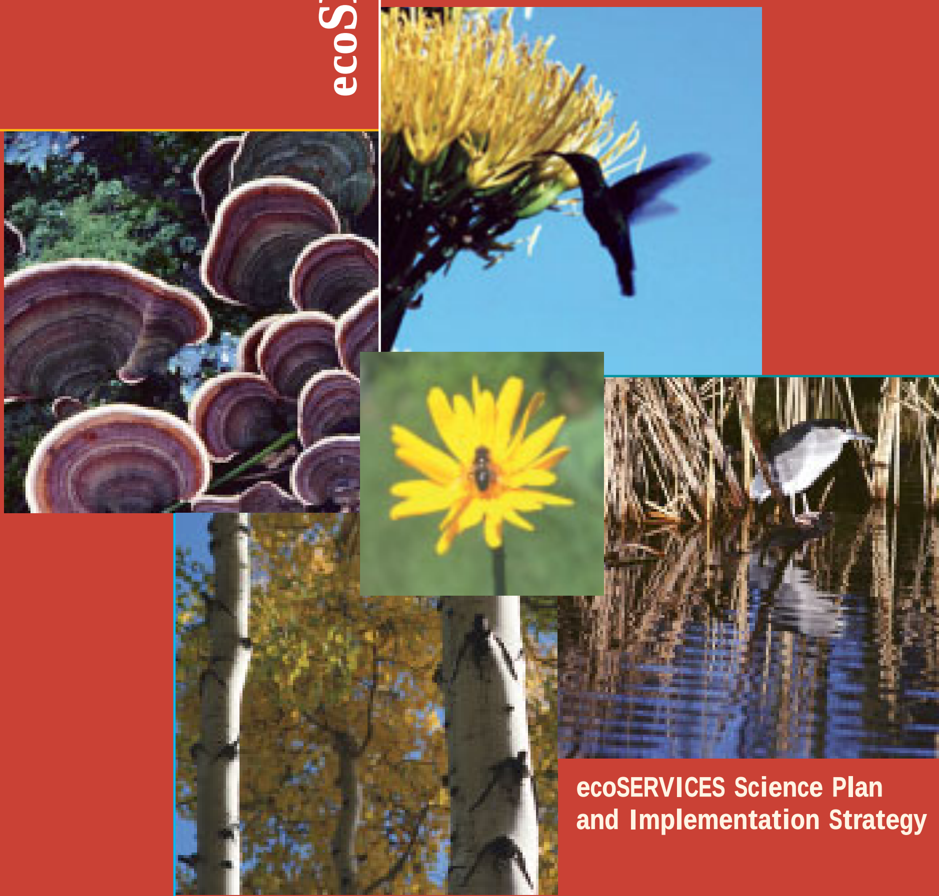
ecoSERVICES

# Assessing the impacts of biodiversity changes on ecosystem functioning and services



## ecoSERVICES Science Plan and Implementation Strategy

ecoSERVICES

a core project of DIVERSITAS

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# DIVERSITAS

## Report N°3, ecoSERVICES Science Plan and Implementation Strategy

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**Cover images legend:** *Pollination, decomposition, air and water filtration, carbon sequestration. These are just some of the vital services ecosystems provide to support human well-being. Understanding the social and economic value of ecosystem goods and services is an important aspect of assessing how changes in biodiversity and in ecosystem functioning may ultimately impact human populations.*

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www.diversitas-international.org/ecoservices


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ecoSERVICES

# Assessing the impacts of biodiversity changes on ecosystem functioning and services

ecoSERVICES Science Plan and Implementation Strategy

Editors:
Erwin Bulte, Andy Hector and Anne Larigauderie

*Prepared by the ecoSERVICES Scoping Team and the ecoSERVICES Scientific Committee*

*Approved by the Scientific Committee of DIVERSITAS*

DIVERSITAS
an international programme of biodiversity science

ecoSERVICES
a core project of DIVERSITAS

# Preface

*The Sabah Biodiversity Experiment (Borneo) examines the relationship between tree diversity, carbon sequestration and general ecosystem functioning, in part by measuring the survival and growth of dipterocarp seedlings.*
© Glen Reynolds

As scientists begin to better understand how biodiversity underpins the life-support system of our Planet, more and more questions arise regarding individual ecosystems—particularly the functions they perform (e.g. biogeochemical processes) and the services they provide (e.g. production of food and fibre, carbon storage, maintenance of water and soil quality, etc.) to human populations.

ecoSERVICES, a Core Project of DIVERSITAS, is dedicated to investigating the impact of biodiversity change on ecosystem functioning and services. Current understanding of the implications of biodiversity change and loss—even at the broadest scale—is still very limited and fragmented. The specific nature of interdependencies between the structure and diversity of biotic communities and the functioning of ecosystems remains one of the most important unresolved questions in ecology. Moreover, it is a question that has immense implications for human societies.

ecoSERVICES represents a new approach to research on the impacts of biodiversity change in several important ways. Firstly, the ecoSERVICES framework will catalyse the collaborative research needed to explore the link between biodiversity change and ecosystem functioning at greater biological complexity and at larger spatio-temporal scales than has previously been carried out.

A second important goal of ecoSERVICES is to enable multi-disciplinary groups to work together to understand the ecological processes underlying ecosystem services and to place an economic value on these services. From the outset, ecoSERVICES has been conceptualised as an integrative project that will design new methodologies and new models to link biodiversity losses with economic losses.

Finally, ecoSERVICES is committed to producing new knowledge of direct policy relevance. Our aim is to understand and predict the changes in ecosystem services and environmental public goods that result from losses in biodiversity. To reflect the interrelated nature of the key questions this Core Project seeks to address, its three Foci have been defined as:

**FOCUS 1** Linking biodiversity to ecosystem functioning

**FOCUS 2** Linking ecosystem functioning to the provision of services

**FOCUS 3** Human responses to changes in ecosystem services

This document is the result of a series of workshops and consultations carried out in 2003 and 2004. It is not meant as a rigid and exhaustive plan. Rather, it is intended to be a flexible road map that will evolve as new knowledge and ideas become available and as new participants join the initiative. Similarly, the activities proposed in the Implementation Plan are intended to stimulate the interest of programme managers and scientists from many nations and disciplines.

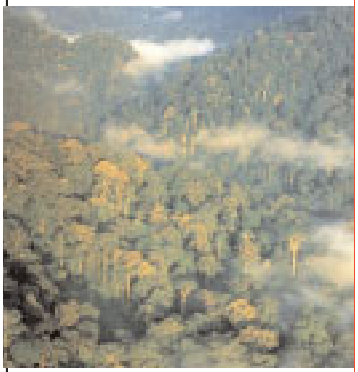
Ultimately, our aim is to inspire a new generation of research on biodiversity and ecosystem functioning. We hope to enable scientists, resource managers and policy makers to work together toward the creation and implementation of more successful policies and programmes based on a better understanding of how ecosystems function.

**Erwin Bulte, Andy Hector**
*Co-chairs, ecoSERVICES*

**Michel Loreau**
*Chair, Scientific Committee DIVERSITAS*

**Anne Larigauderie**
*Executive Director, DIVERSITAS*

# ecoSERVICES Scientific Committee



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# Executive Summary

# I

## Linking biodiversity to ecosystem functioning

The potential impacts of biodiversity loss on the functioning of ecosystems are currently receiving increasing attention. This is mainly due to the simple observation that if biodiversity does affect ecosystem functioning, it could have important indirect impacts on the provision of ecosystem goods and services upon which human societies depend. Examples of such goods and services include the production of food and fibre, carbon storage, soil fertility, nutrient cycling and resistance to climate and other environmental changes. Recent experimental and theoretical studies provide evidence that there may indeed be a relation between biodiversity and ecosystem functioning. This considerably strengthens the need to further assess how changes in biodiversity—and their influence on the provision of ecological goods and services—will affect human societies in the long term.

ecoSERVICES will actively promote the development of research in this area, building, in particular, on the past collaboration between DIVERSITAS and the International Geosphere-Biosphere Programme's project on Global Change and Terrestrial Ecosystems (IGBP-GCTE). It will investigate how the biodiversity changes studied in bioDISCOVERY (DIVERSITAS Core Project 1) affect ecosystem functioning and the provision of ecosystem services, thereby influencing strategies for conservation and sustainable use of biodiversity, the primary focus of bioSUSTAINABILITY (Core Project 3).

## DIVERSITAS – an international programme of biodiversity science

Since its inception in 1991, DIVERSITAS has focused on identifying global concerns related to biodiversity science and on coordinating efforts from around the world to address these issues. In 2001, a second phase of the Programme was launched with the aim of further refining its three main objectives:

- Discovering biodiversity and predicting its changes.
- Assessing impacts of biodiversity changes on ecosystem functioning and services.
- Developing the science of the conservation and sustainable use of biodiversity.

