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76 DIVERSITAS: Biodiversity Science Integrating Research and Policy for Human Well-Being

Bruno A. Walther, Anne Larigauderie and Michel Loreau

76.1 Introduction

Biodiversity, or the variety of life on earth, makes up and sustains all life processes of the biosphere. Therefore, biodiversity contributes utilitarian values, such as ecosystem goods and services, option values for future use, as well as cultural values, such as educational, intellectual and recreational opportunities, aesthetic and spiritual enjoyment, and a sense of identity, to human well-being.

Biodiversity is almost invariably impacted negatively by unsustainable human resource consumption. The main drivers of biodiversity change are direct overexploitation of natural resources as well as the more important indirect drivers of change such as habitat conversion and fragmentation caused by land use changes, pollution, and invasive species.[1] Consequently, current scientific evidence overwhelmingly demonstrates a continued decline in the status of biodiversity since humans became the dominant species on earth.[2] About 1.5–1.8 million species have been scientifically described, but the number of undescribed species is rather uncertain, with the currently accepted estimate being about 10–15 million species; however, estimates range as high as 50–100 million.[3] While the total global number of species will remain uncertain for the foreseeable future, we already know that extinction rates of known species now exceed normal rates by 100–1000 times due to human impacts on the biosphere (Lawton/May 1995; Regan/Lupia/Drinnan/Burgman 2001). Rates of global biodiversity change have reached a magnitude and speed that greatly surpass change due to natural processes except those of cataclysmic events such as meteor strikes. Therefore, many biodiversity scientists insist that we are already experiencing the beginning of a 'sixth extinction event' on the scale of other massive die-offs during the earth's history, such as the disappearance of dinosaurs at the end of the Cretaceous (Wilson 1988; Savage 1995; Myers 2003).

Moreover, even if many species are not yet extinct, their populations have severely declined, both in numbers and distributions. These population declines not only make these species more vulnerable to local and global extinction (Gilpin/Soulé 1986; Hanski 1999; Oborny/Meszena/Szabo 2005) but also reduce their genetic diversity and therefore their future potential to adapt to environmental changes[4], at exactly the time when environmental changes are accelerating dramatically due to human actions.[5] Changes in population have led to reduced and restructured habitats and to altered ecosystem functions, biogeochemical cycles and chemical composition of soils, water and

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1 See: Sala/Chapin III/Armesto/Berlow/Bloomfield/Dirzo/Huber-Sanwald/Huenneke/Jackson/Kinzig/Leemans/Lodge/Mooney/Oesterheld/LeRoy Poff/Sykes/Walker/Walker/Wall (2000); Bennett/Milner-Gulland/Bakarr/Eves/Robinson/Wilkie (2002); Millennium Ecosystem Assessment (2005a); Millennium Ecosystem Assessment (2005b); Secretariat of the Convention on Biological Diversity (2006).

2 See: Vitousek/Mooney/Lubchenco/Melillo (1997); Baillie/Hilton-Taylor/Stuart (2004); Millennium Ecosystem Assessment (2005a); Balmford/Bennun/ten Brink/Cooper/Côté/Crane/Dobson/Dudley/Dutton/Green/Gregory/Harrison/Kennedy/Kremen/Leader-Williams/Lovejoy/Mace/May/Mayaux/Morling/Phillips/Redford/Ricketts/Rodríguez/Sanjayan/Schei/van Jaarsveld/Walther (2005); Loh/Green/Ricketts/Lamoreux/Jenkins/Kapos/Randers (2005); Pauly/Watson/Alder (2005).

3 See: May (1990); Heywood (1995); Baillie/Hilton-Taylor/Stuart (2004); Wilson (2004).

4 See: Brook/Tonkyn/Q'Grady/Frankham (2002); Frankham (2005); O'Grady/Brook/Reed/Ballou/Tonkyn/Frankham (2006); Honnay/Jacquemyn (2007).

5 See: Haberl/Erb/Krausmann/Gaube/Bondeau/Plutza/Gingrich/Lucht/Fischer-Kowalski (2007); Harte (2007); World Resources Institute (2007).

atmosphere (Gitay/Suárez/Dokken/Watson 2002; Millennium Ecosystem Assessment 2005a).

Such massive declines and changes in species distributions invariably affect the functioning of ecosystems. For example, the widespread application of herbicides and insecticides has led to dramatic decreases in insect pollinators and their food plants, so that there is now a 'pollinator crisis' in some agricultural areas such that agricultural crops are no longer sufficiently pollinated.[6] More importantly, the widespread human transformation of once highly diverse natural ecosystems into relatively species-poor managed ecosystems (e.g., food monocultures) has led to irreversible biodiversity loss, with consequent loss of various ecosystem services (see 76.3.3 below). It is becoming increasingly clear that biodiversity of both pristine and well-managed ecosystems delivers important services such as the production of foods and other goods, the capacity to store carbon and recycle nitrogen, or the natural spaces for ecotourism to thrive in, to name just a few (Daily 1997; Farber/Costanza/Wilson 2002; Millennium Ecosystem Assessment 2005a). These examples demonstrate that ecosystem services directly affect human well-being, and biodiversity decline leads directly and indirectly to reduced benefits for people and increasingly limiting opportunities for development and livelihoods options in the short and long term, as well as increasing occurrences of sudden negative changes in the world's ecosystems and life processes (Millennium Ecosystem Assessment 2005a). Further understanding of the status, trends and functions of biodiversity is therefore critical if decision-makers at all scales, as well as the public, are to be informed about the global scale of biodiversity degradation, and the consequences of such degradation on ecosystem services and human well-being.

Based on this rising awareness of the importance of biodiversity to human well-being, society and governments are increasingly prepared to define and implement rules which allow for the long-term sustainable use of biodiversity. Therefore, the most pressing challenge is the need to establish the scientific foundations for the appropriate future social, political and economic actions aimed at maintaining an acceptable level of biological diversity and functional ecosystems on Earth. Towards this ultimate goal, biodiversity science will play a crucial role in understanding the Earth system and thus informing responsible and sustainable policy making. Faced with these challenges, the scientific community decided to organize itself in order to study these complex issues and provide science-based solutions using interdisciplinary and global research networks. This was the ultimate rationale for the establishment of the DIVERSITAS programme.

The DIVERSITAS Science Plan (2002) states that the overall goals of DIVERSITAS are to (1) promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge, and (2) provide the scientific bases for the conservation and sustainable use of biodiversity. DIVERSITAS achieves these goals by implementing a portfolio of international scientific projects and networks which are detailed below. Each programme is built around a few central research challenges (or foci) which advance our scientific knowledge of biodiversity status, trends and functions. With its special focus on the science of the conservation and sustainable use of biodiversity, this increased knowledge in turn supports decision makers to make more rational policies regarding environmental threats, challenges, vulnerabilities and risks.

Below, we will specify the specific scientific contribution of each DIVERSITAS programme to help humankind to cope with global environmental change, disasters and security. Whenever possible, we use work contributed by scientists associated with the DIVERSITAS programme to support our arguments; therefore, citations are made selectively, reviewing the work of DIVERSITAS and not necessarily the entire biodiversity research and conservation community.

After a brief history of DIVERSITAS (76.2), we present the scientific agenda of DIVERSITAS (76.3), beginning with its overall mission and structure (76.3.1). The central message of this chapter is contained in the sections (76.3.2–76.3.4) in which we portray some of the main scientific achievements of DIVERSITAS which have relevance to the theme of this book, i.e. how biodiversity research can identify threats, challenges, and risks to human well-being and thus help humanity to better cope with global environmental change. We round this off with a brief description of the various DIVERSITAS Cross-cutting Networks (76.3.5), of the science policy bridge supported by DIVERSITAS (76.3.6), and our conclusions (76.4).

