Series on Science for Sustainable Development No. 10

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Biodiversity, Science and Sustainable Development

International Biodiversity Observation Year

An Initiative of Diversitas
2001-2002

DIVERSITAS
an international programme on biodiversity science

ICSU Series on Science for Sustainable Development

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Prepared by DIVERSITAS

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Preface

The decade following Rio has seen a wealth of new science related to biological diversity. New fields have emerged documenting, in particular, the functional role of biological diversity in ecosystems. Established fields such as taxonomy or phylogeny have revealed numerous new species and intriguing new metabolisms in all systems considered, from remote habitats (e.g. bottom of the ocean), to our doorstep (soil micro-fauna), thanks in part to the wide use of new molecular techniques. This decade, unfortunately, has also witnessed a further acceleration of human induced decline of species diversity, mainly due to land and sea degradation.

The scientific community has contributed primarily to the environmental pillar of sustainable development, when it comes to biological diversity. As we discuss ways towards a sustainable future at the World Summit on Sustainable Development (WSSD), the scientific community is committed to address all three pillars of sustainable development: Social, Economic and Environmental. Designing strategies that provide incentives for the sustainable use of biodiversity requires the integration of natural sciences with political science, sociology and economics. It also requires opening a dialogue and enhancing co-operation between scientists, decision-makers in the public and private sectors, and other stakeholders.

This work has begun. The medical community, economists and lawyers, in particular, have become interested in biological diversity, as illustrated in this report. These new approaches must be promoted and developed. International programmes have been and will be instrumental in engaging the scientific community in interdisciplinary projects in an integrated way. The International Biodiversity Observation Year (IBOY) has promoted this approach. This report presents some of its achievements as well as scientific priorities towards a sustainable use of biological diversity, in the context of DIVERSITAS, and of the newly established Earth System Science Partnership (ESSP). This partnership was established between IGBP (International Geosphere-Biosphere Programme), IHDP (International Human Dimensions of Global Environmental Change Programme), WCRP (World Climate Research Programme) and DIVERSITAS.

The UN Secretary-General Kofi Annan recently highlighted five priority areas for WSSD, known as the "WEHAB" initiative. The "B" in the acronym stands for biodiversity, which constitutes one of the five priorities. The scientific community stands ready to address the challenges of a sustainable use of biodiversity, and to contribute, in particular, to the ambitious but achievable agenda of the Convention on Biological Diversity.

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Table of Content

7 Introduction: The "sixth extinction"

8 1. Scientific achievements since Rio: human existence depends on biological diversity

1.1 Biological diversity matters to human health
1.2 Biological diversity matters to our economy
1.3 Biological diversity is essential to the functioning of our life-support systems

13 2. Towards a new biodiversity science: providing the proper scientific basis for the sustainable use of the world's biological resources

2.1 Discovering biodiversity and predicting its changes
2.2 Assessing impacts of biodiversity changes on ecosystem goods and services
2.3 Developing the science of conservation and sustainable use of biodiversity

18 The way forward

19 Literature Cited

List of Acronyms

Introduction: The "sixth extinction"

Biological diversity, as defined by the Convention on Biological Diversity (CBD) adopted in Rio, is 'the variability among living organisms from all sources including... 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'.

Extinction is the ultimate fate of all living species. The average life span of a species, estimated from the fossil record, is for example, 11 million years for invertebrates and 1 to 2 million years for mammals (Barbault, 2001). The natural background rate of extinction is estimated to be in the magnitude of 1 to 10 species per year through the geological periods (L vei 2001). Earth has, however, experienced during the past 500 million years, five periods of mass extinction associated with a combination of environmental changes including impacts of extraterrestrial objects, volcanism, lowering of sea level and anoxia (Levinton 2001). The current rates of human-induced species extinction are estimated to be at least 1,000 times greater than these natural rates of extinction (Primack 2001), and all evidence suggests that a "sixth mass extinction" event be underway. Recent calculations, for example, suggest that the life span of a bird species has dropped this century from 1-10 million years to 10,000 years (L vei 2001). The current extinction differs from the five previous ones in that it is the direct result of human activities.

The post-Rio decade has seen major changes in the way biodiversity is conceptualised and studied, with the development of a more dynamic and integrated approach. We have moved from a static and descriptive approach of biodiversity, with the design of enclosed parks as a conservation goal (Stockholm 1972), to the emergence of a strong awareness of the functional role of biodiversity in maintaining life on Earth, and of the dependence of our economic and social development on biological diversity. In Johannesburg, the conditions for a sustainable use of Earth's resources, taking into consideration the important role of biological diversity in human dominated systems, will be discussed.