In 2003, DIVERSITAS hosted a series of scoping meetings to produce a science plan and implementation strategy for each of these Core Projects. In recognition of their primary goals, participants chose to identify the Core Projects by the following names: bioDISCOVERY, ecoSERVICES, and bioSUSTAINABILITY.

bioDISCOVERY
a core project of DIVERSITAS

ecoSERVICES
a core project of DIVERSITAS

bioSUSTAINABILITY
a core project of DIVERSITAS

## The ecoSERVICES Science Plan

This Science Plan highlights the need to develop rigorous, fact-based science that advances current knowledge on the links between biodiversity, ecosystem functioning and ecosystem services. Its end goal is to provide policy-relevant advice to interested parties at local, regional and international levels. To meet these objectives, the ecoSERVICES Science Plan was built upon—and will be carried out through—interdisciplinary collaboration amongst natural and social scientists. The Plan comprises three interrelated Foci.

### FOCUS 1: Linking biodiversity to ecosystem functioning

Recent ecological research has produced a first characterisation of the general relationship between biodiversity and ecosystem functioning (BEF). However, most of this work consisted of small-scale, short-term experimental studies covering only one or two trophic levels. In reality, the changes in biodiversity and ecosystem functioning most likely to affect humans occur at much larger scales over longer periods of time and involve many trophic levels simultaneously. Focus 1 seeks to deal with this complexity by initiating six Tasks, which will require collaborative thinking and experimental work.

#### TASK 1.1 Spatial scale and biodiversity-functioning relationships

Review macro-ecological literature and synthesise results with small-scale experiments to examine biodiversity-ecosystem functioning (BEF) relationships on larger spatial scales. Identify points of agreement and instances in which the level of resolution changes the relationship. Develop large-scale quantitative and conceptual models of biodiversity change based on known drivers.

#### TASK 1.2 Temporal scale and biodiversity-functioning relationships

Enlarge the temporal scale of BEF research by developing new theoretical models that allow for better comparison of alternative approaches and have the capacity to omit various ecological details. Collate existing time-series and experimental datasets for standardised testing to compare diversity-stability relationships. Examine biological patterns and mechanisms identified through experimental research and observational data. Make recommendations for the future development of theory.

#### TASK 1.3 Biodiversity change in complex systems

Develop a new multi-trophic theory of biodiversity and ecosystem functioning. Apply this theory to make recommendations for the next generation of empirical research.

#### TASK 1.4 Microbial diversity and ecosystem functioning

Investigate the unique role of microbes in ecosystems, particularly in two areas:
a) analyse how microbial diversity and activity affects overall ecosystem functioning; and b) link changes in microbial diversity to global change scenarios.

#### TASK 1.5 Biodiversity and biogeochemical cycles

Study how biodiversity changes affect the biogeochemical cycles that regulate ecosystem productivity, respiration and carbon storage. Investigate how biodiversity loss will alter the production of greenhouse gases and volatile organic compounds, which are known to contribute to global environmental changes.

#### TASK 1.6 Second generation of biodiversity-functioning research

Synthesise the limitations of first-generation research in biodiversity-functioning relationships. Develop new approaches for collaborative, second-generation experiments that account for patterns of species loss in real ecosystems and address the processes that underpin the ecological services most valuable to humans.

## FOCUS 2: Linking ecosystem functioning to provision of services

Ecosystem services are broadly defined as the benefits human societies derive as a result of ecosystem processes and functioning. Ecological goods include, for example, the production of food and fibre. Ecosystem services include carbon storage and the reduction of greenhouse gases, the maintenance of water quality and soil fertility, adaptation to climate and other environmental changes, or the maintenance of ecological conditions favourable to human health.

Through the following Tasks, Focus 2 of ecoSERVICES aims to develop an effective means for linking changes in ecosystem structure (e.g. predation) and functioning (e.g. productivity) to changes in ecosystem properties of relevance to human beings, that is, ecosystem services.

### TASK 2.1 Experimental research on the links between ecosystem functioning and ecosystem services

Promote new experimental approaches to study simple systems in which one service can be mapped onto one process (e.g. pollination). Advance to more complex systems across a range of ecosystems. Supplement with theoretical work on ecosystem dynamics, economic activity and service provision.

### TASK 2.2 Ecosystem services and environmental public goods

Classify public goods based on their physical and social properties. Examine how different societies define (from an institutional perspective) the services derived from a particular ecosystem and how that definition affects the use of such services. Identify ecosystems that are threatened by simplification of managed systems.

### TASK 2.3 Biodiversity, resilience and the value of ecosystem services

Develop new research and theory to
a) better understand and predict changes and sudden shifts in biological communities resulting from biodiversity changes, and
b) explore the economic implications of these shifts.

### TASK 2.4 Develop models to predict the impacts of biodiversity change on ecosystem services

Promote the development and application of models to predict and help manage risks and uncertainties in the provision of key ecosystem services.

## FOCUS 3: Human responses to changes in ecosystem services

There are feedback mechanisms between changes in ecosystem services and human responses. Humans trigger biodiversity changes that affect the quantity and quality of services. In the face of these changes, humans adapt by modifying their behaviour. Focus 3 of ecoSERVICES will consider human responses to environmental change as a critical component of the relationship between biodiversity and ecosystem functioning. However, this Science Plan does not deal with management responses, which will be taken up in the bioSUSTAINABILITY Core Project.

### TASK 3.1 Service substitutability, local response and the single service case

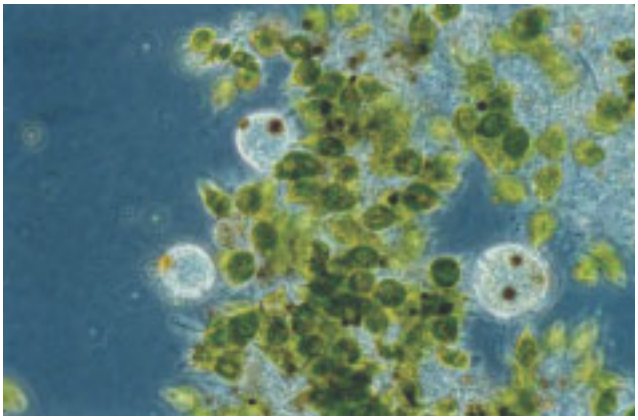
Enhance understanding of the conditions determining positive or negative feedback loops between humans and ecological systems by a) developing integrated ecological-economic models; and b) using these models to derive testable hypotheses about channels of adaptation and choice of adaptive modes. Explore to what extent human capital can be used to substitute for the deterioration of ecosystem services in the face of ongoing biodiversity loss.

### TASK 3.2 Service substitutability, local response and multiple services

Explore the conditions under which a change in biodiversity and the consequent change in service flows induce cooperation, both within a group of users and across groups, or trigger a collapse of this cooperation. Advance theoretical models and develop applied studies to probe the human experience vis-à-vis changes in services.

### TASK 3.3 Predicting changes in ecosystem services and environmental public goods

Predict ecosystem changes by using the correlative and mechanistic approaches predicting species distribution in combination with theories linking species diversity with ecosystem functioning.



## The ecoSERVICES Implementation Strategy

ecoSERVICES aims to implement this Science Plan through the following activities, all of which will contribute to establishing priorities for new experiments and research projects:

- conduct state-of-the-art assessments; review existing literature, synthesise results and perform meta-analyses
- develop new modelling theories and methods; test theory by confronting models with data
- promote experimental and theoretical research networks (e.g. networks of collaborative experimental research sites) at national/international levels; develop research infrastructure and build capacity; facilitate knowledge and technical exchange
- establish global databases
- undertake case studies
- synthesise and disseminate research; initiate dialogue with policy makers to promote application of research results in policy development; pursue outreach activities directed toward other stakeholders and end-users.

Various activities are already underway (see Table 1: Initial Timetable of Activities, page 29), some in partnership with other organisations that share a vested interest in biodiversity science. ecoSERVICES welcomes proposals for collaboration on ongoing and new initiatives from around the world.

## The end goal

DIVERSITAS is committed to building a scientific base to improve our understanding of the links amongst biodiversity change, ecosystem functioning and the provision of ecosystem goods and services. This new knowledge will be used to build environmental policy mechanisms that adequately account for the value of biodiversity.

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Introduction

# II

## The Biodiversity Challenge

The Earth is a complex and sensitive system regulated by physical, chemical and biological processes and influenced, as never before, by human factors. At present, it is a system in crisis. Scientific evidence indicates that the Planet is experiencing an unprecedented rate of species extinction, the consequences of which could be numerous and far-reaching—for ecosystems and for human societies.

Over the past decade, it has become increasingly clear that biodiversity[1] underpins the life-support system of the Earth. Both natural and managed ecosystems deliver important ecological services such as the production of food and fibre, the capacity to store carbon and recycle nitrogen, and the capacity to adapt to climate and other changes. Scientists have also come to understand that changes in the structure and function of a given ecosystem resulting from biodiversity change and loss can reduce the availability of these vital services and affect the aesthetic, ethical and cultural values of human societies.

Despite significant advances in biodiversity science, many questions remain, particularly in terms of the cycle of interactions between natural processes and human activities. To better understand and predict how biodiversity change will affect the Earth system and the organisms that depend upon it, future investigations require a more integrative approach that draws upon the strengths of both natural and social sciences. Initiatives to measure and describe biodiversity at the level of genes, species and ecosystems must continue, but they must also be coupled with efforts to determine how humans can be motivated to conserve biodiversity and use it in sustainable ways.