6 See: Buchmann/Nabhan (1996); Allen-Wardell/Bernhardt/Bitner/Burquez/Buchmann/Cane/Cox/Dalton/Feinsinger/Ingram/Inouye/Jones/Kennedy/Kevan/Koopowitz/Medellin/Medellin-Morales/Nabhan/Pavlik/Tepedino/Torchio/Walker (1998); Kremen/Williams/Thorp (2002).

76.2 DIVERSITAS History: Building Biodiversity Science

76.2.1 Phase I: 1991-1998

DIVERSITAS, in its current structure, was launched in 2002. However, its birth dates back to 1991. In the wake of the negotiations on the *Convention on Biological Diversity* (CBD), the *United Nations Educational, Scientific and Cultural Organisation* (UNESCO), the *Scientific Committee on Problems of the Environment* (SCOPE) and the *International Union for Biological Sciences* (IUBS) – later joined by the *International Council for Science* (ICSU) and the *International Union of Microbiological Societies* (IUMS) – established an international, non-governmental umbrella programme that would address the complex scientific questions posed by the loss of and change in global biodiversity, and provide scientific advice to the CBD. Two main axes were developed during this period:

The first axis consisted in contributing to the implementation of Articles 6–8 and 10 of the CBD, and particularly article 7a: “Identify components of biological diversity important for its conservation and sustainable use.” A number of workshops were held and papers were published, e.g., to implement the *Global Taxonomy Initiative* (GTI) of the CBD (DIVERSITAS 1999). Furthermore, DIVERSITAS initiated the Species 2000 Programme which focused on a global linking of taxonomic databases.

The second axis was the development of a new field for biodiversity science looking at the links between biodiversity and ecosystem functioning. The books below, which were the results of a series of workshops organized under the auspices of SCOPE, established this new field and laid the groundwork for further experimental and theoretical research carried out under DIVERSITAS and the *International Geosphere-Biosphere Programme* (IGBP). These books also contributed to the *Global Biodiversity Assessment* (Heywood 1995), an initiative of the *World Resources Institute* (WRI).

- *Biodiversity and ecosystem function* (Schulze/Mooney 1994).
- *Mediterranean-type ecosystems: The function of biodiversity* (Davis/Richardson 1995).
- *Arctic and alpine biodiversity: Patterns, causes and ecosystem consequences* (Chapin/Körner 1995).
- *Islands: Biological diversity and ecosystem function* (Vitousek/Loope/Adsersen 1995).
- *Biodiversity and savannah ecosystem processes* (Solbrig/Medina/Silva 1996).
- *Functional roles of biodiversity: A global perspective* (Mooney/Cushman/Medina/Sala/Schulze 1996).

Toward the end of its first phase, DIVERSITAS also contributed to the establishment of the *Gobal Invasive Species Programme* (GISP) in 1997 to investigate how invasive species affect biodiversity. During this first phase, which ended in 1998, the DIVERSITAS Secretariat was hosted by UNESCO’s *Man and the Biosphere* (MAB) Programme.

76.2.2 Phase II: Biodiversity Science Evolves

After a lapse of three years, the sponsors of DIVERSITAS decided in 2001 to launch a second phase. They opened a new Secretariat, hosted by ICSU in Paris, and called upon a task force of scientists to develop an international framework for biodiversity research. DIVERSITAS undertook a series of workshops and consultations engaging scientists around the world. The DIVERSITAS Scientific Committee met for the first time in April 2002, marking the beginning of the second phase of DIVERSITAS.

The DIVERSITAS Science Plan (2002) reflects the will to build a dynamic and integrative approach to biodiversity science which took account of the changing concept of biodiversity, which by this time was no longer just the ‘property of biologists’ but had become a concept at the heart of many human activities (Barbault/Cornet/Jouzel/Mégie/Sachs/Weber 2002). Scientists acknowledged that biodiversity changed as a result of its own evolutionary and ecological dynamics, but increasingly also as a result of deliberate human actions as well as their unintentional consequences. In turn, these changes affect the well-being of human societies.[7] To understand this reciprocal interaction of coupled ecological and human systems, a more integrative biodiversity science had to be developed. Therefore, DIVERSITAS recognized the need to continue efforts to integrate its community, which was still fragmented among types of ecosystems (terrestrial, freshwater, and marine), types of organisms and disciplines, especially biology and ecology on one side and the socio-economic sciences on the other (Dirzo/Loreau 2005).

7 See: Liu/Dietz/Carpenter/Folke/Alberti/Redman/Schneider/Ostrom/Pell/Lubchenco/Taylor/Ouyang/Deadman/Kratz/Provencher (2007).

Another important integrative step occurred when DIVERSITAS became a founding partner in 2002 of the *Earth System Science Partnership* (ESSP; chap 74 by Leemans/Rice/Henderson-Sellers/Noone), recognizing the links between biodiversity and other areas of global concern, such as climate change and land use change. The ESSP includes three other partners which are: the *International Geosphere-Biosphere Programme* (IGBP; chap. 77 Noone/Nobre/Seitzinger), the *International Human Dimensions Programme on Global Environmental Change* (IHDP; chap. 75 by Falkenhayn/Rechkemmer/Young), and the *World Climate Research Programme* (WCRP; chap. 78 by Church/Asrar//Busalacchi/Arndt).

76.3 Scientific Agenda of DIVERSITAS

76.3.1 Overall Mission and Structure

After publication of its Science Plan (2002), DIVERSITAS implemented its mission through the initiation of four Core Projects and five Cross-cutting Networks (see DIVERSITAS website, Box 76.1). DIVERSITAS can be considered as a think tank for promoting cutting-edge, innovative and internationally relevant biodiversity research, and its main achievement is the establishment of several interlinked scientific communities, built around these Core Projects and Cross-cutting Networks. Over the years, various types of activities have been performed, which include:

- provide common international frameworks for collaborative research on biodiversity;
- build scientific networks across countries and disciplines;
- perform scientific syntheses;
- engage scientists in scientific workshops and conferences;
- promote standardized methods;
- guide and facilitate global databases;
- build an important link with policy makers.

Box 76.1: The DIVERSITAS programme and related initiatives. **Source**: Compiled by the authors.

DIVERSITAS <http://www.diversitas-international.org/> is one of the four international global environmental change research programmes, the others being the International *Geosphere-Biosphere Programme* (IGBP) <http://www.igbp.net/>, the *International Human Dimensions Programme on Global Environmental Change* (IHDP) <http://www.ihdp.unu.edu/>, and the *World Climate Research Programme* (WCRP) <http://wcrp.wmo.int/wcrp-index.html/>.
Together they founded the *Earth System Science Partnership* (ESSP) <http://www.essp.org/>) which is a partnership for the integrated study of the Earth System, the ways that it is changing, and the implications for global and regional sustainability. Other programmes and initiatives mentioned in this chapter are here listed alphabetically with complete names and websites given:

- *Assembling the Tree of Life project* (ATOL); <http://atol.sdsc.edu/>;
- *Barcode of Life Initiative (*BOLI); <http://www.dnabarcodes.org/>;
- *Consortium for the Barcode of Life* (CBOL); <http://www.barcoding.si.edu/>;
- *Convention on Biological Diversity* (CBD); <http://www.cbd.int/>;
- *Encyclopedia of Life* (EOL); <http://www.eol.org/>;
- *Global Invasive Species Programme* (GISP); <http://www.gisp.org/>;
- *Global Mountain Biodiversity Assessment* (GMBA); <http://gmba.unibas.ch/index/index.htm/>;
- *Global Taxonomy Initiative* (GTI); <http://www.cbd.int/gti/>;
- *Group on Earth Observations Biodiversity Observation Network* (GEO BON); <http://www.earthobservations.org/cop_bi_geobon.shtml/>;
- HERBIS project; <http://www.herbis.org/>;
- *Intergovernmental Panel on Climate Change* (IPCC); <http://www.ipcc.ch/>;
- *International Council for Science* (ICSU); <http://www.icsu.org/index.php/>;
- *International Mechanism of Scientific Expertise on Biodiversity* (IMoSEB); <http://www.imoseb.net/>;
- *International Union for Biological Sciences* (IUBS); <http://www.iubs.org/>;
- *International Union of Microbiological Societies* (IUMS); <http://www.iums.org/>;
- ISI Web of Knowledge; <http://apps.isiknowledge.com.gate1.inist.fr/>;
- *Man and the Biosphere* (MAB) Prog*ramme*; <http://www.unesco.org/mab/>;
- *Millennium Ecosystem Assessment* (MA); <http://www.millenniumassessment.org/en/index.aspx/>
- NatureUganda; <http://www.natureuganda.org/>;
- Ramsar Convention on Wetlands; <http://www.ramsar.org/>;
- *Scientific Committee on Problems of the Environment* (SCOPE); <http://www.icsu-scope.org/>;
- Species 2000 Programme; <http://www.sp2000.org/>;
- *Subsidiary Body for Technical and Technological Advice* (SBSTTA); <http://www.cbd.int/convention/sbstta.shtml/>;
- United Nations Educational, Scientific and Cultural Organisation (UNESCO); <http://portal.unesco.org/>;
- *United Nations Environment Programme* (UNEP); <http://www.unep.org/>;
- *United Nations Framework Convention on Climate Change* (UNFCCC); <http://unfccc.int/2860.php/>;
- *World Resources Institute* (WRI); <http://www.wri.org/>;
- 2010 Biodiversity Indicators Partnership (2010 BIP); <http://www.twentyten.net/>.

It is not the subject of this chapter, however, to summarize the many activities of these various projects, but to portray some of the main scientific achievements of DIVERSITAS which have relevance to the theme of this book, i.e. how biodiversity research can identify threats, challenges, and risks to human well-being and thus help humanity to better cope with global environmental change. Three main themes have crystallized over the years:

1. To improve our capacity to observe and model biodiversity change, which in turn improves our ability to identify challenges and threats much earlier (early warning function).
2. To develop a better understanding of how biodiversity change affects ecosystem functioning and services, and how ecosystem services link to human well-being.
3. To investigate the social, legal, economic and political motivators that have an impact on the drivers of biodiversity change to guide the sustainable use of biodiversity and its associated ecosystem services.

Below, we present the contribution of DIVERSITAS towards each theme.

76.3.2 Improving Capacity to Observe and Model Biodiversity Change

While it is widely accepted that we are in the midst of a biodiversity crisis, with both populations and species experiencing often dramatic losses, we still experience major gaps in our global observation of biodiversity status and trends. There are several reasons for this: (a) the myriad forms of biodiversity, from genes to populations, species and ecosystems, are often extremely localized in their distribution, relatively expensive to sample and tantalizingly difficult to identify, and thus do not render themselves easily to global observation, unlike, for example, atmospheric gases; (b) biodiversity observation needs to include not just composition, but also structural complexity, functional relationships and evolutionary dynamics, as these factors greatly determine the responses of biodiversity to environmental change; (c) while some biodiversity observation systems exist, there are still large geographical gaps (often in the most biodiversity-rich regions, e.g., tropical rainforests), taxonomic gaps (most monitoring is focused on vertebrates and higher plants), or methodological gaps (most monitoring is not long-term and inconsistent in space and time and between observers); and (d) biodiversity data is held by a very large number of heterogeneous data providers (e.g., government agencies, NGOs, scientists, lay people, etc.), and many of these data are then only used by the data collector but do not become globally available because the delivery pipeline is blocked, either because data sets are not made available or because they are not made interoperable for use through global search engines and internet providers (Scholes/Mace/Turner/Geller/Jürgens/Larigauderie/Muchoney/Walther/Mooney 2008).

DIVERSITAS addresses these challenges mainly through three initiatives, its two Core Projects called bioGENESIS and bioDISCOVERY and the newly formed network called *Group on Earth Observations Biodiversity Observation Network* (GEO BON).

One of the aims of bioGENESIS is to facilitate the development of new strategies and tools for discovering and documenting biodiversity (Donoghue/Yahara/Conti/Cracraft/Crandall/Faith/Häuser/Hendry/Joly/Kogure/Lohmann/Magallón/Moritz/Tillier/Zardoya/Prieur-Richard/Larigauderie/Walther 2009). For example, it would revolutionize our ability to document and monitor biodiversity to develop rapid-capture technologies for identifying known species and discovering new ones. Of special interest is the development of a cost-effective, hand-held, automated species-identifier. The idea is to analyse a tiny sample of an organism; quickly extract, amplify, and sequence a set of target DNA markers; and then compare these to known sequences to situate the unknown within the tree of life. In this context, a key bioGENESIS initiative is to coordinate workshops aimed specifically at connecting the current efforts to develop DNA barcoding as a global standard for species identification (represented by the *Barcode of Life Initiative* (BOLI) and the *Consortium for the Barcode of Life* (CBOL) and the 'Tree of Life' activities, represented by the *Assembling the Tree of Life* project (ATOL)). Furthermore, new technologies are being promoted, e.g., real-time analysis of field images, use of remote-controlled microscopes, development of image recognition identification tools and automated digital capture of museum specimens and associated information (for a good example, see the HERBIS project). Information gained through such methods then needs to be connected to knowledge bases used by decision-makers, including the emerging *Encyclopedia of Life* (EOL).

While bioGENESIS thus addresses challenges of identification, bioDISCOVERY aims to promote the science that will improve our ability to objectively assess, monitor and predict biodiversity status and trends on a global scale. Such knowledge is essential given that biodiversity underpins all life processes on earth, and with it all the ecosystem services so vital to human well-being (76.3.3). Given the inherent complexity of biodiversity outlined above, bioDISCOVERY tackles this challenge from both a scientific as well as an institutional angle.

The scientific goals to address this challenge are outlined in the bioDISCOVERY Science Plan (Ash/Jürgens/Leadley/Alkemade/Araujo/Asner/Bachelet/Costello/Finlayson/Lavorel/Mace/Mooney/Parr/Scholes/Soberon/Turner/Prieur-Richard/Larigauderie/Walther 2009) whose aim is to develop a scientific framework to assess the current extent of biological diversity, to monitor its change, to understand the underlying processes responsible for those changes, and to predict future changes. Assessment of global biodiversity must be improved across spatial and temporal scales, at different levels of biological organization (i.e. genes, populations, species, functional groups and ecosystems), and in terms of the various attributes and functions of biodiversity. This will lead to advances in the spatial and temporal assessment of genetic, population, species and ecosystem biodiversity, and of the interactions between them. For example, almost nothing is known about the global status of genetic, microbial or marine biodiversity, while global data on landcover change also remain elusive. In addition to encouraging the collection of more primary biodiversity data, existing but often dispersed and heterogeneous data need to be better linked through the use of global data clearinghouses.[8] Improved data availability would enable the inclusion of a wider range of taxa[9] as well as an assessment of their functions; e.g., assess functional groups which deliver essential ecosystem processes, such as nitrogen-fixing soil organisms (Barrios 2007) or which deliver disservices such as invasive species.[10] Broader, functional approaches to classification will thus provide a considerably improved foundation for assessment, particularly in light of increasing attention of decision-makers to ecosystem functioning and services (76.3.3).