In what follows, (I) we review some of the main scientific achievements and major on-going international scientific initiatives that have taken place since Rio; (II) articulate gaps in our knowledge and scientific priorities for a sustainable use of Earth's biological diversity; and close with some views on how scientists can work better with policy makers and other stakeholders to design science-based strategies towards sustainable development.

1. Scientific achievements since Rio: Human existence depends on biological diversity

The post Rio decade has seen a wealth of new science related to biological diversity, characterised by the development of new concepts, the use of new methods and the will to produce policy relevant information. International programmes have played a major role in initiating and facilitating these efforts.

New concepts – Scientists have moved from a static to a dynamic view of biodiversity. Biodiversity was seen as a sum of species, or genes, or ecosystems to be preserved from external human destruction. The principal scientific objective was the establishment of a catalogue of life on Earth, and the principal social objective was conserving the existing (Loreau 2002). New scientific questions and entirely new research areas have emerged during the last decade on the causes of biodiversity loss, on its potential consequences for ecosystem functioning and ecological "services", and on its human dimensions.

New methods – Development of new methods, at the micro-scale and at the landscape scale have allowed scientists to broaden the scale of their investigation and of their understanding. The design and wide use of molecular biology techniques have led to the discovery of many new microorganisms. An entirely new domain of life, the Archaea, has been identified and added to the two known domains, the Eukaryota and the Bacteria. Microbiologists have discovered, for example, novel eukaryotic lineages occurring in large amounts in the ocean (e.g. Lopez-Garcia et al. 2001). These techniques also have allowed scientists to analyse the metabolism of these microorganisms and their role in marine systems (Beja et al. 2000), such as their influence on climate through their role in the cycle of elements. At the landscape scale, new methods using satellite imagery have been and are being developed. Coral reef health can for example now be monitored from the air, reducing costly and impractical field measurements (Mumby et al. 2001). Projects, such as the European Community project, BIOASSESS (Biodiversity Assessment Tools), are developing methods linking remote imagery to species biological diversity, with the aim of gaining an ability to develop biodiversity indicators for monitoring.

International programmes, by providing an international framework for particular aspects of biodiversity research and by promoting scientific research and syntheses, have considerably strengthened research on biodiversity and its link to policy. Examples described below include the Global Invasive Species Programme (GISP), the project on biodiversity and ecosystem functioning of IGBP-GCTE and DIVERSITAS, and IBOY, the International Biodiversity Observation Year.

Policy relevance – Much of the science that has emerged over the past ten years is policy relevant, and illustrates how essential biodiversity is for life on Earth. We have chosen to highlight some of these discoveries as they relate to human health, economy and the functioning of our life-support systems. It is often argued that biodiversity should, first and foremost, be preserved for its cultural, spiritual and intellectual values. The anthropologist Anderson (1996, quoted by Berkes, 2001) observes that traditional societies which have succeeded in using their resources in a sustainable way, have used emotionally powerful cultural symbols inspiring a sense of sacred respect. These avenues continue to be investigated, through, for example the UNESCO-MAB programme on sacred sites and cultural values (Ramakrishnan et al. 1998). Accelerated trends in biodiversity loss, however, make it clear that conservation must become a politically and economically viable concept worldwide.

1.1 Biological diversity matters to human health

Biological diversity constitutes our major source of pharmaceutical compounds. Over the course of millions of years, living organisms have evolved complex chemical compounds for a variety of purposes including materials for membrane and cell walls, photosynthetic pigments, hormonal signals, defensive compounds, or protective pigments (Cox 2001). These have provided some of today's most important pharmaceutical agents. The World Health Organisation estimates that 85% of the world's population depends directly on plants for medicine, and more than 25% of current prescription drugs have at least one active component derived from a flowering plant (Cox 2001). Marine organisms produce highly toxic compounds, such as the recently discovered bryostatin, derived from the Californian bryozoan *Bugula neritina,* currently tested in clinical trials for its ability to inhibit melanoma. These compounds are discovered by various screening methods, which may rely on phylogenetic, ecological or ethnobotanical information. The loss of biological diversity leads to the extinction of species of potential medical interest, thus reducing our options to cure human diseases.

Aside from the search for pharmaceutical compounds, the relation between biodiversity and human health has previously received little attention by scientists, public health experts, or medical doctors, and is now considered as a research priority by the scientific community (see section II). Recent scientific studies, however, indicate that biodiversity can protect human health (Ostfeld and Keesing 2000). In the case of Lyme disease, for example, high diversity within vertebrates that serve as hosts for vectors or reservoirs for zoonotic diseases may dilute the power of disease transmission to humans. Although many features of these diseases are well known to biomedical researchers, knowledge of their key ecological variables is incomplete and lacking. New approaches to better understand the spread of diseases, and help predict the emergence of new diseases must take into account research on biological diversity, the environment and the health of animal and human populations, and promote analyses of the ecological and evolutionary mechanisms involved in the emergence and transmission of diseases. The science of ecology has much to contribute to the epidemiology of infectious diseases.