Without question, the most pressing challenge is the need to establish the scientific foundations for appropriate future social actions aimed at maintaining an acceptable level of biological diversity on this Planet.

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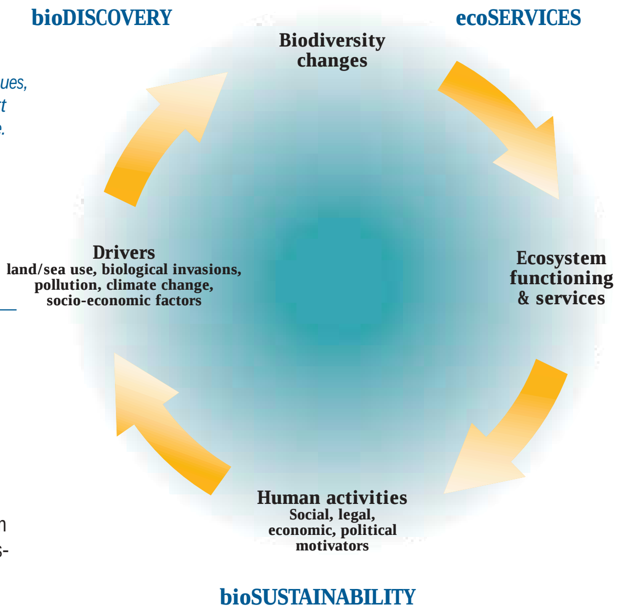
[1]The UN Convention on Biological Diversity defines biological diversity as "*the variability among living organisms from all sources including…terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part: this includes diversity within species, between species and of ecosystems*".

*Each DIVERSITAS Core Project targets specific issues, yet the new knowledge acquired in any given area will support development of the field of biodiversity science as a whole.*




## DIVERSITAS

DIVERSITAS is an international, non-governmental programme, established under the auspices of ICSU, IUBS, IUMS, SCOPE and UNESCO (see side bar), that aims to address the complex scientific questions posed by the loss of and change in global biodiversity. By networking individuals across natural and social science disciplines, it facilitates research that extends beyond national or regional boundaries to address issues of global concern, thereby adding value to research projects being undertaken around the world.

In accordance with the mandate developed by its sponsoring bodies, the mission of DIVERSITAS is two-fold:

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

**DIVERSITAS Sponsors**

- International Council for Science (ICSU)
- International Union of Biological Sciences (IUBS)
- International Union of Microbiological Societies (IUMS)
- Scientific Committee on Problems of the Environment (SCOPE)
- United Nations Educational, Scientific and Cultural Organisation (UNESCO)

## Scientific Core Projects

The primary means by which DIVERSITAS carries out its mission is through catalysing research aligned with its three Scientific Core Projects (DIVERSITAS Science Plan, 2002).

Collectively, DIVERSITAS Core Projects form an integrated programme that can be illustrated by a cycle:

- bioDISCOVERY focuses on biodiversity change, asking how much biodiversity exists on the planet, how it is changing and what are the mechanisms of actions of the drivers of these changes.
- ecoSERVICES examines the impact of these biodiversity changes on ecosystem functioning and services.
- bioSUSTAINABILITY investigates human activities and, in particular, the social, legal, economic and political motivators that could have an impact on the drivers of biodiversity change. This will be used to guide conservation and sustainable use of biodiversity.

### Core Project 1: bioDISCOVERY

Knowledge about the diversity of life and its change remains limited and fragmentary. As a foundation for other Core Projects, bioDISCOVERY initiatives centre on:

**FOCUS 1** Assessing current biodiversity
**FOCUS 2** Monitoring biodiversity change
**FOCUS 3** Understanding and predicting biodiversity change

### Core Project 2: ecoSERVICES

Ecosystem services are essential to human well-being. Yet many of the processes that underlie their delivery remain poorly understood or undervalued. Efforts in the ecoSERVICES Core Project strive to better comprehend:

**FOCUS 1** Linking biodiversity to ecosystem functioning
**FOCUS 2** Linking ecosystem functioning to the provision of services
**FOCUS 3** Human responses to changes in ecosystem services

### Core Project 3: bioSUSTAINABILITY

In order to encourage more sustainable use of biodiversity, bioSUSTAINABILITY develops new knowledge to guide policy and decision making. Its three main objectives are:

**FOCUS 1** Evaluating the effectiveness of current measures for conservation and sustainable use of biodiversity
**FOCUS 2** Social, political and economic drivers of biodiversity loss
**FOCUS 3** Social choice and decision making about conservation and sustainable use of biodiversity

## Additional initiatives and activities

### Cross-cutting Networks

DIVERSITAS also establishes Cross-cutting Networks, which embrace issues addressed in all three Core Projects in the context of specific topics or ecosystems. At present, these include:

**Global Mountain Biodiversity Assessment (GMBA)**
www.unibas.ch/gmba/

Steep terrain, extreme climates, and severe land-use pressure make mountain ecosystems among the most endangered in the world. Established in 2002, GMBA synthesises knowledge on ethical, ecological, economic and aesthetic values to tackle issues of societal relevance, including land-use management practices such as fire, grazing and erosion.

**Agro-biodiversity**

Examining both agricultural and plantation systems, this Network promotes research on how contrasting land-use patterns affect biodiversity, ecological economics, and standard economic gains.

**Freshwater biodiversity**

Despite their critical role for basic life support, freshwater ecosystems remain poorly understood. In addition to identifying and monitoring freshwater biodiversity and its role in ecosystem functioning, this Network will seek to understand how biological and social processes interact.

**Global Invasive Species Programme (GISP)** www.gisp.org

Non-native organisms that cause, or have the potential to cause, harm to the environment, economies, or human health, invasive alien species (IAS) are one of the most significant drivers of environmental change worldwide. GISP aims to conserve biodiversity and sustain human livelihoods by minimising the spread and impact of such species.

### Earth System Science Partnership (ESSP)
www.ess-p.org

Recognising the links between biodiversity and other areas of global concern, DIVERITAS is a founding member of the **Earth System Science Partnership**. This network includes other bodies that focus on global issues such as climate change and human impacts on the planet:

- International Geosphere-Biosphere Programme (IGBP) www.igbp.kva.se
- International Human Dimensions Programme on global environmental change (IHDP) www.ihdp.org
- World Climate Research Programme (WCRP) www.wmo.ch/web/wcrp

Established in 2001, ESSP supports the integrated study of the Earth system: its structure and functioning; change occurring within the System; and the implications of change for global sustainability. ESSP currently oversees four Joint Projects.

**Global Environmental Change and Food Systems (GECAFS)** www.gecafs.org

GECAFS develops strategies to address food provision concerns while also analysing the environmental and socio-economic consequences of adaptation.

**Global Carbon Project (GCP)**
www.globalcarbonproject.org

The GCP investigates carbon cycles and energy systems to develop policy-relevant knowledge that encompasses natural and human dimensions, as well as their interactions.

**Global Water System Project (GWSP)**
www.gwsp.org

GWSP examines how humans are altering the global water cycle, the associated biogeochemical cycles, and the biological components of the global water system, as well as human response to these changes.

**Global environmental change and human health**

This fourth project will study how worldwide environmental change affects human well-being, with the aim of developing policies for adaptation and mitigation.

## National Committees and Regional Networks

One of DIVERSITAS' primary objectives is to create a worldwide network in support of biodiversity science that fosters integration across disciplines and establishes links at regional and international levels. Two types of bodies play important roles in the achievement of this objective: National Committees and Regional Networks.

National Committees enlarge DIVERSITAS' scientific and policy networks, thereby helping to establish crucial links between national biodiversity programs and international framework activities. They also make it possible to implement, adapting where necessary, the DIVERSITAS Science Plan to local and regional concerns.

**The following list indicates existing National Committees, as well as those under development.**

| | |
|---|---|
| Argentina | New Zealand |
| Austria | Norway |
| Australia | Pakistan |
| Belarus | Poland |
| Belgium | Romania |
| Chile | Russia |
| China-CAST | Saudi Arabia |
| China-Taipei | Slovak Republic |
| Estonia | South Africa |
| France | Spain |
| Germany | Sweden |
| Hungary | Switzerland |
| Indonesia | United Kingdom |
| Japan | USA |
| Mexico | Venezuela |
| The Netherlands | Vietnam |

Because many issues related to biodiversity transcend national boundaries, it is often vitally important for several countries to collaborate in scientific research and in policy development. The knowledge and experience gained through such integrative approaches is invaluable across the DIVERSITAS network. Currently, DIVERSITAS in Western Pacific and Asia (DIWPA), which comprises various countries in the Asia-Pacific Region, is actively engaged in DIVERSITAS activities.

