

Article 38. Withdrawals
1. At any time after two years from the date on which this Convention has entered into force for a Contracting Party, that Contracting Party may withdraw from the Convention by giving written notification to the Depositary.

2. Any such withdrawal shall take place upon expiry of one year after the date of its receipt by the Depositary, or on such later date as may be specified in the notification of the withdrawal.
3. Any Contracting Party which withdraws from this Convention shall be considered as also having withdrawn from any protocol to which it is party.

Article 39. Financial Interim Arrangements
Provided that it has been fully restructured in accordance with the requirements of Article 21, the Global Environment Facility of the United Nations Development Program, the United Nations Environment Program and the International Bank for Reconstruction and Development shall be the institutional structure referred to in Article 21 on an interim basis, for the period between the entry into force of this Convention and the first meeting of the Conference of the Parties or until the Conference of the Parties decides which institutional structure will be designated in accordance with Article 21.

Article 40. Secretariat Interim Arrangements
The secretariat to be provided by the Executive Director of the United Nations Environment Program shall be the secretariat referred to in Article 24, paragraph 2, on an interim basis for the period between the entry into force of this Convention and the first meeting of the Conference of the Parties.

Article 41. Depositary
The Secretary-General of the United Nations shall assume the functions of Depositary of this Convention and any protocols.

Article 42. Authentic Texts
The original of this Convention, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations. IN WITNESS WHEREOF the undersigned, being duly authorized to that effect, have signed this Convention. Done at Rio de Janeiro on this fifth day of June, one thousand nine hundred and ninety-two.

Annex I
IDENTIFICATION AND MONITORING
1. Ecosystems and habitats: containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social, economic, cultural or scientific importance; or, which are representative, unique or associated with key evolutionary or other biological processes;
2. Species and communities which are: threatened; wild relatives of domesticated or cultivated species; of medicinal, agricultural or other economic value; or social, scientific or cultural importance; or importance for research into the conservation and sustainable use of biological diversity, such as indicator species; and
3. Described genomes and genes of social, scientific or economic importance.

Annex II
Part 1
ARBITRATION
Article 1
The claimant party shall notify the secretariat that the parties are referring a dispute to arbitration pursuant to Article 27. The notification shall state the subject-matter of arbitration and include, in particular, the articles of the Convention or the protocol, the interpretation or application of which are at issue. If the parties do not agree on the subject matter of the dispute before the President of the tribunal is designated, the arbitral tribunal shall determine the subject matter. The secretariat shall forward the information thus received to all Contracting Parties to this Convention or to the protocol concerned.

Article 2

1. In disputes between two parties, the arbitral tribunal shall consist of three members. Each of the parties to the dispute shall appoint an arbitrator and the two arbitrators so appointed shall designate by common agreement the third arbitrator who shall be the President of the tribunal. The latter shall not be a national of one of the parties to the dispute, nor have his or her usual place of residence in the territory of one of these parties, nor be employed by any of them, nor have dealt with the case in any other capacity.
2. In disputes between more than two parties, parties in the same interest shall appoint one arbitrator jointly by agreement.
3. Any vacancy shall be filled in the manner prescribed for the initial appointment.

Article 3

1. If the President of the arbitral tribunal has not been designated within two months of the appointment of the second arbitrator, the Secretary-General of the United Nations shall, at the request of a party, designate the President within a further two-month period.
2. If one of the parties to the dispute does not appoint an arbitrator within two months of receipt of the request, the other party may inform the Secretary-General who shall make the designation within a further two-month period.

Article 4

The arbitral tribunal shall render its decisions in accordance with the provisions of this Convention, any protocols concerned, and international law.

Article 5

Unless the parties to the dispute otherwise agree, the arbitral tribunal shall determine its own rules of procedure.

Article 6

The arbitral tribunal may, at the request of one of the parties, recommend essential interim measures of protection.

Article 7

The parties to the dispute shall facilitate the work of the arbitral tribunal and, in particular, using all means at their disposal, shall:
(a) Provide it with all relevant documents, information and facilities; and
(b) Enable it, when necessary, to call witnesses or experts and receive their evidence.

Article 8

The parties and the arbitrators are under an obligation to protect the confidentiality of any information they receive in confidence during the proceedings of the arbitral tribunal.

Article 9

Unless the arbitral tribunal determines otherwise because of the particular circumstances of the case, the costs of the tribunal shall be borne by the parties to the dispute in equal shares. The tribunal shall keep a record of all its costs, and shall furnish a final statement thereof to the parties.