The Centre for Health and the Global Environment of the Harvard Medical School is currently compiling, under the auspices of WHO and UNEP and the leadership of Dr. Eric Chivian, what is known about the implications for human health from a loss of species and the degradation of ecosystems ("Biodiversity: its importance to human health"). The final product will contribute to the section on human health of the Millennium Ecosystem Assessment.

1.2 Biological diversity matters to the economy

Biological diversity, until recently, has been neglected in economics. Most economists view it as an "amenity", and sustainable use of natural resources is still widely considered as a luxury, reserved for developed countries (Dasgupta 2001). The fast expanding field of biodiversity economics constitutes one key element towards sustainability. It has thus far shown, in economic terms, that biological diversity contributes to ecosystem productivity, provides an insurance against environmental variability and environmental disasters and delivers a multitude of valuable ecosystem services (Heal 2000, Dasgupta 2001). It has further revealed that the loss of biological diversity is neither reflected in market prices, nor in government policies and is thus ignored by resource users. Market and policy failures are considered as the main underlying causes of biodiversity loss (Perrings 1995). Economists interested in biodiversity are focusing their efforts on devising ways to value natural resources and the ecosystem services they provide. Cases where this approach has been taken, such as the Catskills watershed project briefly described below, prove that conservation and sustainable use constitute profitable alternatives to non-renewable use.

• Economics of invasive species

During the period between 1982 and 1988, the Scientific Committee on Problems of the Environment (SCOPE) engaged the scientific community in an international study to document the nature of the invasive species problem (Mooney 2000). This led to the publication of a synthesis volume by Drake et al. (1989) entitled "Biological invasions: A global perspective". This book identified the nature of the problem, and showed that invasive species were altering ecosystem functioning in virtually all ecosystems. The book did not offer any solutions to managers dealing with these problems, but laid the groundwork for the first international meeting on invasive alien species (IAS), organised in 1996 by the United Nations and the Government of Norway. Participants concluded that IAS had become one of the most significant threats to biodiversity worldwide, and recommended that a global strategy and mechanism to address the problem be established. The Global Invasive Species Programme (GISP) was established in 1997, under the auspices of SCOPE, the World Conservation Union (IUCN), and the Centre for Agriculture and Biosciences International (CABI). This collaboration between scientists, environmentalists, lawyers, economists, natural resource managers, policy makers and other experts resulted in a series of global assessments, as well as a global strategy (2001), a toolkit of best prevention and management practices (2001) and an initial pilot database. GISP is now in its second phase, which places an emphasis on national and regional capacity building, education and outreach, and law and policy. GISP is providing advice to the Secretariat of the CBD and to the Contracting Parties with respect to Article 8(h) which exhorts the Parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species".

In a synthesis volume on "The Economics of biological invasions", by Perrings et al. (2000), produced by GISP, several authors present data on the costs associated with the impact of invasive species. These include Turpie and Heydenrych on the invasion of Fynbos in South Africa by alien plants, and Kasulo on the introduction of water hyacinth into African lakes and rivers. Nigeria, for example, estimates the economic cost associated with water hyacinth infestation of the Niger River system to be US $50 million per year. The economic framework discussed by Perrings et al. (2000) goes beyond cost-benefit analyses of invasions impact, and considers the development of decision models for prevention, control and mitigation given socio-economic and environmental conditions. The authors highlight some gaps in our knowledge and advocate the need for a strong collaboration between economists, ecologists and experts from other disciplines so as to base economic and policy decisions on sound science.

• Conservation can be profitable

Examples are starting to abound showing that the use of an ecosystem service can constitute a profitable choice, compared to the construction of a costly man-made alternative. New York City chose in 1997 to utilize nature's capacity to filter its water. The city decided against a $6 billion water filtration facility (plus running costs of about $300 million a year), and in favour of a $1.5 billion investment in buying land and restoring the ecosystems of the Catskill mountain watershed (Daily and Ellison 2002, Heal 2000). Additional benefits of this choice included the provision of other ecosystem services such as protection against flooding and mudslides.