DIVERSITAS also collaborates on scientific initiatives with the following organisations:

- Asia-Pacific Network for Global Change Research (APN)
- Inter-American Institute for Global Change Research (IAI)

## Capacity building

The quest to expand knowledge about biological diversity holds inherent challenges. While most species are located in tropical areas, financial resources and technical capacity are severely lacking outside the developed world. Thus, it is critically important to pursue science while also making technological advances more widely available and building the skills necessary to carry out integrative research. As far as possible, all DIVERSITAS activities will be designed to support direct involvement of scientists from all regions of the world.

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*Involving local people into research projects is one of the ways DIVERSITAS both gains traditional knowledge and helps build scientific capacity in developing nations.*

# III

Recent biodiversity research demonstrates that loss of biodiversity can impact the functioning of both natural and managed ecosystems. This raises important questions related to the ways in which human societies benefit—both directly and indirectly—from the ecosystems within which they live. It also demands recognition of the fact that human activity influences those ecosystems, often in ways that undermine future access to the benefits that support human well-being. Over the long term, the key issue is the capacity of impoverished ecosystems to continue delivering goods and services and to maintain the aesthetic, ethical and cultural value that human societies attach to biodiversity.

At present, knowledge of the reciprocal relationship between ecosystems and human beings is woefully simplistic. Scientists agree on the urgent need to manage biodiversity more effectively. But this cannot be achieved without first developing a better understanding of four major elements: **ecosystem processes, ecosystem functioning, ecosystem services** and **sustainable use** (see side bar).

The ecoSERVICES Science Plan aims to study these elements and to investigate the interplay amongst them. The Plan recognises that:

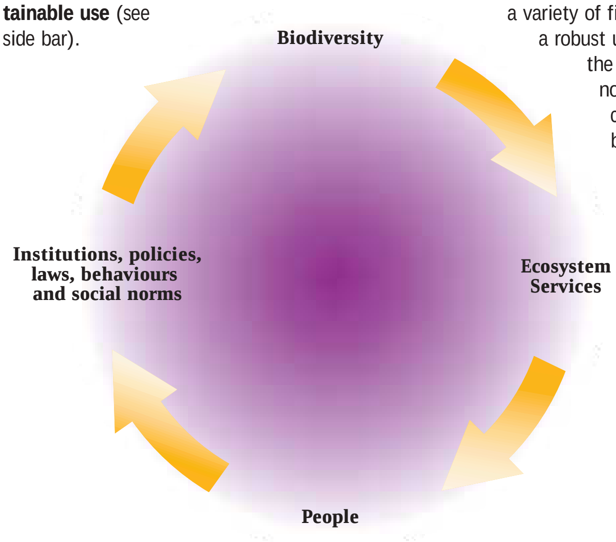
- Biodiversity is essential for the maintenance of Earth's life-support systems, for sustainable development and for human well-being
- The primary causes underlying the loss of biodiversity are of human origin and include demographic, economic and institutional factors.
- Effective solutions for the conservation and sustainable use of biodiversity lie in developing innovative social, economic, institutional and legal frameworks that take into account the multiple values of biodiversity, including the value of ecosystem services related to biodiversity

Advancing this area of biodiversity science requires a concerted effort to integrate the best basic and applied research in the social and biological sciences. This Science Plan is therefore inherently synthetic, bringing together specialists from a variety of fields to establish a robust understanding of the ecological, economic and cultural consequences of biodiversity loss.

**Definitions**

- **Ecosystem processes:** The biogeochemical processes that transfer energy and matter within and between ecosystems (e.g. primary production is the process that fixes solar energy into ecosystems via photosynthesis).
- **Ecosystem functioning:** A collective term for the biogeochemical processes operating in an ecosystem.
- **Ecosystem services:** Benefits derived by humans as a result of ecosystem processes and functioning. Ecological goods are typified by the production of food and fibre. Ecosystem services include carbon storage and the reduction of greenhouse gas emissions, the maintenance of water quality and soil fertility, resistance to climate and other environmental changes, and the maintenance of ecological conditions favourable for human health.
- **Sustainable use:** The use of components of biological diversity in ways and at rates that support their long-term availability. Emphasis is placed on maintaining biodiversity's potential to meet the needs and aspirations of present and future generations.

The Science Plan comprises three interrelated Foci and is designed to complement research being undertaken by DIVERSITAS' other two Core Projects: bioDISCOVERY and bioSUSTAINABILITY.



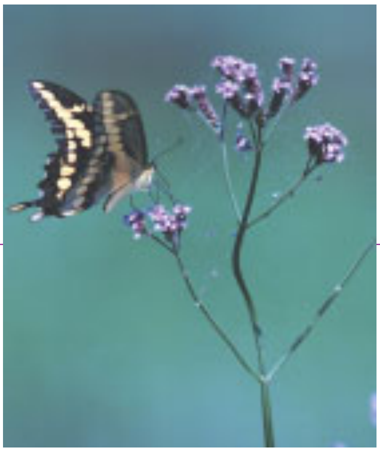

*Biodiversity sustains human populations by maintaining life-support services and goods. In turn, humans influence biodiversity through a plethora of activities and behaviours. Unravelling these relationships and feedbacks is vital if society wishes to understand how coupled human-ecological systems can be best managed.*

## FOCUS 1: Linking biodiversity to ecosystem functioning

Recent ecological research has produced a first characterisation of the form of the general relationship between biodiversity and ecosystem functioning. This work has consisted mostly of small-scale, short-term experimental studies covering only one or two trophic levels (e.g. plants and insects or plants and soil organisms). A summary of conclusions from recent experimental studies highlights three important points:

- In general, experimentally reducing biodiversity within ecosystems leads to reduced resource utilisation and productivity while increasing susceptibility to invasion (Loreau *et al.* 2001; Kinzig *et al.* 2002; Loreau *et al.* 2002; Hooper *et al.* 2005).
- Reducing levels of diversity can increase spatial and temporal variation in ecosystem processes.
- The strength of these relationships varies between studies, probably moderated by local environmental conditions.

However, changes in biodiversity and ecosystem services in which society has a particular interest often occur at much larger spatial scales and over longer time periods. They also involve many trophic levels simultaneously. Therefore, Focus 1 of ecoSERVICES will examine the effects of increasing scale and system complexity on the relationship between biodiversity and ecosystem functioning through a variety of specific Tasks.



*Pollination is one example of a vitally important ecosystem service.*

### TASK 1.1 Spatial scale and biodiversity-functioning relationships

Current knowledge of the link between biodiversity and ecosystem functioning (BEF) has been derived largely from small-scale experiments. The challenge is to find ways to apply it to real changes in biodiversity that are occurring at larger scales of landscapes and whole ecosystems.

One potential way to scale-up would be to carry out experiments with larger plots and for longer time periods (Task 1.2) and that involve a greater range of trophic levels (Task 1.3). However, such large experiments require amounts of resources than are only rarely available. A second approach is to exploit correlational data on patterns of biodiversity and ecosystem functioning in relation to gradients of physical factors at large scales.

**Research Objectives**

- Compare the BEF patterns from macroecology literature with small-scale experiments.
- Develop large-scale quantitative and conceptual models of biodiversity change and ecosystem functioning.

This Task will assemble and review biodiversity-functioning patterns from the macroecological literature and synthesise the results with those of small-scale experiments to see where the two are in agreement and where the level of resolution can change the relationships between diversity and functioning.

Another aim of this Task is to develop quantitative and conceptual models of biodiversity change based on known drivers (in collaboration with researchers of the bioDISCOVERY Core Project, who focus on causes of biodiversity loss).

© J. Baade

*The Jena Experiment, a large biodiversity project in Jena, Germany, uses experimental grassland communities of varying species richness and functional diversity to study the role of biodiversity for element cycling and trophic interactions.*

## TASK 1.2 Temporal scale and biodiversity-functioning relationships

Theory and experiments have shown that diversity can increase rates of production and other ecosystem processes when niche-differences allow resource partitioning and when communities are dominated by species with traits that lead to high levels of ecosystem processes. However, much of this work has considered the relationship in the short-term; only recently have theory and experiments begun to address the longer-term relationships.

Diversity-stability theory, in particular, has potential for exploring such longer-term relationships (McCann 2000). The first large body of work on the relationship between diversity and stability focused on how the complexity of ecological communities affected their tendency to return to their initial conditions following a small change in biodiversity (McCann 2000). The general conclusion of this work was that more diverse and complex systems tended to be less stable in these terms. However, more recent theory developed to address the longer-term relationship between diversity and the stability of ecosystem functioning has often come to different conclusions. The incorporation of new concepts—e.g. the insurance hypothesis[2], portfolio effect[3], statistical averaging, and reliability—shows that temporal niche differences between species can buffer aggregate ecosystem process variables. In other words, asynchronies in the responses of different species indicate that ecosystem functioning can be maintained by some species when others are adversely affected.