While assessments evaluate the status of biodiversity, continuous monitoring is essential to establish time lines that can detect biodiversity change, e.g., the disappearance of global fish stocks.[11] Detecting trends must go hand-in-hand with the identification of the main drivers of biodiversity change, e.g., land degradation or harvesting levels, so that not only the species or ecosystems at greatest risk can be pinpointed (early warning function) but that also the underlying causes of declines can be determined (cause-effect relationship). This will give decision-makers much better scope to identify risks and avert disasters before they happen.[12]

To operationalize global biodiversity monitoring, bioDISCOVERY has played a key role in developing the scientific framework during the early planning stages for the GEO BON which is a global partnership to collect, manage, analyze and report on the status and trends of the world's biodiversity.[13] The network will provide a scientifically robust framework for global biodiversity monitoring and define a strategy to reach strategic network goals and objectives.[14]

However, monitoring systems cannot monitor everything. Because of the complex nature of ecosystems, any effective early warning system will have to

8 For example, GIS Internet Resources, at: <http://www.tec.army.mil/gis/>, GISWiki: free portal for Geoinformatics, at: <http://en.giswiki.net/wiki/Main_Page/>; Global Invasive Species Database, at: <http://www.issg.org/database/welcome/>; Global Resource Information Database - Sioux Falls, at: <http://www.na.unep.net/>; Websites for Digital GIS Data, at: <http://www-sul.stanford.edu/depts/gis/web.html/>.

9 A taxon (plural: taxa) is the term used for a taxonomic unit, with each taxon receiving a name which designates an organism or a group of organisms. In biological nomenclature according to Carl Linnaeus, a taxon is assigned a taxonomic rank and can be placed at a particular level in a systematic hierarchy reflecting phylogenetic relationships. Taxonomy is the science of classification, and taxonomies are composed of taxa arranged in a hierarchical structure which should, but not always do reflect phylogenetic relationships between the taxa.

10 See: Perrings/Williamson/Dalmazzone (2000); Graham/Newman/Jarnevich/Shory/Stohlgren (2007).

11 See: Pauly/Watson/Alder (2005); Worm/Barbier/Beaumont/Duffy/Folke/Halpern/Jackson/Lotze/Micheli/Palumbi/Sala/Selkoe/Stachowicz/Watson (2006); Lovett/Burns/Driscoll/Jenkins/Mitchell/Rustad/Shanley/Likens/Haeuber (2007).

12 See: Cortet/Gomot-De Vauflery/Poinsot-Balaguer/Gomot/Texier/Cluzeau (1999); Kshatriya/Cosner/van Jaarsveld (2001); Tegler/Sharp/Johnson 2001; Grenfell/Ellery/Preston-Whyte (2005); Thuiller/Richardson/Pysek/Midgley/Hughes/Rouget (2005); Duchev/Distl/Groeneveld (2006); Gotelli/Ellison (2006); Fleming/van der Merwe/McFerren (2007).

13 See: Ash/Jürgens/Larigauderie/Leadley/Mace/Mooney/Scholes/Walther/Lane/Muchoney/Geller/Turner (2007); Walther/Larigauderie/Ash/Geller/Jürgens/Lane (2007); Ash/Jürgens/Larigauderie/Leadley/Walther (2008).

14 See: Andrefouet/Costello/Ferrier/Geller/Höft/Jürgens/Lane/Larigauderie/Mace/Miazza/Muchoney/Parr/Pereira/Sayre/Scholes/Stiassny/Turner/Walther (2008).

include a fair amount of modelling (Anderson/Bugmann/Dearing/Gaillard 2006). Therefore, another scientific challenge is to fill monitoring gaps with ecological modelling which uses the inevitably limited data base to extrapolate biodiversity status and trends across space and time.[15] For example, one of the key weaknesses of remote sensing is its uncertain link to lower levels of biodiversity. While a West African forest may still be structurally intact to the eyes of a remote sensor, with an undisturbed canopy of healthy trees, hunting may have completely decimated the mammalian fauna.[16] Furthermore, forests with the most intense hunting pressures may often be in civil war zones, making on-the-ground monitoring a practical impossibility. Therefore, to get a true picture of biodiversity change in such intractable situations, we need ecological models that may use parameters such as human population, food consumption or gun availability as proxies to estimate biodiversity loss. Likewise, modelling may be needed to estimate biodiversity trends for mega-diverse taxa such as invertebrates, fungi and microbes, where monitoring simply cannot do the job.

It is of further strategic importance for biodiversity science to turn monitoring data, which by themselves are rather useless to data users such as conservation or government agencies, into products which relay critical information to data users. Some of the most important such products are biodiversity indicators.[17] It is widely acknowledged that current global indicators of biodiversity are insufficient to provide representative measures of biodiversity change – due to lack of data and methodological constraints. Building on ongoing initiatives such as the CBD (CBD 2003; Mace/Baillie 2007) and its associated *2010 Biodiversity Indicators Partnership* (2010 BIP), the review and refinement of existing[18] and the development of new, global biodiversity indicators is a high priority. For example, indicators need to be developed that monitor not just the conservation status of various taxa, but also relate to ecosystem functions and services such as carbon sequestration, water regulation (76.3.3) or to ecosystem productivity, stability and resilience *per se*, and can easily be incorporated into biodiversity models and scenarios. The aim is to develop indicators that are sufficiently robust, representative, and sensitive to monitor global biodiversity change, but also fulfil the requirement to communicate complex biodiversity data in an easily understandable manner to decision-makers and the public, e.g., by indicating when dangerous thresholds are being reached.[19]

The final goal of bioDISCOVERY is to enhance our understanding of biodiversity change in response to multiple natural and anthropogenic drivers based on integrated analyses of observations, experiments and models which will be used to develop improved, quantitative scenarios of future biodiversity change. Such computer-based model scenarios will have to integrate ecological concepts such as food webs, species interactions and community assemblage as well as conservation concepts such as meta-population theory, minimum viable population, area selection algorithms, fragmentation and connectivity, into a spatially explicit *Geographic Information System* (GIS) modelling framework that draws on data gathered from various monitoring approaches.[20] Furthermore, variables such as drivers of change and ecosystem services need to be linked into the modelling framework to finally create an operational biodiversity model that can render regional and global biodiversity scenarios given various socio-economic inputs, thus delivering a key tool for conservation managers and policy makers which will allow them to weigh the consequences of various policy options for biodiversity,

15 See: Thuiller/Lavorel/Araújo/Sykes/Prentice (2005); Anderson/Bugmann/Dearing/Gaillard (2006); Bugmann/Gurung/Ewert/Haeberli/Guisan/Fagre/Kaab (2007); Katzner/Milner-Gulland/Bragin (2007); Leyequien/Verrelst/Slot/Schaepman-Strub/Heitkonig/Skidmore (2007); Turner/Lambin/Reenberg (2007); Wessels/Prince/Malherbe/Small/Frost/VanZyl (2007).

16 See: Walsh/Abernethy/Bermejo/Beyersk/De Wachter/Akou/Huljbregis/Mambounga/Toham/Kilbourn/Lahm/Latour/Maisels/Mbina/Mihindou/Obiang/Effa/Starkey/Telfer/Thibault/Tutin/White/Wilkie (2003); Brugiere/Badjinca/Silva/Serra/Barry (2006).

17 See: Niemi/McDonald (2004); Müller/Lenz (2006); Levrel (2007); Mace/Baillie (2007); Smyth/Watzin/Manning (2007).

18 See: Butchart/Stattersfield/Bennun/Shutes/Akçakaya/Baillie/Stuart/Hilton-Taylor/Mace (2004); Loh/Green/Ricketts/Lamoreux/Jenkins/Kapos/Randers (2005); Global Footprint Network (2006).

19 See: Balmford/Bennun/ten Brink/Cooper/Côté/Crane/Dobson/Dudley/Dutton/Green/Gregory/Harrison/Kennedy/Kremen/Leader-Williams/Lovejoy/Mace/May/Mayaux/Morling/Phillips/Redford/Ricketts/Rodríguez/Sanjayan/Schei/van Jaarsveld/Walther (2005); Buckland/Magurran/Green/Fewster (2005); Green/Balmford/Crane/Mace/Reynolds/Turner (2005).