• Ecotourism

One of the most straightforward examples of economic incentives leading to a protection of the natural environment and its services is ecotourism, a particular kind of travel which usually consists of visiting a country for its Flora and Fauna, and implies a lighter impact on the visited region, compared to conventional tourism. Tourism underpins economies in many areas, and ecotourism constitutes a financial return on the preservation of ecosystems. Over the 1990s, ecotourism has turned into a thriving niche of the tourism industry, the world's largest profit making enterprise (Daily and Ellison 2002). In 1997, international travellers spent, according to the World Tourism Organisation, US $425 billion. Ecotourism, according to the International Ecotourism Society, makes up as much as 60 percent of these expenditures, with an annual growth of 10 to 30 percent, compared to an average 4 percent increase in overall tourism (Daily and Ellison 2002).

Ecotourism is further developed and better documented in Africa, than elsewhere. The South African Company ConsCorp (Conservation Corporation) has agreed with local landowners to restore several hundred thousand hectares of farmland to their original state and to stock them with animals (Masood and Garwin 1998; Heal 2000). Land that yielded $25 to $70 per hectare a year for farming and ranching now yields $200 to $300. Visitors pay a fee to see (and hunt) lions and leopards.

Overall, the prospects of developing market-based incentives to conserve biodiversity and make ecosystems attractive to tourists seem great, and ecotourism is being developed in all regions of the world (see di Castri and Balaji 2002). The United Nations have declared the year 2002 as the International Year of Ecotourism.

• LOSS OF POLLINATORS AFFECTS FUNCTIONING OF AGRICULTURAL SYSTEMS AND ECONOMIC GAIN

Pollinators face a large variety of threats due to human activities, including habitat fragmentation, use of pesticides and herbicides and the introduction of exotic pollinators and plants. Seventy percent of the 1,300 crops cultivated worldwide require animal pollinators (Kremen et al. 2002), and the global value of pollination services has been estimated to be $117 billion per year (Inouye 2001). Several international initiatives have over the past years focused their efforts on the loss of pollinators. A project headed by Dr. Farooq Ahmad, from the International Centre for Integrated Mountain Development, Nepal, in the context of the International Biodiversity Observation Year (IBOY, see Box) reports that in some of the regions at the border between China and Nepal, such as Maoxian county, native bees have gone extinct, and farmers are now forced to pollinate their apple trees by hand. It takes 20 to 25 people to perform the work of two bee colonies (pollination of about 100 trees). The aims of this project are to complete knowledge on the indigenous honeybee *Apis cerana* selection and management, promote indigenous honeybees and honey hunting communities and train beekeepers, farmers, and honey-hunting communities to understand and build capacity to maximise the economic and ecological benefits of native honeybees. A related IBOY project includes the African Pollinator Initiative (API) directed by Dr. Connal Eardley (Agricultural Research Council, South Africa). API is a network of 15 African countries that monitor pollinator decline, its causes and its economic consequences, and promote the conservation and sustainable use of pollinator diversity in agriculture and related ecosystems.

IBOY

The DIVERSITAS-International Biodiversity Observation Year (IBOY) 2001-2002 is a window in time in which scientists and educators across the world are joining forces to increase the communication of important science-based information about biodiversity to a broader audience. IBOY focuses global attention on the Earth's biodiversity, its contributions to ecosystems and society, and the voyages of discovery that are revealing its treasures through science, exploration, art, and education. Today, one hundred and nine projects with activities in more than one hundred and forty countries are participating in IBOY. Nearly half the projects are led by developing countries. Each project addresses one or more of these important questions:

(1) What biodiversity do we have and where is it? Examples include biodiversity in deep-sea chemosynthetic communities, the exploration and conservation of anchialine fauna, an inventory of caterpillars in Costa Rica, or the Global Litter Invertebrate Decomposition Experiment (GLIDE).

(2) How is biodiversity changing? Example: the Committee on Recently Extinct Organisms (CREO)

(3) What goods and services does biodiversity provide? Example: conserving and increasing the use of neglected and under-utilised crop species.

(4) How can we conserve biodiversity? Example: DNA banks for endangered species.

The IBOY Secretariat draws the projects together in a capacity-building and outreach campaign. Activities of the IBOY Secretariat include: organising meetings and workshops for IBOY scientists to share scientific information and receive media communication training; organising national and international symposia for IBOY scientists to communicate their findings to other scientists, policy-makers and media; helping IBOY scientists promote scientific information on biodiversity through publications, the internet outreach activities and media relations

1.3 Biological diversity matters to the functioning of our life support systems

The potential impact of biodiversity loss on the functioning of ecosystems has emerged in the last decade as a central issue in ecological and environmental sciences (Loreau et al. 2001). Ecosystems determine the biogeochemical processes that regulate the Earth system. Consequently, the loss of species in an ecosystem might modify its functioning, and thus affect our life support systems.