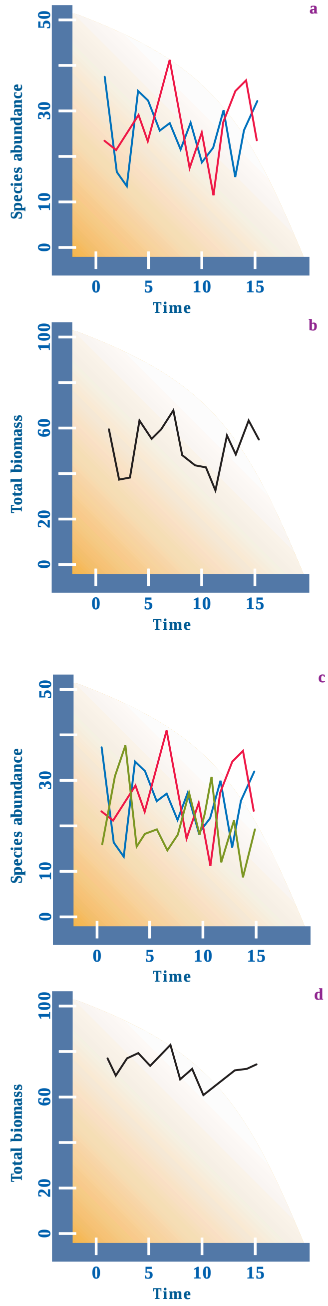
Initial tests of these ideas using analyses of long-term time series and experimental tests with organisms with short generation times have supported these ideas in some cases but not in others. There have been fewer tests for organisms with longer generation times but these also produce mixed results. On the one hand, analyses of time-series have produced some support for the portfolio hypothesis and related ideas. On the other hand, experimental perturbation of different diversity plant communities has found that more diverse communities can be less resistant in some respects. How does current knowledge of the relationship between biodiversity and the functioning and stability of ecosystems in the short term need to be modified to take account of temporal variation?

**Research Objectives**

- Bring together existing time-series and experimental datasets for standardised testing and comparison of diversity-stability relationships.
- Develop models and experiments, based on current knowledge of BEF, taking into account temporal variability.
- Make recommendations for the future development of theory given the biological patterns and mechanisms revealed by the analysis of experiment and observational data.

[2] **The insurance hypothesis** (Yachi and Loreau 1999) proposes that biodiversity buffers ecosystem processes against environmental changes because different species or phenotypes respond differently to these changes, leading to functional compensations among species or phenotypes, and hence more predictable aggregate or community ecosystem properties.

[3] Under the **Portfolio effect** asynchronous fluctuations in the populations of different species can buffer ecosystem level variation through an averaging effect, just as a diverse portfolio of investments is thought to give greater stability in the face of stock market fluctuations.




***Potential Insurance Effect of Biodiversity:*** *Asynchronous population fluctuations buffer total community biomass. In this hypothetical example the total biomass of the three-species community (**d**) is less variable than the two-species community (**b**) due to greater asynchrony of individual species biomasses (**a** versus **c**; the green species often negatively covaries with the red and blue species).*

© A. Hector; modified from Cottingham et al. 2001.

## TASK 1.3 Biodiversity change in complex systems

The majority of studies on the relationship between biodiversity and ecosystem functioning has so far focused on the experimental manipulation of species richness within a single trophic level, usually plants (see Task 1.1). However, the dynamics of a restricted set of species, and the ecosystem processes they drive, cannot be realistically understood without reference to the dynamics of other species and processes within the system at both higher and lower trophic levels. In other words, in the plant-only experiments carried out to date, the outcome of complex food web interactions between trophic levels (herbivores, predators, detritivores, etc.) has the potential to modify the relationship between plant diversity and ecosystem functioning. Where such effects have been explored, the relation between biodiversity and ecosystem functioning has often been modified.

The experimental manipulation of higher trophic levels has so far rarely been attempted outside of aquatic microcosms. However, biodiversity change affects more than a single trophic level. Furthermore, biodiversity change scenarios are expected to impact different trophic levels in different ways. This is partly because species at each trophic level vary in body size, longevity, vulnerability to stress, home or feeding range, population size, turnover rate and ability to adapt in an evolutionary sense to rapid environmental change. For example, reduction in habitat area (fragmentation) is likely to impact more heavily on species with larger body-size at the top of the food web, particularly predators. In contrast, acute toxicity from contamination or rapid climate change (temperature) is more likely to lead to loss of smaller organisms towards the base of the web. Simultaneous changes in biodiversity at different trophic levels are expected to have particularly complex outcomes for ecosystem functioning.

These early findings support the need for further investigation of how food web structures influence the relationship between biodiversity and ecosystem functioning in natural systems.

**Research Objectives**

- Develop a new, multi-trophic theory of biodiversity and ecosystem functioning.
- Make recommendations for the next generation of empirical research based on this theory.



*In the Valley of Quindio (Colombian Western Andes) farmers plant their crops wisely using rows that follow natural slopes but intercalating different species. Thus, during harvesting the soil is never totally bare and exposed to erosion.*

## TASK 1.4 Microbial diversity and ecosystem functioning

Microbes play specific and key functional roles in ecosystems including decomposition, element cycling, decontamination of man-made chemicals, and even maintenance of Earth's atmospheric gases. Microbes also have characteristics that set them apart from other organisms, particularly their fast growth rates, range of metabolic properties and ability to exchange genetic material across the usual species barriers through horizontal gene transfer. The methods needed to investigate the taxonomic and functional diversity of microbes are still at an early stage and in urgent need of further development.

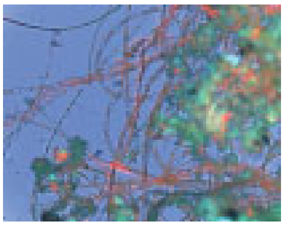
Most studies of microbial communities to date have shown that changes in the biotic or abiotic properties of the ecosystems result in changes of microbial biodiversity through turnover and replacement, as well as mutation of *in situ* organisms. These changes in community structure are presumed to correlate with changes in the functions that are performed by those microbes. There have been fewer studies that have directly manipulated the diversity of targeted components of microbial communities. Some experimental work in grassland (using different endomycorhizal strains in microcosms) has shown a positive correlation between diversity and plant growth. This type of study needs to be expanded to other ecosystems and to other microbial groups, and to test for novel microbial functions such as the suppression of infectious disease outbreaks.

This will be done both by advancing current work targeting the specific link between microbial diversity and ecosystem functioning, and by promoting study of the role of microbial communities in other targeted research projects described in this Science Plan.

This Task will be developed based on results from the activities of the bioDISCOVERY Core Project on taxonomy and monitoring of microbial diversity.

**Research Objectives**

- Provide recommendations for experiments to study the relationships between microbial biodiversity and ecosystem functioning.
- Link microbial diversity changes to global change scenarios.



*Cyanobacteria (blue algae) is one example of the micro-organisms whose role in ecosystem functioning remains poorly understood.*


## TASK 1.5 Biodiversity and biogeochemical cycles

Many of the services humans derive from ecosystems relate closely to biogeochemical cycles. Some, such as sequestration of carbon from the atmosphere, are direct components of global cycles. The sensitivity of global geochemical cycles to changes in biodiversity and the identification of key elements of biodiversity for each biogeochemical cycle therefore deserve particular attention.

How biodiversity influences carbon sequestration and trace gas emissions is of particular interest given predictions of anthropogenic climate change. Humans also now introduce more nitrogen into ecosystems than do natural processes. Current gaps in human understanding of global cycles limit the ability to develop rational policies to cope with global change and to promote sustainability.

The role of biodiversity in the magnitude of carbon sinks and trace-gas emissions is of immediate relevance to climate change policy. This part of Task 1.5 will be performed as a DIVERSITAS contribution to the Global Carbon Project, a joint project of the Earth System Science Partnership, in the context of their study of the mechanisms and feedbacks controlling carbon stocks and fluxes. Some activities will also be performed in collaboration with the IGBP-IHDP Global Land Project.

**Research Objectives**

- Study the consequences of changes in biodiversity (particularly of primary producers and micro-organisms - see links with Task 1.4) for ecosystem productivity, respiration and carbon storage.
- Study the consequences of biodiversity loss for the production of greenhouse gases (GHGs, including $N_2O$, $CH_4$) and volatile organic compounds (VOCs).
- Perform a global comparison of the impact of biodiversity change in different types of ecosystems (wetlands, forests, oceans, grasslands) for a range of key biogeochemical cycles and global regulatory functions.



*Eddy covariance instrumentation measures $CO_2$ and $H_2O$ flux at the BIOTREE (BIOdiversity and ecosystem processes in experimental TREE stands) site in Mehrstedt, Thuringia, Germany.*

## TASK 1.6 Second generation of biodiversity-functioning research

The first generation of biodiversity experiments have characterised the general form of the relationship between changes in biodiversity and the response of ecosystem functioning for several ecosystem types—a question previously unexplored by direct experimental work. However, to take this first step the research made a number of simplifying assumptions that may restrict its application to specific real-world scenarios. For example, the assembly of experimental communities by random selection equates to the assumption of random loss of species from ecosystems—something we know will usually not be the case. A second generation of experiments is now needed to extend this initial work into unstudied ecosystems and to explore the consequences of its simplifying assumptions and restrictions. This Task will bring together many of the research demands mentioned above in Tasks 1.1 to 1.3 on issues of system complexity, scale and key gaps in current understanding of the functional diversity and ecosystem processes. The goal is to ensure that these issues are more adequately addressed by a second generation of research.