20 See: Bani/Massimino/Bottoni/Massa (2006); Peterson/Sanchez-Cordero/Martínez-Meyer/Navarro-Sigüenza (2006).

ecosystem services, and, ultimately, human well-being.[21] How ecosystem services and socio-economic drivers of change are related to biodiversity change is the subject of the next two themes.

76.3.3 Exploring the Links between Biodiversity Change, Ecosystem Functioning and Services, and Human Well-being

Given that the world is in the midst of a biodiversity crisis, what are actually the arguments for conserving biodiversity? Three main arguments on how biodiversity enhances human well-being have been advanced:

1. Biodiversity has an intrinsic value because it enriches life by providing educational, intellectual and recreational opportunities, aesthetic and spiritual enjoyment, and a sense of identity. While some argue that all such services can be enumerated in economic terms (e.g., earnings from ecotourism), others argue that they are essentially fundamental rights to a good life, equivalent to human rights and thus cannot be given a monetary value. Conservation and sustainable use of biodiversity thus become ethical issues of good moral conduct towards other life forms as well as towards fellow human beings and cultures.
2. Biodiversity has an economic value by providing ecosystem goods and services, which can be extracted goods (e.g., foods, fibres, medicines) or indirect services (e.g., pollination, carbon sequestration, nutrient cycling, pest control, ecotourism).
3. Biodiversity has an option value by providing future services, especially as a legacy to future generations and as an insurance against future challenges and risks, e.g., by storing genetic diversity which might be needed to design new foods or medicines or to adapt to rapid environmental change.

Because of a growing realization among biodiversity scientists that the second argument may have the strongest impact on current decision-makers, a conscious effort was made by DIVERSITAS to advance the science of ecosystem functioning and how it relates to biodiversity on the one side and ecosystem services on the other. DIVERSITAS addresses this challenge through its Core Project called ecoSERVICES which examines the impact of biodiversity changes on ecosystem functioning and services (Bulte/Hector/Larigauderie 2005). While the very concept of ecosystem services goes back to at least Plato (Daily 1997), the recent scientific interest in ecosystem services has been staggering. There has been an exponential increase in the number of publications on this topic over the last two decades (figure 76.1), perhaps only comparable to the explosion of interest in global climate change. DIVERSITAS has been at the forefront of this scientific endeavour with a series of workshops, publications and policy initiatives beginning in 1991.

Together with SCOPE and the *United Nations Environment Programme* (UNEP) which early on published global summaries on the subject (Heywood 1995; Mooney/Cushman/Medina/Sala/Schulze 1996), DIVERSITAS developed the field of ecosystem functioning and services through several landmark publications on the topic which were also the basis for some of the conclusions made in the *Millennium Ecosystem Assessment* (2005a).[22]

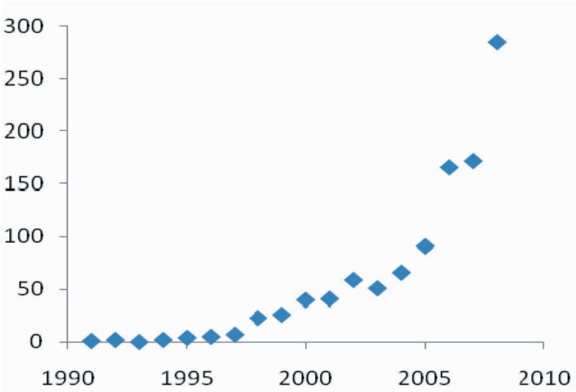
From all this research, several important conclusions for the relationship between biodiversity and ecosystem functioning were drawn:

1. The loss of genetic variability within a population of a species can reduce its flexibility to adjust to environmental change, e.g., climate change.
2. The loss of biodiversity within ecosystems generally reduces resource utilization, productivity and the capacity to resist changing environmental conditions and rebound from extreme conditions, while increasing spatial and temporal variation in ecosystem processes as well as susceptibility to invasion (however, several other factors, such as propagule pressure, disturbance regime, and

21 See: Parr/Sier/Battarbee/Mackay/Burgess (2003); Williams/Moore/Toham/Brooks/Strand/D'Amico/Wisz/Burgess/Balmford/Rahbek (2003); Santelmann/White/Freemark/Nassauer/Eilers/Vache/Danielson/Corry/Clark/Polasky/Cruse/Sifneos/Rustigian/Coiner/Wu/Debinski (2004); Carpenter/DeFries/Dietz/Mooney/Polasky/Reid/Scholes (2006); Naidoo/Ricketts (2006).

22 See: Chapin/Schulze/Mooney (1992); Schulze/Mooney (1994); Mooney/Lubchenco/Dirzo/Sala (1995); Mooney/Lubchenco/Dirzo/Sala (1995b); Emmerson/Solan/Emes/Paterson/Raffaelli (2001); Loreau/Naeem/Inchausti/Bengtsson/Grime/Hector/Hooper/Huston/Raffaelli/Schmid/Tilman/Wardle (2001); Kinzig/Pacala/Tilman (2002); Loreau/Naeem/Inchausti (2002); Statzner/Moss (2004); Hooper/Chapin/Ewel/Hector/Inchausti/Lavorel/Lawton/Lodge/Loreau/Naeem/Schmid/Setala/Symstad/Vandermeer/Wardlem (2005).

Figure 76.1: The number of publications per year enumerated by the scientific literature search engine ISI Web of Knowledge (see box 76.1) when the search word "ecosystem services" was used. The search was carried out on 16 December 2008.



resource availability also strongly influence invasion success).

3. The addition or deletion of dominant or keystone species (even if they are rare, such as top predators) can have profound effects on the capacity of an ecosystem to provide services. Keystone species are those with unique traits, e.g., for fixing nitrogen, capturing water, avoiding erosion, causing disturbance, and so forth; consequently, the effects of their removal or addition can be predicted *a priori*. Although the success of an invasive species in a new habitat is difficult to predict, its impact on ecosystem functioning upon establishment can be predicted based on whether the new species utilizes or produces a unique resource.
4. The simplification of ecosystems to produce greater yield of individual products (e.g., food monocultures) comes at the cost of the loss of ecosystem stability and ecosystem services, which then need to be subsidized by the use of often costly inputs, e.g., water, fertilizers and pesticides.
5. Certain ecosystems, e.g., those found in arid regions and on islands, appear particularly vulnerable to disturbance and hence alteration of their functioning. These sensitive systems all have low representation of key functional types (organisms that share a common role).
6. Anthropogenic alteration and fragmentation of ecosystems and landscapes reduces the overall amount of ecosystem services. Many of these ecosystem changes are difficult, expensive, or impossible to reverse or fix with technological solutions. Therefore, human societies will have to learn to maintain and increase the buffering capacity provided by biodiversity to ensure the long-term sustainable use of ecosystems.

While these conclusions hold in general, they can to some extent differ among different ecosystems, and should be treated with more caution for freshwater and marine ecosystems, as these have been severely understudied compared to terrestrial ecosystems.