International collaboration on this issue was initiated by SCOPE (Scientific Committee on Problems of the Environment), which co-ordinated between 1991 and 1994 a series of six scientific syntheses summarising the state of our knowledge and articulating scientific priorities for various ecosystems (Schulze and Mooney 1993, Davis and Richardson 1995, Chapin and K rner 1995, Vitousek et al. 1995, Mooney et al. 1996, Solbrig et al. 1996; see also Baskin 1997). This work contributed to the Global Biodiversity Assessment (1995). It also helped design the agenda for future international collaboration in this field and led, in particular, to several on-going international projects such as: "Biodiversity, Global Change and Ecosystem Functioning", initiated by the Global Change and Terrestrial Ecosystems (GCTE) project of the International Geosphere-Biosphere Programme (IGBP), and DIVERSITAS; or the Global Mountain Biodiversity Assessment (GMBA).

The GCTE-DIVERSITAS project just produced a synthesis of the knowledge gained over the past few years (Loreau et al. 2002). Experiments in which species diversity was manipulated, together with theoretical models, show that ecosystems poorer in plant species are less productive (lower primary productivity), and display a lower nutrient retention (Tilman et al. 1996, 1997; Hooper and Vitousek 1997; Hector et al. 1999). Experimental evidence also suggests that these impoverished systems might have a lower capacity to adapt to perturbations (McGrady-Steed et al. 1997), and in particular to rising atmospheric carbon dioxide concentrations and nitrogen deposition levels (Reich et al. 2001).

The Global Mountain Biodiversity Assessment (GMBA) of DIVERSITAS, established in 1999, is looking, in particular, at the role of species diversity in preventing and controlling soil erosion, and at its implications for sustainable agriculture in montane/alpine areas (K rner and Spehn 2002).

Overall, this international collaboration has showed that biodiversity loss can have a profound impact on the functioning of the Earth system and the maintenance of our life-support system. Important gaps in our knowledge remain on this issue (see section II).

2. Towards a new biodiversity science: providing the proper scientific basis for the sustainable use of the world's biological resources

In September 2001, an international group of forty scientists met in Paris, under the auspices of DIVERSITAS, an international programme dedicated to biodiversity established by ICSU, IUBS, IUMS, SCOPE and UNESCO (see annex for definition of acronyms). Their discussion, based on a wide consultation of the scientific community, concluded that a new ambitious effort was needed for biodiversity science at the international level to meet the challenges of sustainability. They identified a new mission for DIVERSITAS, and a new science plan articulated around three priorities. This was adopted in April 2002 by the Scientific Committee of DIVERSITAS, and is described in the next sections.

The overall missions of the new DIVERSITAS programme are:

- promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge;
- provide the scientific bases for the conservation and sustainable use of biodiversity.

The will to build the proper scientific basis for the sustainable use of the world's biological resources, and the decision to engage social scientists, economists, lawyers in a formerly biological/ecological programme constitute particularly important aspects of this mission. DIVERSITAS will achieve these goals by synthesising existing scientific knowledge, identifying gaps and emerging issues of global importance, promoting new research initiatives, building bridges across countries and disciplines, investigating policy implications of biodiversity science, and communicating these to policy makers and international conventions.

In order to be successful, DIVERSITAS has established partnerships with a number of the programmes mentioned below (see Box on the Earth System Science Partnership, ESSP), and will seek additional ones. Above all, DIVERSITAS, and more widely, scientists involved world wide in research related to the many facets of biodiversity science, will need a stronger support of the policy community, and in particular, help with engaging developing countries scientists (see concluding remarks).

The "Earth System Science Partnership"

The ESSP, was established in 2001, between the four global change programmes of the ICSU family:

- WCRP (the World Climate Research Programme),
- IGBP (the International Geosphere-Biosphere Programme),
- IHDP (International Human Dimensions Programme on Global Environmental Change) and
- DIVERSITAS

The ESSP has launched two global-scale collaborative joint projects, one on food security, called Global Environmental Change and Food Systems (GECaFS; see Number 7 in this ICSU Series on Science for Sustainable Development), and one on the carbon cycle, called the Global Carbon Project (GCP), and is developing a third one on water resources and global change.

2.1 Priority 1 "Discovering biodiversity and predicting its changes"

Core Project 1 of DIVERSITAS: Discovering biodiversity and predicting its changes

- Focus 1.1 Assessing current biodiversity
- Focus 1.2 Monitoring biodiversity changes
- Focus 1.3 Understanding and predicting biodiversity changes

To understand and predict the consequences of changes in biodiversity for natural ecosystems and human societies, it is first necessary to know how much biodiversity there is on

Earth, how it is changing and why. This first Core Project of DIVERSITAS will contribute to assessing current biodiversity , develop the scientific bases for monitoring biodiversity changes, and provide critical knowledge on the processes that determine these changes, with a view to predicting future changes.