**Research Objectives**

- Synthesise the limitations of the first generation of research on biodiversity and ecosystem functioning; anticipate new problems and limitations yet to be encountered.
- Devise recommendations and new approaches (e.g. type of ecosystems to be studied and some simplifying assumptions of the first generation) that will maximise the efficiency, productivity and impact of a second generation of diversity-function research.

## FOCUS 2: Linking ecosystem functioning to provision of services

The impacts of biodiversity change on ecosystem functioning are passed on to human welfare through changes in ecosystem services (e.g. regulatory services, provision of goods, etc.). The capacity of ecosystems to provide these services may be compromised by their degradation, resulting from biodiversity change. Understanding of these linkages and the value of ecosystem services needs to be much improved.

ecoSERVICES Focus 2 therefore examines the link between ecosystem functioning, ecosystem services and biodiversity loss and change through the following Tasks.

### TASK 2.1 Experimental research on the links between ecosystem functioning and ecosystems services

Considerable research effort has been directed at analysing the link between biodiversity and ecosystem functioning. The same is not true for the link between ecosystem functioning and provision of services that are relevant to human societies. Little is known about how processes map onto services (Daily 1997). Is a single ecosystem process translated into a single ecosystem service, or are the relationships more complex? How do these relationships change from one ecosystem to another? One major problem is that ecosystem processes are often measured at different spatial scales than are ecosystem services.

The main long-term research objective of this Task is to analyse the relationship and mapping between ecosystem functioning and ecosystem service provision. This implies bringing together ecology (ecosystem functioning) and socio-economic aspects (preferences for certain ecological services and commodities). Medium-term objectives should focus on two areas:
a) expanding experimental work; and
b) building integrated economic-ecological models. Experimental work should ensure that analyses of the link between diversity and functioning also extend to embrace ecosystem services. Particular emphasis should be given to those services that are critical to human societies (e.g. the provision of food and materials, carbon sequestration, etc.) and efforts should be made to incorporate existing management practices at the landscape level.

**Research Objectives**

- Develop integrated economic-ecological models to study the effects of biodiversity changes on ecosystem services.
- Assess whether early work in a limited range of experimental systems can be generalised to a broader range of ecosystems that include multiple trophic levels.
- Supplement experimental work with theoretical work on ecosystem dynamics, economic activity and service provision.

© Glen Reynolds

*The nursery at the Sabah biodiversity project (Borneo) provides seedlings for large-scale experiments on the links between biodiversity, carbon sequestration, timber production and other ecosystem functions*

In terms of developing integrated economic-ecological models, the ultimate goal is to study the effect of biodiversity change on ecosystem services. Various frameworks to support this type of work currently exist including: a) conventional bio-economic modelling (integrating ecological and economic models); and b) general equilibrium ecosystem models (in which the interaction between individuals and species within the ecosystem is represented by economic relationships). Further development in this area can be best achieved by facilitating cooperation amongst theoretical modellers from different disciplines.

## TASK 2.2 Ecosystem services and environmental public goods [4]

Biodiversity loss includes two different phenomena. The first is the irreversible loss of genetic information caused by the extinction or extirpation of species. This threatens an inter-generational global public good—the genetic information now contained in the existing set of species—as well as the information that may be provided through the genotypic evolution of those species. The second is the exclusion or removal of populations from managed ecosystems. This also threatens a variety of public services, typically at the local scale including: watershed protection and the mitigation of floods and droughts; waste assimilation, detoxification and decomposition; microclimatic stabilisation; purification of air and water; generation and renewal of soil and its fertility; pollination of crops and other vegetation; control of agricultural pests; and the dispersal of seeds and the transport of nutrients (Daily 1997).

The public good nature of all local environmental services depends largely on institutions and especially on property rights. Where property rights allow open access to ecosystem services, such services are likely to be overexploited. Lack of property rights also inhibits the development of markets for scarce ecosystem services—when potential users can gain free access, such services will not be supplied via competitive markets.

Markets have certainly developed for aspects of biodiversity. Bio-prospecting contracts between individual pharmaceutical companies and developing countries, such as that between MERCK and the National Biodiversity Institute (INBIO) in Costa Rica, have received a great deal of publicity. Such contracts seek to mobilise investment in biodiversity conservation by offering access to genetic resources, protected by the assignment of intellectual property in genetic "discoveries". Although they are very well known, such contracts are not at all widespread, and have not generally yielded competitive rates of return. In other instances, market development has negatively affected local institutions and the "social fabric" of rural local communities that promoted sustainable use of resources.

There are also markets that offer biodiversity conservation benefits as a side-effect (an externality[5]). Joint implementation and carbon offset schemes are one example. Other markets, such as those for the external benefits of protected areas, offer different prospects for biodiversity conservation. The location and structure of many protected areas is driven by the potential for ecotourism and the recreational or commercial harvest of wild living resources. The co-location of many wildlife reserves, wildlife management areas and hunting concessions in terrestrial systems reflects the dual role of the protected area (this is also true of marine protected areas and fisheries in aquatic systems). Co-location is both a conservation mechanism and a reservoir for the harvested species.

Protected areas are also widely used to assure water supplies; the relative location of protected areas and reservoirs is determined hydrologically rather than ecologically, but the principle is the same. Revenues from water sales typically finance the costs of protection. Nonetheless, most local environmental public goods that depend on biodiversity-supported ecosystem services are not priced in the marketplace. They are subject to open access common property and are therefore overexploited.

**Research Objectives**

- Consider how the services derived from particular ecosystems are institutionally defined in different societies, and how this affects their use.
- Seek to identify ecosystem services threatened by the simplification of managed systems, and the services they provide.
- Develop a classification of public goods based on their physical and social properties.

[4] **Public goods (PGs)** can be defined as 'non-exclusive, non-rival goods'. A PG can be made available cheaply to many users; however, once provided to some users, it is very difficult to prevent others from consuming it as well (non-exclusive). PGs are non-rival in the sense that having some people consume a particular PG does not impact on the benefits others can derive from it. In this context, public goods refer to products or services provided by ecosystems.

[5] **Externality** - an externality exists when an activity by one person/party causes a gain (positive) or loss (negative) of welfare to another person/party.

## TASK 2.3 Biodiversity, resilience and the value of ecosystem services

This Task seeks to examine the economic implications related to the complex nature of ecological systems. Complex systems theories are emerging in parallel in several disciplines, including biology and economics. These theories portray both ecological and economic systems not as deterministic, predictable and mechanistic, but as process dependent, organic and evolving. This approach is being used to bridge social and biophysical sciences, and underpins many new integrative approaches, such as ecological economics and sustainability science. In many cases the effect of biodiversity loss is to reduce the capacity of ecosystems to cope with disturbance and change. Biodiversity loss threatens the resilience of coupled ecological and social systems.

Biological communities have been observed to go through sudden shifts that punctuate periods of relative stability. Disrupting disturbances seem the most obvious explanation for such shifts but the cause is not always clear. Recent analyses suggest that some ecosystems have multiple attractors and therefore jump suddenly to contrasting states when certain threshold conditions are met.

Our ability to predict and prevent such shifts is poor, and although the phenomenon is now well understood in some systems, an overview across different ecosystems is lacking. It is important to identify the types of ecosystems in which catastrophic shifts to alternative attractors are more likely to occur. It is necessary to develop a unifying framework for understanding and predicting this highly important, but poorly understood, phenomenon in complex natural systems. The implications for the value of biodiversity in supporting ecosystem resilience needs to be explored and methods developed for incorporating the insights gained into biodiversity and ecosystem service conservation measures in different ecosystem types.

One of the partners in developing this Task will be the Resilience Alliance (RA), a research organization of scientists and practitioners from many disciplines who collaborate to explore the dynamics of social-ecological systems. The RA's aim—to improve understanding of the dynamics of social-ecological systems with a view to learning how to effectively influence their resilience, adaptability and transformability—is an excellent complement to the goals of ecoSERVICES and of DIVERSITAS.

One of the issues that will be explored within this Task concerns the economic impacts of invasive or exotic species. How do such species affect the composition and functioning of the native ecosystem? What are the implied costs and benefits of the successful establishment of exotics, considering that some of them may be profitably harvested?

**Research Objectives**

- Identify ecosystems in which catastrophic shifts to alternative attractors may occur.
- Evaluate the economic consequences of biodiversity change that affect ecosystem resilience and ecosystem services.

## TASK 2.4 Develop models to predict the impacts of biodiversity change on ecosystem services

This Task will evaluate the possibility to predict changes in the flow of the ecosystem services induced by biodiversity change.

There are two main sources of uncertainty about system dynamics: a) uncertainty about the dynamic effects of biodiversity change on ecosystem functioning and services; and b) uncertainty about the impact of changes in ecosystem services on the production of economic services. Although uncertainty compromises standard risk assessment to some degree, it does not preclude rational management or policy. This Task will develop models to aid the prediction and management of risks and uncertainties in the provision of key ecosystem services.