Article 10

Any Contracting Party that has an interest of a legal nature in the subject-matter of the dispute which may be affected by the decision in the case, may intervene in the proceedings with the consent of the tribunal.

Article 11

The tribunal may hear and determine counterclaims arising directly out of the subject-matter of the dispute.

Article 12
Decisions both on procedure and substance of the arbitral tribunal shall be taken by a majority vote of its members.

Article 13
If one of the parties to the dispute does not appear before the arbitral tribunal or fails to defend its case, the other party may request the tribunal to continue the proceedings and to make its award. Absence of a party or a failure of a party to defend its case shall not constitute a bar to the proceedings. Before rendering its final decision, the arbitral tribunal must satisfy itself that the claim is well founded in fact and law.

Article 14
The tribunal shall render its final decision within five months of the date on which it is fully constituted unless it finds it necessary to extend the time-limit for a period which should not exceed five more months.

Article 15
The final decision of the arbitral tribunal shall be confined to the subject-matter of the dispute and shall state the reasons on which it is based. It shall contain the names of the members who have participated and the date of the final decision. Any member of the tribunal may attach a separate or dissenting opinion to the final decision.

Article 16
The award shall be binding on the parties to the dispute. It shall be without appeal unless the parties to the dispute have agreed in advance to an appellate procedure.

Article 17
Any controversy which may arise between the parties to the dispute as regards the interpretation or manner of implementation of the final decision may be submitted by either party for decision to the arbitral tribunal which rendered it.

Part 2
CONCILIATION
Article 1
A conciliation commission shall be created upon the request of one of the parties to the dispute. The commission shall, unless the parties otherwise agree, be composed of five members, two appointed by each Party concerned and a President chosen jointly by those members.

Article 2
In disputes between more than two parties, parties in the same interest shall appoint their members of the commission jointly by agreement. Where two or more parties have separate interests or there is a disagreement as to whether they are of the same interest, they shall appoint their members separately.

Article 3
If any appointments by the parties are not made within two months of the date of the request to create a conciliation commission, the Secretary-General of the United Nations shall, if asked to do so by the party that made the request, make those appointments within a further two-month period.

Article 4
If a President of the conciliation commission has not been chosen within two months of the last of the members of the commission being appointed, the Secretary-General of the United

Nations shall, if asked to do so by a party, designate a President within a further two-month period.

Article 5
The conciliation commission shall take its decisions by majority vote of its members. It shall, unless the parties to the dispute otherwise agree, determine its own procedure. It shall render a proposal for resolution of the dispute, which the parties shall consider in good faith.

Article 6
A disagreement as to whether the conciliation commission has competence shall be decided by the commission.

SIGNATORIES OF THE CONVENTION ON BIOLOGICAL DIVERSITY AT THE TIME OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (RIO DE JANEIRO, 3-14 JUNE 1992)

Signatory Date of signature

1. Antigua and Barbuda 5 June 1992	49. Croatia 11 June 1992
2. Australia 5 June 1992	50. Dem. People Rep. of Korea 11 Jun 1992
3. Bangladesh 5 June 1992	51. Israel 11 June 1992
4. Belgium 5 June 1992	52. Jamaica 11 June 1992
5. Brazil 5 June 1992	53. Jordan 11 June 1992
6. Finland 5 June 1992	54. Kenya 11 June 1992
7. India 5 June 1992	55. Latvia 11 June 1992
8. Indonesia 5 June 1992	56. Lesotho 11 June 1992
9. Italy 5 June 1992	57. Lithuania 11 June 1992
10. Liechtenstein 5 June 1992	58. Monaco 11 June 1992
11. Republic of Moldova 5 June 1992	59. Myanmar 11 June 1992
12. Nauru 5 June 1992	60. Niger 11 June 1992
13. Netherlands 5 June 1992	61. Qatar 11 June 1992
14. Pakistan 5 June 1992	62. Trinidad and Tobago 11 June 1992
15. Poland 5 June 1992	63. Turkey 11 June 1992
16. Romania 5 June 1992	64. Ukraine 11 June 1992
17. Bostwana 8 June 1992	65. United Arab Emirates 11 June 1992
18. Madagascar 8 June 1992	66. Zaire 11 June 1992
19. Sweden 8 June 1992	67. Zambia 11 June 1992
20. Tuvalu 8 June 1992	68. Afghanistan 12 June 1992
21. Yugoslavia 8 June 1992	69. Angola 12 June 1992
22. Bahrain 9 June 1992	70. Argentina 12 June 1992
23. Ecuador 9 June 1992	71. Azerbaijan 12 June 1992
24. Egypt 9 June 1992	72. Bahamas 12 June 1992
25. Kazakhstan 9 June 1992	73. Barbados 12 June 1992
26. Kuwait 9 June 1992	74. Bulgaria 12 June 1992
27. Luxembourg 9 June 1992	75. Burkina Faso 12 June 1992
28. Norway 9 June 1992	76. Cape Verde 12 June 1992
29. Sudan 9 June 1992	77. Chad 12 June 1992
30. Uruguay 9 June 1992	78. Colombia 12 June 1992
31. Vanuatu 9 June 1992	79. Cook Islands 12 June 1992
32. Cote d'Ivoire 10 June 1992	80. Cuba 12 June 1992
33. Ethiopia 10 June 1992	81. Cyprus 12 June 1992
34. Iceland 10 June 1992	82. Denmark 12 June 1992
35. Malawi 10 June 1992	83. Estonia 12 June 1992
36. Mauritius 10 June 1992	84. Gabon 12 June 1992
37. Oman 10 June 1992	85. Gambia 12 June 1992