These important conclusions on the link between biodiversity and ecosystem functioning and services then led to the next phase of scientific inquiry which is to link ecosystem services to human well-being, e.g., through quantification of economic benefits. Consequently, the scientific goals of the ecoSERVICES Science Plan (Bulte/Hector/Larigauderie 2005) are not only to further expand the research on the above conclusions by expanding the scale and complexity of future studies[23], but also to include economic and social researchers to investigate (1) how preferences for certain ecosystem services influence decision-making both at the individual and the societal level and (2) how to translate scientific knowledge about ecosystem services into economics to inform decision-makers about current versus future costs and benefits in comparable units of impact on human well-being.[24] Towards this goal, experimental and field studies need to be supplemented by the development of integrated ecological-economic models.[25] Such models

23 See: Loreau/Mouquet/Gonzalez (2003); Naeem/Wright (2003); Cardinale/Ives/Inchausti (2004); Gessner/Inchausti/Persson/Raffaelli/Giller (2004); Giller/Hillebrand/Berninger/Gessner/Hawkins/Inchausti/Inglis/Leslie/Malmqvist/Monaghan/Morin/O'Mullan (2004); Petchey/Downing/Mittelbach/Persson/Steiner/Warren/Woodward (2004); Raffaelli (2004); Vinebrooke/Cottingham/Norberg/Scheffer/Dodson/Maberly/Sommer (2004); Hooper/Chapin/Ewel/Hector/Inchausti/Lavorel/Lawton/Lodge/Loreau/Naeem/Schmid/Setala/Symstad/Vandermeer/Wardlem (2005); Balvanera/Pfisterer/Buchmann/He/Nakashizuka/Raffaell/Schmid (2006); Bulling/White/Raffaelli/Pierce (2006); Raffaelli (2006); Duffy/Cardinale/France/McIntyre/Thebault/Loreau (2007); Hector/Bagchi (2007).

24 See: Costanza/D'Arge/de Groot/Farber/Grasso/Hannon/Limburg/Naeem/O'Neil/Paruelo/Raskin/Sutton/van den Belt (1997); Daily/Söderqvist/Aniyar/Arrow/Dasgupta/Ehrlich/Folke/Jansson/Jansson/Kautsky/Lubchenco/Mäler/Simpson/Starrett/Tilman/Walker (2000); Balmford (2002); Farber/Costanza/Wilson (2002); Wätzold/Drechsler/Armstrong/Baumgartner/Grimm/Huth/Perrings/Possingham/Shogren/Skonhoft/Verboom-Vasiljev/Wissel (2006); Baumgärtner (2007); Tschirhart (2007).

will contribute towards a scientific basis for sustainable ecosystem-based management which is essential to achieve conclusion 6 (Tschirhart 2007); in other words, without reliable ecological-economic models, decision-makers and managers will find it difficult to choose policy and management options that maintain the buffering capacity of functional ecosystems and, at the same time, satisfy other societal needs, e.g. the provision of foods and fibres.

Yet quantifying the value of ecosystem services in specific localities and measuring their worth against that of competing land uses is no simple task. For example, a typical tradeoff is to quantify the economic benefits of a particular development project versus the benefits supplied by the ecosystem that would be destroyed. While in many cases the value of ecosystem services remains highly uncertain, the pace of destruction of natural ecosystems and the irreversibility of most such destruction warrants that we begin valuing ecosystem services, even if such an enterprise is fraught with difficulties. Just as societies have recognized fundamental human rights, it may be prudent to establish fundamental ecosystem protections even though uncertainty over economic values remains.

Two short examples shall illustrate that the research led by DIVERSITAS and many others on the value of ecosystem services is already making an impact on actual decision-making and global policy setting.

In the rush to produce sugar cane for biofuels, Uganda's President Yoweri Museveni wanted to give away a third of the 30,000 hectare Mabira Forest Reserve which is globally recognized as an *Important Bird Area* (IBA).[26] However, in October 2007, after months of intensive campaigning by several environmental organizations, the Uganda Ministry of Finance and Economic Planning announced that these plans had been dropped. What made this decision significant was that it was heavily influenced by a report published by *Nature-Uganda* which clearly showed that the economic value of the forest if conserved would surpass the anticipated economic value from future sugarcane harvests. The list of 'ecosystem services' (livelihoods, food, clean water, protection from soil erosion, ecotourism, etc.) provided by the reserve to over 120,000 adjacent community members was another important finding in the report which eventually won over the government.[27] This may very well be the first instance in which the explicit enumeration of ecosystem services changed a major policy decision within one of Africa's poorest nations.

Going from the local to the global scale, the German Federal Ministry for the Environment and the European Commission, with the support of several other partners, jointly presented an interim report of *The Economics of Ecosystems & Biodiversity* (TEEB) (European Communities 2008) during the Ninth Conference of the Parties to the *Convention on Biological Diversity* (CBD COP-9) in Bonn, Germany, in May 2008. The study evaluates the costs of the loss of biodiversity and the associated decline in ecosystem services worldwide, and compares them with the costs of effective conservation and sustainable use. It is intended to sharpen awareness of the value of biodiversity and ecosystem services and facilitate the development of cost-effective policy responses, notably by preparing a 'valuation toolkit'. Mimicking the Stern report on the economics of climate change (Stern 2006) and hoping for a similar impact on global awareness and policy-making, the TEEB will continue its investigation and present its final report at the Tenth Conference of the Parties to the *Convention on Biological Diversity* (CBD COP-10) in Nagoya, Japan, in 2010.

76.3.4 Investigating the Socio-economic Drivers of Biodiversity Change to Guide the Sustainable Use of Biodiversity

Given the realization of the irreplaceable value of ecosystem services (be it intrinsic, economic or optional value), there is an urgent need to investigate what motivates people and societies to keep using biodiversity in unsustainable ways, and how human behaviour may

25 See: Williams/Moore/Toham/Brooks/Strand/D'Amico/Wisz/Burgess/Balmford/Rahbek (2003); Moore/Balmford/Allnutt/Burgess (2004); Santelmann/White/Freemark/Nassauer/Eilers/Vache/Danielson/Corry/Clark/Polasky/Cruse/Sifneos/Rustigian/Coiner/Wu/Debinski (2004); Polasky/Nelson/Lonsdorf/Fackler/Starfield (2005); Bulling/White/Raffaelli/Pierce (2006); Naidoo/Balmford/Ferraro/Polasky/Ricketts/Rouget (2006); Naidoo/Ricketts (2006); Pitcher/Ainsworth (2008); and especially recent issues of the journal Ecological Economics.

26 An Important Bird Area (IBA) is a definition adopted by BirdLife International to recognize those terrestrial areas which are key sites for bird conservation, especially of threatened and endemic species; at: <http://www. birdlife.org/action/science/sites/index.html/>.

27 Anonymous, 2007: "BirdLife Partners applaud Uganda's decision to drop Mabira Forest give-away"; at: <http://www.birdlife.org/news/pr/2007/10/mabira.html/> (6 June 2008).

be changed to guide us towards the path of the sustainable use of biodiversity and its associated ecosystem services. DIVERSITAS addresses this challenge through its Core Project called bioSUSTAINABILITY which investigates the social, legal, economic and political motivators that have an impact on the drivers of biodiversity change to guide the sustainable use of biodiversity and its associated ecosystem services (DIVERSITAS 2004). Within these broader goals, a major focus of bioSUSTAINABILITY is to understand the reasons for the successes and failures of current conservation policies. Failures can often be attributed to one of the following factors:

1. policies do not recognize and effectively address the underlying motivations and incentives of individuals, organizations, and governments whose actions impact biodiversity,[28]
2. society often fails to appreciate the full value of the ecosystem services that biodiversity provides[29] (76.3.3 above) and/or
3. society at large has become dysfunctional to such a degree that conservation is not feasible.[30]

To measure success or failure, bioSUSTAINABILITY is developing indicators of the effectiveness of programmes and policies that impact on biodiversity, e.g., by identifying the positive or negative net effects on biodiversity of various social, political and economic drivers.[31] Understanding the effects of drivers of change is a prerequisite to develop successful conservation policies and to understand the mechanisms and conditions associated with various outcomes. Finally, bioSUSTAINABILITY investigates how to (1) incorporate this information into decision-making processes, (2) improve understanding of cause and effect mechanisms, and (3) develop adequate incentives to minimize impacts.[32]