One innovative approach combines economic general equilibrium modelling with interactions (energy exchange) between species within an ecosystem. This model relies on three components: a) constructing a computable general equilibrium ecosystem model (GEEM) using individual plant and animal optimizing behaviour to predict population dynamics of many interacting species; b) combining GEEM with an economic module to obtain one integrated ecological-economic model; and c) gathering ecological and economic data for application to real ecosystems and economies.

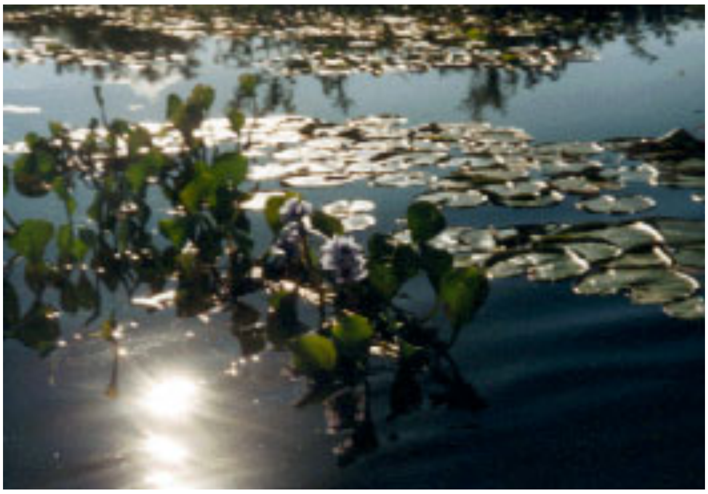
This model predicts economic variables including prices, quantities, investment, and incomes and profits for consumers and firms, and ecological variables including species populations and biomass transfers between predators and prey. Therefore the model is capable of linking changes in the abundance of certain species to changes in services provided to society. It can also rigorously study the entire chain from diversity to functioning and from functioning to services. Pilot versions of the model are ready but must be extended through interaction with ecologists and calibrated to fit specific cases and systems. Theoretical and experimental work will be combined to further guide specification of models, involving frequent interaction between ecologists and economists.

Additional modelling approaches will be developed in later phases of the Project. In particular, ecoSERVICES hopes to exploit recent developments in climate modelling, which are moving towards risk-based assessment of the impacts of climate change that require climate predictions (rather than scenarios). These models represent the likelihood of climate change in terms of probability density functions (PDFs) or confidence intervals. Such probabilistic climate information can then be used to drive impact models, including models of changes in the geographical distribution of species and the functions they support.

The contributing projects to this Task will include, among others, the Resilience Alliance (RA; see Task 2.3) and BIOdiversity and Economics for CONservation (BIOECON). An interdisciplinary network working to advance economic theory and policy for biodiversity conservation, BIOECON assembles economists, lawyers and scientists from leading European academic and research institutions as well as members of prominent policy organisations to design and implement cutting-edge economic incentives for biodiversity conservation.

**Research Objectives**

- Develop ecosystem models that will account for the effects of biodiversity, food-web structure, community assembly history and the history of evolution on ecosystem vulnerability to biodiversity change. These will be connected to the functional properties of ecosystems.
- Model the effect of human decisions on the provision of ecosystem services. Contrast various approaches to model human-ecosystem interaction, search for common ground and derive conditions under which the various approaches are valid.



© Graciela Canziani

*An important wetland conservation strategy is the prevention of stress that reduces the ecosystem's adaptive capacity. Reducing chemical pollution, avoiding vegetation removal, and protecting wetland biodiversity and integrity are viable activities to maintain and improve the ecosystem's resilience—and its ability to continue providing important services even under altered climatic conditions (Esteros de Ibera, Argentina).*

## FOCUS 3: Human responses to changes in ecosystem services

As an integral part of the biosphere, humans trigger biodiversity losses and affect the quantity and quality of services provided by the environment. In the face of such changes, humans adapt to their new conditions by modifying their behaviour (Freeman 1993; van Kooten and Bulte 2000). For example, the loss of a local source of potable water may be replaced by importing bottled water from another location. A reduction in a fish stock might cause the fishing sector to adopt more advanced fishing technologies, to start fishing another more abundant or less valued species, or to develop harvest-sharing rules that promote conservation of the stock. After the local loss of indigenous bee species, fruit growers may choose to leave the industry, purchase bees or pollinate flowers by hand.

Changes in environmental services trigger human responses—a phenomenon that is currently poorly understood. The primary objectives of the proposed research is to describe the process of human adaptation to changes in environmental services, assess its costs (and sometimes benefits), and analyse the efficiency and equity losses that result. In Focus 3, ecoSERVICES aims to address the following overarching question: What is the initial response of humans to changes in ecosystem services, and how does that feed back onto the ecological system?

The emphasis in this set of Tasks is on the initial response of directly affected or 'local' individuals (e.g. resource users) and not on valuation issues or the management or policy response (which is considered by the bioSUSTAINABILITY Core Project). Since policies and conservation will impact on human behaviour, and human behaviour often triggers policy responses, ecoSERVICES and bioSUSTAINABILITY are seamlessly connected through Focus 3. This Focus should therefore initially be developed jointly by researchers from both Core Projects.

### TASK 3.1 Service substitutability, local response and the single service case

Changes in the provision of ecosystem services often trigger a direct human response aimed at mitigating any negative consequences. Consider the simplest case where species are only harvested for food, one particular type of ecosystem service. Fishers harvest a subset of species from the system for consumption. Depending on characteristics of the harvesting process, individual resource users might specialise in taking one or a few species, or target a broader set of species instead. Assume that overharvesting of some highly valued species (or some other exogenous shock) leads to a change in the fishery's species composition. What will be the response of resource users, and how will this response feed back into the ecological system?

To address such issues, using the fishing industry as an example, ecoSERVICES must take the following factors into account:

1) Demand for fish: To what extent will changes in local supply of certain species affect prices of these species and other species? Is locally harvested fish traded on world markets at given prices or is there a local market with endogenous prices? Similarly, are there close substitutes for fish available (e.g. meat)?

2) Supply of labour to fishery: When profits in harvesting adjust in response to a change in the species composition of the local ecosystem, will users be able to re-allocate their labour to activities other than fishing?

3) Technical substitution: To what extent are specialised fishers able to switch from their preferred target species to more abundant species?

4) Ecological resilience: How will ecosystem functioning change when certain species disappear from the ecosystem and how will the system respond to changes in harvest pressure exerted towards remaining species? Depending on the specific context, a decline in abundance of one species might trigger a variety of outcomes. It may set the stage for a process in which the entire system unravels. Alternatively, there might be cases in which fishers change their focus and gear towards a new subset of species ('fishing-down-the-food-chain') or fishing area, or cases in which fishers exit the industry (reducing harvest pressure).

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The ongoing interaction between humans and ecosystems, as in the example above, might trigger positive or negative feedback loops, with adverse or beneficial outcomes in terms of welfare and ecosystem integrity. Identifying the circumstances under which the various possible cases materialise is clearly very important for successful policy making. The main objective of Task 3.1 is to enhance understanding of the interaction between humans and ecological systems, and the nature of the conditions that determine whether positive or negative feedback loops materialise. Further, ecoSERVICES aims to empirically assess the validity of theoretical results by analysing the direct human response to a change in species composition in a number of studies.

While many changes in ecological services are easily accommodated by tailored human responses, the cost associated with the loss of other services is unknown. Indeed, it is an open question whether it is technically, socially and economically feasible to accommodate all changes in ecological services. This begs the question: For what critical ecological services are no managed substitutes available, and how should that affect conservation efforts in light of limited budgets? Key issues are the availability of substitution possibilities for ecological services and the spatial scale at which alternatives are viable.

Improved knowledge about critical ecosystem services might help to prioritise conservation efforts and enable society to target those species and habitat types that are essential to humankind.

**Research Objectives**

- Develop a series of integrated ecological-economic models that simulate ecosystem-user interactions under a variety of conditions (including various property rights regimes) and formalise positive and negative feedback loops.
- Derive testable hypotheses regarding channels of adaptation and choice of adaptive mode. Combine a series of case studies to construct a global unified database. Perform a detailed statistical analysis of choice of the adaptive mode in a single service case.
- Develop spatially explicit methodologies to assess the degree of substitutability of ecological services by managed systems or man-made capital.
- Apply these methodologies to a series of case studies to help identify the ecological services most critical to human welfare.

## TASK 3.2 Service substitutability, local response and multiple services

In many instances, environmental change affects a number of individuals or groups who make use of diverse services provided by the environment. It is also typical that these systems exhibit common pool (open access) resource characteristics, one of which being that individuals and groups compete to capture ecosystem services for their own use. In such cases, it is costly to exclude individuals from benefiting from the flows of services associated with the ecosystem. Furthermore, once a resource unit from the resource base comprising the ecosystem is appropriated (e.g. fish harvesting or water use), this unit is no longer available to other individuals. In systems with multiple services and users, resource users are expected to respond to changes in environmental services by adjusting their behaviour. These modifications may trigger fierce competitive pressure and conflict over the remaining resources or for the substitutes of these resources. Such conflicts lead to non-cooperative outcomes that have been associated with resource over-exploitation and stock collapse.