38. Rwanda 10 June 1992 39. San Marino 10 June 1992 40. Seychelles 10 June 1992 41. Sri Lanka 10 June 1992 42. Belarus 11 June 1992 43. Bhutan 11 June 1992 44. Burundi 11 June 1992 45. Canada 11 June 1992 46. China 11 June 1992 47. Comoros 11 June 1992 48. Congo 11 June 1992 97. Mauritania 12 June 1992 98. Micronesia 12 June 1992 99. Mongolia 12 June 1992 100. Mozambique 12 June 1992 101. Namibia 12 June 1992 102. Nepal 12 June 1992 103. New Zealand 12 June 1992 104. Paraguay 12 June 1992 105. Peru 12 June 1992 106. Philippines 12 June 1992 107. Saint Kitts and Nevis 12 June 1992 108. Samoa 12 June 1992 109. Sao Tome and Principe 12 June 1992 110. Swaziland 12 June 1992 111. Switzerland 12 June 1992 112. Thailand 12 June 1992 113. Togo 12 June 1992 114. Uganda 12 June 1992 115. United Kingdom of Great Britain and Northern Ireland 12 June 1992 116. United Rep. of Tanzania 12 June 1992 117. Venezuela 12 June 1992 118. Yemen 12 June 1992 119. Zimbabwe 12 June 1992 120. Algeria 13 June 1992 121. Armenia 13 June 1992 122. Austria 13 June 1992 123. Belize 13 June 1992 124. Benin 13 June 1992 125. Bolivia 13 June 1992 126. Central African Republic 13 June 1992	86. Germany 12 June 1992 87. Ghana 12 June 1992 88. Greece 12 June 1992 89. Guinea 12 June 1992 90. Guinea-Bissau 12 June 1992 91. Lebanon 12 June 1992 92. Liberia 12 June 1992 93. Malaysia 12 June 1992 94. Maldives 12 June 1992 95. Malta 12 June 1992 96. Marshall Islands 12 June 1992 127. Chile 13 June 1992 128. Costa Rica 13 June 1992 129. Djibouti 13 June 1992 130. Dominican Republic 13 June 1992 131. El Salvador 13 June 1992 132. European Econ. Comm. 13 June 1992 133. France 13 June 1992 134. Guatemala 13 June 1992 135. Guyana 13 June 1992 136. Haiti 13 June 1992 137. Hungary 13 June 1992 138. Honduras 13 June 1992 139. Ireland 13 June 1992 140. Japan 13 June 1992 141. Mexico 13 June 1992 142. Morocco 13 June 1992 143. Nicaragua 13 June 1992 144. Nigeria 13 June 1992 145. Panama 13 June 1992 146. Papua New Guinea 13 June 1992 147. Portugal 13 June 1992 148. Republic of Korea 13 June 1992 149. Russian Federation 13 June 1992 150. Senegal 13 June 1992 151. Slovenia 13 June 1992 152. Solomon Islands 13 June 1992 153. Spain 13 June 1992 154. Suriname 13 June 1992 155. Tunisia 13 June 1992 156. Cameroon 14 June 1992 157. Iran 14 June 1992 - - - - -

GLOSSARY

"**Biological diversity**" means 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.