(Focus 1.1) A large number of national and international initiatives, established following Rio, focus on the inventory and classification of biodiversity, such as GBIF (Global Biodiversity Information Facility), GTI (Global Taxonomy Initiative of the CBD), ETI (Expert Centre of Taxonomic Identifications), Species 2000, Tree of Life (ToL), Census of Marine Life (CoML) and the All-Species inventory project. Some of these programmes focus on the discovery of species and clades, and others on databasing museum specimens, taxonomic names, or phylogenetic knowledge. Most of these programmes are in their infancy, and are not yet well co-ordinated. DIVERSITAS, through Focus 1.1, will foster sustained and effective communication among these efforts. Through workshops and research activities, it will provide a critical forum for the exchange of information and will facilitate the development of new tools to allow synthesis across existing programmes. Despite the growing interest in biodiversity during the last decades, our knowledge of the true diversity of life that inhabits our planet is still very limited and fragmentary. While large animals and plants are reasonably well known, only a small fraction of the existing small-sized organisms, such as bacteria, protists, microarthropods and insects, has been discovered and described by science. Many of these organisms probably fulfil important functions in biogeochemical cycles, from local to global scales. Special benefits will derive from the systematic analysis of key functional groups. For example, linking knowledge of the functional traits of microorganisms discovered in soils and marine habitats with knowledge of phylogenetic relationships should make it possible to better assess their role in biogeochemical cycles

More specifically, Focus 1.1 will stimulate development in areas that require special attention, such as:

- integration of new methods, such as genomic approaches, into the study of biodiversity at species, population, and ecosystem levels;
- linking of species-level taxonomic information to phylogenetic hypotheses and to data on functional ecology;
- synthesis of collection-based information technology with geographic mapping efforts, to better describe the spatial distribution of biodiversity, and to understand how it is organised in areas of endemism, communities, and habitats;
- expansion of the information attached to microbial data, notably by developing integrated databases linking molecular sequences and environmental data.

(Focus 1.2) Even in those taxonomic groups and locations where diversity has been described, diversity is changing rapidly following increasing human activities, so that there is an important need to monitor and assess these changes. The objective of this focus 1.2 is to develop the scientific basis for monitoring biodiversity, as well as the tools for monitoring and the use of these tools. This focus will:

- foster the development of new methodologies and protocols (including indicators) for monitoring biodiversity changes;
- promote regional and global networks of biodiversity observatories that rely on a commonly agreed methodology;
- integrate modern techniques into monitoring methods (e.g., genomics, remote sensing);
- promote and facilitate the use of monitoring data in the construction of models of biodiversity change, as developed in Focus 1.3.

(Focus 1.3) A predictive biodiversity science requires an understanding of the factors that cause biodiversity changes. Changes in the nature and intensity of human activities are known to lie behind the accelerated loss of biodiversity both locally and globally. These changes reflect demographic, cultural, political and economic factors. They have reduced and restructured most habitats, changed the distribution and abundance of species to support economic production, altered biogeochemical cycles and the chemical composition of soils, water and atmosphere. We need to understand these changes and the way they interact with the complex ecological and evolutionary processes.

Accordingly, this focus will:

- foster research into the anthropogenic drivers of change in biodiversity in terrestrial and aquatic systems;
- develop theoretical, experimental and empirical know-

ledge of the ecological and evolutionary processes that have shaped biological diversity in the past and determine it today;
- develop an understanding of the impact of changes in the pattern and intensity of human resource use on ecological structure and processes, and the implications of this for biodiversity at multiple spatial and temporal scales;
- contribute to the capacity to predict future biodiversity changes, in order to support conservation and the sustainable use of biodiversity at appropriate spatial and temporal scales.

2.2 Priority 2 Assessing impacts of biodiversity changes

This Core Project 2 will assess how biodiversity changes affect ecosystem functioning and thereby the provision of ecological goods and services of relevance to human societies. A particular emphasis, within the context of ecological services, will be placed on impacts of biodiversity changes on human health.

Core Project 2 of DIVERSITAS Assessing impacts of biodiversity changes

Focus 2.1	Impact of biodiversity changes on ecosystem functioning and ecosystem services
Focus 2.2	Impacts of biodiversity changes on human health

(Focus 2.1) Our current knowledge and theoretical framework concerning the impacts of biodiversity loss on ecosystem functioning is based mainly on experiments on plant communities in temperate grasslands (see section I). To reach greater generality and predictive ability, it is now vital to extend this knowledge to other organisms (animals, microorganisms), other trophic levels (herbivores, predators, decomposers) and other ecosystems (forest, tropical, freshwater and marine ecosystems), in which environmental constraints and ecological processes may be vastly different from those explored so far. IGBP-GCTE, Linkecol of ESF and DIVERSITAS initiated this process by holding in 2002 an international workshop on biodiversity and ecosystem functioning in aquatic systems (Ascona, Switzerland, April 2002).