What makes evaluating different policy options so difficult is that different groups within society often have diverse views about which outcomes are desirable and which trade-offs are acceptable. For example, one group may be interested in the value of the production of commodities, while another one may be more interested in conserving biodiversity (Deacon/Parker 2008). Reaching decisions which are acceptable to all stakeholders is a complex process. While top-down decisions may be easy to formulate, they usually ignore important stakeholder groups and are therefore likely to fail in the long term. Efforts to reach a consensus from the bottom-up, which require participatory processes and the involvement of all stakeholder groups, are more difficult, but their inclusive nature means that solutions are more likely to persist. Using case studies ranging from the local to the international scale, scientists involved in bioSUSTAINABILITY have examined the dynamics of multiple stakeholder groups, the criteria used to decide who participates and who makes decisions and best practice for building consensus, including cost-benefit analyses of conservation investments.[33]

Even with an improved understanding of these decision-making processes, much uncertainty remains because both ecological and socio-economic systems exhibit complex dynamic behaviours that interact in often unpredictable ways.[34] A challenge for long-term

28 See: Bohn/Deacon (1997); Mitchell/Keilbach (2001); Clark/Mitchell/Cash/Alcock (2002); Mitchell (2002); Mitchell (2003); Tarui/Polasky (2005); Clark/Mitchell/Cash (2006); Polasky (2006); Mitchell (2007); Deacon/Parker/Costello (2008); Tarui/Mason/Polasky/Ellis (2008).

29 See: Tilman/Polasky/Lehman (2005); Hassan/Ngwenya (2006); Matete/Hassan (2006); Dale/Polasky (2007).

30 See: Deacon (1994); Bohn/Deacon (1997); Dudley/Ginsberg/Plumptre/Hart/Campos (2002); Deacon/Mueller (2004); Bulte/Damania/Deacon (2005); Fjeldså/Alvarez/Lazcano/Leon (2005); Aldhous (2006).

31 See: Niemi/McDonald (2004); Pardal/Cardoso/Sousa/Marques/Raffaelli (2004); Müller/Lenz (2006); Dale/Polasky (2007); Smyth/Watzin/Manning (2007).

32 See: Deacon/Brookshire/Fisher/Kneese/Kolstad/Scrogin/Smith/Ward/Wilen (1998); Cash/Clark/Alcock/Dickson/Eckley/Guston/Jäger/Mitchell (2003); Colding/Folke/Elmqvist (2003); Tarui/Polasky (2005); Matete/Hassan (2006); Polasky (2006); Mehta/Haight/Homans/Polasky/Venette (2007); Deacon/Parker/Costello (2008); Deacon/Parker (2008); Tarui/Mason/Polasky/Ellis (2008).

33 See: Bohn/Deacon (1997); Mitchell/Keilbach (2001); Clark/Mitchell/Cash/Alcock (2002); Mitchell (2002); Mitchell (2003); Tarui/Polasky (2005); Clark/Mitchell/Cash (2006); Matete/Hassan (2006); Mitchell (2006); Mitchell (2007); Murdoch/Polasky/Wilson/Possingham/Kareiva/Shaw (2007); Nelson/Uwasua/Polasky (2007); Barbier/Koch/Silliman/Hacker/Wolanski/Primavera/Granek/Polasky/Aswani/Cramer/Stoms/Kennedy/Bael/Kappel/Perillo/Reed (2008); Costello/Polasky (2008); Tarui/Mason/Polasky/Ellis (2008).

34 See: Folke/Carpenter/Elmqvist/Gunderson/Holling/Walker (2002); Scheffer/Carpenter (2003); Folke/Carpenter/Walker/Scheffer/Elmqvist/Gunderson/Holling (2004); Carpenter/Brock (2006); Kinzig/Ryan/Etienne/Allison/Elmqvist/Walker (2006); Liu/Dietz/Carpenter/Folke/Alberti/Redman/Schneider/Ostrom/Pell/Lubchenco/Taylor/Ouyang/Deadman/Kratz/Provencher (2007).

biodiversity conservation and sustainability is to understand the dynamics of these coupled systems to predict how these dynamics might be affected by different social and economic decisions.[35] However, the very complexity of these systems means that it will be difficult to forecast the future. Surprises and uncertainty inherent in such dynamics make traditional approaches, which assume nearly complete information, of little use. Long-term sustainable management of biodiversity resources requires novel approaches (see e.g. GEO BON in 76.3.2 above).

Therefore, the analysis of the potential usefulness of a range of methodological approaches to assess the sustainability of coupled socio-ecological systems is a key goal of bioSUSTAINABILITY. In particular, bioSUSTAINABILITY intends to analyse the following promising methods: stochastic dynamic programming;[36] management of resilience;[37] multi-agent systems;[38] integrated environmental assessment modelling;[39] safe minimum standards (Berrens 2001; Drucker 2006); and the precautionary principle.[40] Such methods promise to deliver better early warning functions which will be able to detect when dangerous thresholds are reached at which system functions may change in dramatic and irreversible ways (e.g., collapse of fisheries, coral bleaching, landslides due to deforestation). Wherever possible, reversible damage needs to be redressed through implementation of restorative efforts and sustainable policies.[41] Such investigations are therefore invaluable as human societies attempt to cope with the challenges associated with global environmental change.

76.3.5 DIVERSITAS Cross-cutting Networks

The work of the four Core Projects of DIVERSITAS is mirrored and amended by the work of five Cross-cutting Networks which have gradually evolved and focused on specific themes or ecosystems, embracing issues also partially addressed in the Core Projects:

- *agroBIODIVERSITY* investigates relationships between biodiversity and agriculture (Jackson/Bawa/Pascual/Perrings 2005).
- *ecoHEALTH* explores relationships between biodiversity and health.
- *freshwaterBIODIVERSITY* researches issues related to freshwater biodiversity.[42]
- *Global Invasive Species Programme* (GISP) addresses issues related to invasive species (McNeely/Mooney/Neville/Schei/Waage 2001).
- *Global Mountain Biodiversity Assessment* (GMBA) focuses on mountain biodiversity issues (Spehn/Körner 2005; Spehn/Liberman/Körner 2006).

In the context of this chapter, it would go too far to detail their substantial contributions (for details, see DIVERSITAS website, box 76.1), but they all contribute to building global scientific capacity to focus on how to address biodiversity change and its implications on human societies.

76.3.6 Strengthening the Science Policy Bridge

To cope with *global environmental change* (GEC), an efficient flow of information is crucial. To bridge the

35 See: Janssen/Bodin/Anderies/Elmqvist/Ernstson/McAllister/Olsson/Ryan (2006); Moorcroft (2006); Tallis/ Kareiva (2006); Turner/Lambin/Reenberg (2007); Polasky (2008).

36 See: Costello/Polasky (2008); Hauser/Possingham (2008); Li/Huang/Nie/Nie (2008).

37 See: Folke/Carpenter/Elmqvist/Gunderson/Holling/Walker (2002); Folke/Carpenter/Walker/Scheffer/Elmqvist/Gunderson/Holling (2004); Janssen/Bodin/Anderies/Elmqvist/Ernstson/McAllister/Olsson/Ryan (2006); adaptive management (Daily 2000); Folke/Carpenter/Elmqvist/Gunderson/Holling/Walker (2002); Folke/Carpenter/Walker/Scheffer/Elmqvist/Gunderson/Holling (2004); Hauser/Possingham (2008).

38 See: Abielmona/Petriu/Groza (2007); Marcos/Flores/Ogbinar/Jose/Taborda (2007); Peyravi/Pashaci/Taghiyareh (2007).

39 See: Matete/Hassan (2006); Krol/Bronstert (2007); Lacitignola/Petrosillo/Cataldi/Zurlini (2007); Matthies/Giupponi/Ostendorf (2007); Smith/Fulton/Hobday/Smith/Shoulder (2007); Sutherst/Maywald/Bourne (2007); Weber (2007); Aranzabal/Schmitz/Aquilera/Pineda (2008); Buckley (2008); Ferreira/Hawkins/Monteiro/Moore/Service/Pascoe/Ramos/Sequeira (2008).