"**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.

"Bioregion" is a territory defined by a combination of biological, social, and geographic criteria, rather than geopolitical considerations; generally, a system of related, interconnected ecosystems.

"**Biome**" are ecosystems where several habitats intersect. The earth itself is one large biome. Smaller biomes include desert, tundra, grasslands, and rainforest

"**Biota**" means the living organisms of a region

"**Biotechnology**" means any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.

"**Country of origin of genetic resources**" means the country which possesses those genetic resources in in-situ conditions.

"**Country providing genetic resources**" means the country supplying genetic resources collected from in-situ sources, including populations of both wild and domesticated species, or taken from ex-situ sources, which may or may not have originated in that country.

"**Domesticated or cultivated species**" means species in which the evolutionary process has been influenced by humans to meet their needs.

"**Ecosystem**" means a dynamic complex -of plant, animal and micro-organism- communities and their non-living environment interacting as a functional unit.

"Endemic species": A species native and confined to a certain region; Normally restricted locally

"**Ex-situ conservation**" means the conservation of components of biological diversity outside their natural habitats.

The **"Gaia Hypothesis"** proposed by James Lovelock in 1979 claim that the earth's "biota", tightly coupled with its environment, acts (and has acted since life on earth developed any complexity) as a single organism, self regulating living system in such a way as to maintain the conditions that are suitable for life and its survival. The system includes the near-surface rocks and atmosphere. In particular, it regulates the chemistry of the oceans, composition of the atmosphere and surface temperature

"**Genetic material**" means any material of plant, animal, microbial or other origin containing functional units of heredity.

"**Genetic resources**" means genetic material of actual or potential value.

"**Habitat**" means the place or type of site where an organism or population naturally occurs.

"**In-situ conditions**" means conditions where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

"**In-situ conservation**" means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

" **Niche**" would be the position occupied by an organism (or group of organisms) within an ecosystem, including its role and functions in nature and all resources it uses for survival, growth or reproduction.

"**Population**" is a group of individuals of one species in an area

The "**Precautionary principle**" states that "where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat"

"**Protected area**" means a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives.

"**Regional economic integration organization**" means an organization constituted by sovereign States of a given region, to which its member States have transferred competence in respect of matters governed by this Convention and which has been duly authorized, in accordance with its internal procedures, to sign, ratify, accept, approve or accede to it.

"**Sustainable use**" means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

"**Technology**" includes biotechnology.

"**e. g.** " abbreviation of exempli gratia

FURTHER READING

Surfing the World Wide Web (www)

Biodiversity' on a search engine throws up a whole load of material; some useful, and much not. To save you time there are some lists of biodiversity WWW sites

http://www.groms.de/data/zoology/riede/taxalinks.html;
http://biodiversity.uno.edu;
http://www.biodiversity.org.uk/ibs/other/env/biodiv.htm).

However, there are three web sites that call for special mention:

The Convention on Biological Diversity and all of the material associated with it accessible at http://www.biodiv.org

The World Resources Institute (WRI) web site (http://wri.igc.org/wri/biodiv) is valuable source of biodiversity facts and figures

The UNEP-World Conservation Monitoring Centre (UNEP-WCMC) is an internationally recognized body for collation of information on conservation and sustainable use of biodiversity. Visitors to their web site (http://www.unep-wcmc.org) will find good general information and also fairly detailed information in the form of statistics and maps, generated from their databases. These include details of protected areas, national biodiversity strategies and data on threatened species.

Other sites include:
IUCN http://www.iucn.org
UNEP http://www.unep.org

Books

- Biodiversity. E.O. Wilson, Editor. Frances M. Peter, Associate Editor. National Academy Press. Washington, D.C. 1988
- Biodiversity II. Understanding and protecting our biological resources. Marjorie L. Reaka-Kudla, Don E. Wilson, and Edward O. Wilson, editors. Joseph Henry Press. Washington, D.C. 1997
- Biodiversity and Conservation. Michael J. Jeffries. Routledge
- Biodiversity, A Challenge for development research and policy. W. Barthlott and M.Winiger (Eds). Springer.
- Biodiversity. A reference Handbook. Anne Becher. Contemporary world issues. ABC-CLIO
- GEO-3: Global Environmental Outlook 2002. PNUMA. Ediciones Mundi-Prensa