Emphasis in terrestrial science should also be progressively shifted from the small scale typically considered in recent experiments to larger spatial and temporal scales, at which management decisions and human-induced biodiversity changes take place. In contrast, in marine biodiversity science, with the exception of the intertidal areas, there is still a considerable lack of knowledge about small-scale processes and experimental verification, whereas the large scales have been better studied on the whole.

As mentioned in Focus 1.3, land-use changes are currently the most important driver of biodiversity changes on land, a trend likely to be reinforced in the future by the increasing pressure exerted on land use due to demographic and economic changes in human societies. Therefore, the knowledge developed in focus 1.3 on the impacts of land-use changes on biodiversity should be used to assess the impacts of realistic scenarios of biodiversity loss induced by land-use changes on ecosystem processes at landscape scales. An analogous approach is needed to assess the impact on aquatic biodiversity of fisheries and – in coastal and freshwater areas – of aquaculture and of changes in water use.

Lastly, it is important to go beyond a basic science assessment of the effects of biodiversity changes on ecosystem functioning, and include impacts on ecosystem goods and services of societal relevance, which few studies have done so far. The development of research in the area of ecosystem goods and services will add a missing socio-economic perspective to current research into the relationship between biodiversity and ecosystem functioning.

Thus, the priorities for this focus will be:
- to extend current knowledge on plant-based processes in temperate grasslands to other organisms, other trophic levels and other ecosystems;
- to assess impacts of biodiversity changes at larger temporal and spatial scales in interaction with other environmental changes, in particular land- and water-use changes;
- to identify the impacts on the provision of ecosystem goods and services of relevance to human societies.

(Focus 2.2) Core Project 2 will further develop a particular focus on the impacts of biodiversity changes on human health. The invasion of pests and pathogens is generally the intended or unintended consequence of human decisions involving the use of exotic species in production and consumption, the conversion and fragmentation of habitat, or the movement of goods and people. These are affected by the regulatory and market structures governing people choices. Epidemiological predictions and control policies both require understanding of the incentive effects of existing institutional, regulatory and market conditions. The ultimate goal of this focus is to contribute to developing a broader, predictive science of infectious diseases.

Priorities for this focus are:

- to develop an understanding of the connection between pathogen pathways and changing patterns of trade, transport and travel;
- to promote improved predictive models of the invasion of pests and pathogens;
- to foster research into the impact of land use change on vulnerability to invasive pests and pathogens;
- to foster research into changes in biodiversity and biological interactions that affect the epidemiology of human diseases.

2.3 Priority 3 Developing the science of conservation and sustainable use of biodiversity

Core Project 3 of DIVERSITAS

Focus 3.1. Evaluation of the effectiveness of conservation measures and incentives for achieving the conservation and sustainable use of biodiversity.

Focus 3.2. Establishing scientific approaches for optimising multiple uses of biodiversity, considering possible trade-offs between economic and environmental goals, and the uncertainty associated with novel developments

The judicious use of biodiversity is essential both for the maintenance of our life-support system and for the sustainable development of our world's resources. The primary driver of changes in biodiversity is human activity. Effective solutions for the sustainable management of biodiversity therefore lay in understanding how individuals and societies value that biodiversity, especially those who own and use living resources and the biogeochemical systems on which they depend. Many of the present international conventions and directives, national policies and local regulatory tools have not resulted in the sustainable management of biodiversity because they do not recognise and deal with the underlying motivations of individuals and governments (see, e.g., the global failure of marine fisheries policies). Addressing the causes and consequences of biodiversity loss requires good basic and applied science, together with their integration with the social sciences.

There has been considerable progress in understanding the more proximate mechanisms generating biodiversity changes, such as land-use changes, habitat fragmentation, pollution, and invasive species, as well as the effects of such changes on ecosystem processes, goods and services. Incorporating such information into strategies that provide incentives for the sustainable use of biodiversity requires the integration of the natural sciences with political science, sociology and economics. Establishing such an interdisciplinary community of like-minded researchers represents one of the primary goals of DIVERSITAS under Core Project 3. The task will be challenging and will most likely require the establishment of new methodologies to occupy the vacant ground between the traditional sciences. This core project is seeking advice from and collaboration with the International Human Dimension Project for global change research (IHDP), in the context of the Earth System Science Partnership (ESSP).