40 See: Gable (2003); Prato (2005); Aronson/Precht (2006); Failler/Pan (2007); Finnoff/Shogren/Leung/Lodge (2007); Morgan/Tsao/Guinotte (2007); Fenichel/Tsao/Jones/Hickling (2008); Hauser/Possingham (2008).

41 See: Young (2000); van Andel/Aronson (2003); Mitsch/Jørgensen (2004); Temperton/Hobbs/Nuttle/Halle (2004); Young/Petersen/Clary (2005); Falk/Palmer/Zedler (2006); Irwin/Ranganathan (2007); Mooney (2007); Schuster/Smits/Ullal (2008).

42 See: Dudgeon/Arthington/Gessner/Kawabata/Knowler/Lévêque/Naiman/Prieur-Richard/Soto/Stiassny/Sullivan (2006); Naiman/Prieur-Richard/Arthington/Dudgeon/Gessner/Kawabata/Knowler/O'Keeffe/Lévêque/Soto/Stiassny/Sullivan (2006).

gap between the monitoring, science and assessment communities dealing with biodiversity change, DIVERSITAS has made extensive use of the scientific community built through its Core Projects and Cross-cutting Networks to take the lead in the on-going consultations on a global monitoring network and a global assessment mechanism, namely the GEO BON (see 76.3.2 above) and the consultation on an *International Mechanism of Scientific Expertise on Biodiversity* (IMoSEB). IMoSEB was initiated by the French Government in January 2005 at a summit entitled "Biodiversity: Science and Governance"[43] and gained momentum in 2006 through a vibrant process involving hundreds of scientists, representatives of governments, international and non-governmental organizations, as well as UN agencies. The central focus of this consultation is the need for a new mechanism, called IMoSEB, which, like the *Intergovernmental Panel on Climate Change* (IPCC), would provide independent and regular scientific expertise on and assessment of biodiversity to the biodiversity-related conventions, such as the CBD, the *Ramsar Convention on Wetlands*, or the *United Nations Framework Convention on Climate Change* (UNFCCC).

During this consultation process, a broad consensus has been emerging on the fact that the current situation in terms of availability and use of scientific expertise for decision-making on biodiversity is not satisfactory. The *Subsidiary Body for Technical and Technological Advice* (SBSTTA) of the CBD is not fulfilling this role, and would benefit from such a mechanism. Issues that have been debated in the consultation include the governance of IMoSEB, the framework of IMoSEB (what should its relation with the CBD be?), the time frame (should IMoSEB produce regular assessments or fast expertise on emerging topics, or both?), and the geographical scale (could a global mechanism deliver relevant information at the local level?). A final meeting of the International Steering Committee, at the end of 2007, discussed all these major issues, and came up with final recommendations on the mandate and governance of IMoSEB.

IIn broad strokes, they recommend that IMoSEB should be:

- scientifically independent, credible and inclusive;
- policy-legitimate through inter-governmental and multi-stakeholder involvement;
- policy-relevant without being policy-descriptive;
- based on a robust and relevant conceptual framework;
- communicated in an appropriate form for consideration and possible action;
- supported by networking efforts of scientific and knowledge holders.

IMoSEB should address decision-makers from governments and other sectors of society at global, regional and national scales and promote dialogue between international agencies and decision-makers. IMoSEB would thus provide scientific support to multilateral environmental agreements, national governments and other decision-makers which are concerned with consequences of biodiversity change. The main activities of IMoSEB would include

- influencing the research agenda by highlighting scientific gaps,
- generating interdisciplinary knowledge through regular independent assessment,
- providing policy support by responding to requests for information on specific issues,
- identifying emerging issues and threats and
- building capacity at the regional and national level.

Since May 2008, IMoSEB and the follow-up process to the Millennium Ecosystem Assessment (2005a) have engaged in discussions and come to the agreement that a single mechanism for both initiatives would be more appropriate than two separate ones, given the high level of congruence between the two initiatives. All modalities of this new mechanism, referred to as the *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES, <http://ipbes.net/en/index.aspx/>) were considered by governments and other stakeholders at an "ad hoc intergovernmental and multi-stakeholder meeting on an intergovernmental science-policy platform on biodiversity and ecosystem services" held in Putrajaya, Malaysia, from 10–12 November 2008 under the auspices of the UNEP Executive Director. Delegates from 78 countries and 25 organizations discussed needs and modalities to strengthen the science-policy interface on biodiversity and ecosystem services. There was broad recognition of the need to improve the science-policy interface which should use existing relevant assessments and the best available multidisciplinary knowledge (i.e., natural, social and economic sciences, including traditional and indigenous knowledge). Many delegates agreed that the role

43 See: Loreau/Oteng-Yeboah/Arroyo/Babin/Barbault/Donoghue/Gadgil/Häuser/Heip/Larigauderie/Ma/Mace/Mooney/Perrings/Raven/Sarukhan/Schei/Scholes/Watson (2006).

of an independent science policy platform should be to compile, assess and synthesize existing scientific knowledge, thereby indentifying areas of science requiring further development, and to provide policy-relevant, evidence-based and peer-reviewed information to multiple stakeholders including multilateral environmental agreements without being policy-prescriptive. A second meeting, most likely to be held in 2009, will continue this process. DIVERSITAS will continue to ensure a strong representation of the biodiversity community in this process.

76.4 Conclusions

This chapter illustrates how biodiversity science has changed over this past decade, moving from a purely 'naturalist' view of the world excluding humans to a vision that takes into account human activities and their interaction with earth system processes. Consequently, the scientific community has changed the way it works and built numerous bridges across disciplines. Biodiversity scientists have learned to interact with politicians and other decision-makers, and have increasingly been called upon to shape policies to protect biodiversity at the national and international level. Strong concepts have emerged, such as the consequences of biodiversity change and loss for ecosystem functioning and services and human well-being, thanks to DIVERSITAS and the *Millennium Ecosystem Assessment* (2005a).

Yet, in spite of all these efforts, losses of populations and species and destruction of ecosystems continue unabated. A strong case still needs to be made for biodiversity. Public opinion does not feel threatened by the loss of biodiversity, as is the case for climate change. Biodiversity losses remain seen by most as the disappearance of a charismatic species far away from home, a sad event, but not of a threatening nature to daily life. Therefore, the biodiversity crisis, even more than the climate change crisis, will require a multi-disciplinary approach both on the science side as well as on the policy, education and management side, combining and integrating different approaches, subjects and disciplines. The main challenge for the biodiversity community in the few years ahead is to make a strong enough case for biodiversity, to influence public opinion, and to make an impact on political agendas. Humankind does not have much time to avert the further irreversible loss of biodiversity in all its multifaceted splendour.

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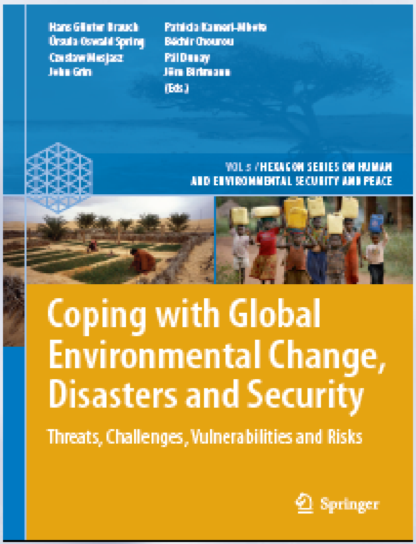

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