The following foci have been selected as priorities under Core Project 3:

(Focus 3.1) This focus has two objectives. The first is concerned with the scientific evaluation of the effectiveness of existing conservation measures. The second identifies the socio-economic causes of the failure or success of conservation measures.

(Focus 3.2) Societies make choices regarding land management, such as the conversion of a natural system to a production system, or the incremental changes in a production regime, which have impacts on biodiversity and ecosystem services. These impacts are often not taken into account, and the trade-offs between the production of market commodities and ecosystem services are not assessed. This may be because the scientific information on which to assess alternatives is lacking. It may also be because decision-makers lack incentives to take the effects of biodiversity loss into account.

This focus will develop the science required to optimise multiple uses of biodiversity, including the production of goods for the market, the provision of ecological goods and services, and the recreational/cultural value of scenic areas and native species. Modelling the sustainable use of biodiversity in this way could facilitate adaptive management plans that respond to changing economic and ecological factors.

The focus has two objectives. One is to identify the economic consequences of biodiversity change in particular systems or landscapes, to evaluate the trade-offs involved in alternative strategies, and to identify the scope for biodiversity enhancement. A second is to develop the scientific basis of precautionary decision-making, and to apply this in specific cases.

The way forward

- DIVERSITAS is committed to contributing to the implementation of the Convention on Biological Diversity (CBD) and to sustainable development in general by providing the proper science basis for the sustainable use of the world's biological resources. It will do so by engaging natural and social scientists in collaborative undertakings, as described in this document.

- National committees will be established in order to promote discussions of the programme priorities between scientists, managers of research programmes, policy makers, and other stakeholders, and in order to adapt these priorities to local and regional concerns.

In order for this new knowledge to result into actions, a new contract between the Science and Technology community (S&T) and Society is necessary, and called for by the S&T community in the dialogue paper prepared for PrepCom IV(Bali, May 2002). The scientific community active in research on biological diversity is thus calling upon the stakeholders involved in WSSD, to consider, in particular, the following prerequisites for success:

- Existing governance systems will need to be transformed to ensure better scientific input. One crucial notion to convey in that context is that the sustainable use of biological diversity does not constitute a luxury but contributes to poverty alleviation (Dasgupta 2001). A formal link between the Commission on Sustainable Development (CSD) and the organising partners of the Dialogue Segment for the S&T community (ICSU and WFEO) is proposed as a way to ensure a better interaction between science and governance.

- Education and capacity building in science will need to be considerably strengthened by governments. The S&T community has been active in involving scientists from developing countries in international programmes (e.g. the global change System for Analysis Research and Training, START). The level of engagement, however, remains unsatisfactory. If science, and in particular biodiversity science, is to improve its contribution to poverty alleviation, it is necessary, as stated by T.O. Odhiambo, President of the African Academy of Sciences, at the World Conference on Science in 1999, that the questions that the poor are asking be formulated by the poor, and in terms that science can answer.

- Current levels of funding in S&T for sustainable development are too low in both rich and developed countries. As stated in the document prepared by the S&T community for PrepCom IV (cited above), "larger investments in S&T should be seen primarily as increased investments in a country's socio-economic development and in preserving natural life-support systems for the present and future generations, rather than simply as research expenditures".

Exciting new developments are happening in the many fields of biodiversity research, an area fundamental to human well being. International programmes are in place, that will build on this new progress, and contribute to bring it to the fore-font of policy discussions. It is our hope that these programmes will lead to more science-based policy decisions towards sustainable development.

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List of Acronyms

CABI	Centre for Agriculture and Biosciences International
CBD	Convention on Biological Diversity
ESF	European Science Foundation
ESSP	The Earth System Science Partnership
ETI	Expert Centre of Taxonomic Identifications
GBIF	Global Biodiversity Information Facility
GCP	Global Carbon Project
GCTE	Global Change and Terrestrial Ecosystems
GECaFS	Global Environmental Change and Food Systems
GISP	Global Invasive Species Programme
GLIDE	Global Litter Invertebrate Decomposition Experiment
GMBA	Global Mountain Biodiversity Assessment
GTI	Global Taxonomy Initiative
IBOY	International Biodiversity Observation Year
ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IGFA	International Group of Funding Agencies for global change research
IHDP	International Human Dimensions Programme on Global Environmental Change
IUBS	International Union of Biological Sciences
IUCN	The World Conservation Union
IUMS	International Union of Microbiological Societies
SC-DIVERSITAS	Scientific Committee-DIVERSITAS
SCOPE	Scientific Committee on Problems of the Environment
START	Global change System for Analysis Research and Training
S&T	Science and Technology community
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WFEO	World Federation of Engineering Organisations
WSSD	World Summit on Sustainable Development
WHO	World Health Organisation

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