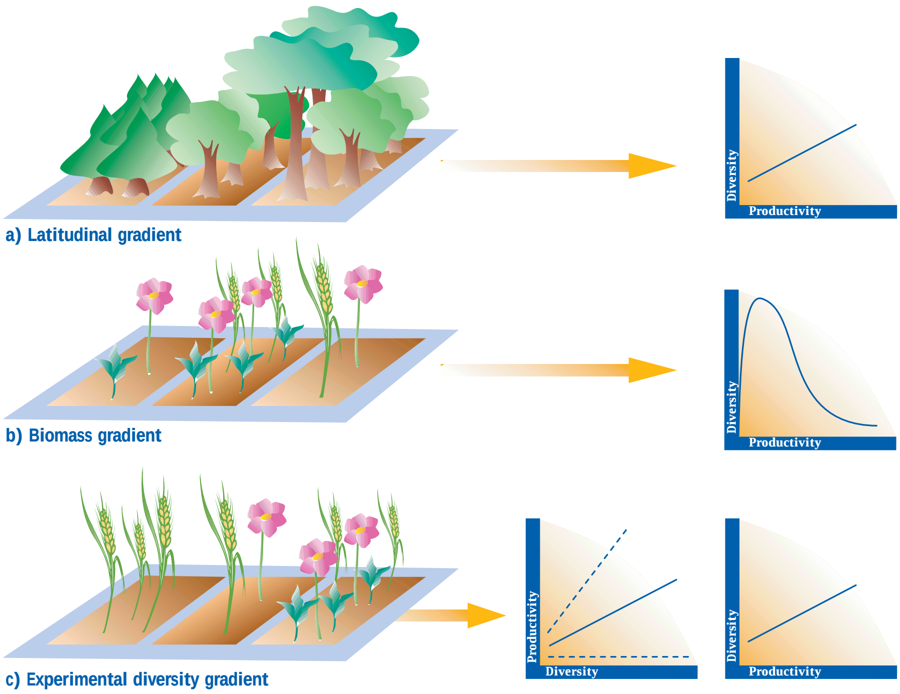
To analyse these issues in detail requires both new theoretical advances and empirical studies. On the theoretical front, much remains to be understood about the determinants of cooperation and conflict in systems with many groups of users of ecosystem services. Consider the example of water quality as it relates to the agriculture, aquaculture and tourism sectors. The agriculture sector views bodies of water primarily as sinks that have the capacity to absorb nitrates emitted through farming practices. For the aquaculture and tourism sectors, high nitrate concentrations essentially pollute the water and have a negative effect on business. What factors may lead these groups to cooperate? How does the level of dependence of any one of these groups affect the mode of adaptation? Does the presence of substitutes help or hinder cooperation? What is the role of technological innovation? Are defined property rights always beneficial in the presence of multiple services and multiple groups?

The main objective of this activity is to explore the conditions under which a change in biodiversity and the consequent change in service flows induce cooperation both within a group of users but also across groups. In addition, this Task will seek to identify when a change in biodiversity that also affects ecosystem functioning and services is likely to trigger a collapse of cooperation.

**Research Objectives**

- Advance theoretical models of multiple users and ecosystem services.
- Develop applied studies to provide opportunities for an in-depth look at the human experience with environmental service changes. The objective of these studies is to accumulate a body of knowledge from individual studies (e.g. nitrogen fixation, pollination, green farming, and game ranching) and examine patterns of response and adaptation to changes in the flow of environmental services.

## Plant diversity and productivity legend




*For plants, the relationship between diversity and productivity changes with scale. At global scales (panel* **a** *in the figure above), from high latitudes to the tropics, plant diversity in large areas may be positively related to increasing productivity. At regional scales (***b***), plant diversity in small plots is frequently negatively related to increasing productivity, often as part of a larger unimodal 'hump-shaped' distribution of diversities. Numbers of species correlate with several factors including the size and hence the number of individual plants sampled, spatial heterogeneity and competitive exclusion as productivity increases. Experimental manipulations of plant diversity within habitats (***c***) reveal that, although relationships vary, productivity tends to increase with diversity owing to increasing complementary or positive interactions between species and the greater likelihood of diverse communities containing a highly productive species. In manipulation experiments, biodiversity is the explanatory variable and productivity the response, whereas in observational studies the relationship is usually viewed the other way around as illustrated here for all three cases.*

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## TASK 3.3 Predicting changes in ecosystem services and environmental public goods

This Task will seek to assess what predictions can be made about trends in ecosystem services and environmental public goods. Addressing this issue involves combining knowledge about expected rates of extinction with measures of the impact of biodiversity loss on the provision of services (Focus 2). It also involves searching for appropriate frameworks to deal with uncertainty. Species extinctions and extirpations are rare and usually irreversible events. Because these extinctions and extirpations have either no or few historical precedents, it may not be possible to predict a probability distribution of outcomes with confidence.

Nevertheless, decision makers need to be able to act on the basis of non-probabilistic information on the outcomes of their actions. Historically, decision makers have applied tests such as "scientifically based suspicion", "reasonable grounds for concern" or the "balance of evidence" (Harremoës et al. 2001). These approaches fail standard tests of scientific proof—they offer "early warning systems" rather than conclusive proof. Nevertheless, they do provide a basis for decision making. In cases where insufficient data exist to make probabilistic predictions, models can provide important early warnings. If preliminary theoretical research indicates the possibility of outcomes that involve significant irreversible cost, then the precautionary response involves actions that avoid those costs while yielding the data to test the model predictions.

Two main types of approaches have been developed to predict species distribution: the correlative approach (climatic envelopes) and the mechanistic approach. This Task will apply both approaches to assess the impact of change on ecosystems services. Correlative approaches can be widely and rapidly applied to any organism because they assume that species populations inhabiting homoclimes (areas with similar biotic and abiotic factors) should exhibit similar behaviour. Inductive correlative techniques for predicting species distribution have already been used to identify potentially invasive species. These techniques are the basis for bioclimatic predictive models.

Mechanistic approaches provide more robust predictions and better insights into understanding species niches and identifying key traits involved in species distribution boundaries. However, these approaches require greater depth of information on the biology of species. This Task will implement both approaches and will combine them with theories that link species diversity and ecosystem functioning in order to predict changes in ecosystem services.

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*Apple farmers in Maoxian Country (China) hired local people to hand pollinate blossoms after bee populations dwindled.*

**Research Objectives**

- Develop a genetic algorithm approach to locate the bioclimatic envelopes (niches) of particular functional groups. Use high-resolution general circulation models to predict changes in the spatial distribution of functional groups. Relate resulting biodiversity patterns, through ecosystem services, to environmental public goods.
- Compare models by applying the different methods to identical datasets and compare results using statistics that measure the predictive accuracy of each model.
- Identify the range of possible outcomes, given predictions of changes in ecosystem services and given the alternative outcomes possible under different strategic behaviours and institutional conditions.

# IV

## Activities

ecoSERVICES will implement its Science Plan through interdisciplinary and international activities coordinated by an International Project Office (IPO).

The key deliverables will include scientific syntheses, experimental and theoretical networks, case studies, and new modelling theories and methods.

It is anticipated that more activities will emerge as the Project sets up specific agenda-setting workshops, assembles networks of scientists, and undertakes submitted proposals.

**Table 1 Initial Timetable of Activities for ecoSERVICES**

| FOCUS 1. Linking biodiversity to ecosystem functioning (BEF) | Phase 1 Years 0 to 2 (2004-2005) | Phase 2 Years 3 to 5 (2006-2008) | Phase 3 Years 6 to 10 (2009-2014) |
|---|---|---|---|
| **TASK 1.1 Spatial scale and BEF relationships** | | | |
| • Compare the BEF patterns from macro-ecology literature with small scale experiments | X | | |
| • Develop large-scale quantitative and conceptual models of biodiversity change and ecosystem functioning | | X | |
| **TASK 1.2 Temporal scale and BEF relationships** | | | |
| • Compare existing time-series and experimental datasets of diversity-stability relationships | X | | |
| • Develop models and experiments, based on current knowledge of BEF, taking into account temporal variability | | X | |
| • Provide recommendations for future development of theory on BEF | | X | X |
| **TASK 1.3 Biodiversity change in complex ecosystems** | | | |
| • Develop multi-trophic theory of BEF | X | X | |
| • Provide recommendations for the next generation of empirical research | | X | X |
| **TASK 1.4 Microbial diversity and ecosystem functioning** | | | |
| • Provide recommendations for experiments to study the relationships between microbial biodiversity and ecosystem functioning | | X | X |
| • Link microbial diversity changes to global change scenarios | | | X |
| **TASK 1.5 Biodiversity and biogeochemical cycles** | | | |
| • Study consequences of biodiversity change for ecosystem productivity, respiration and carbon sequestration | X | X | |
| • Study consequences of biodiversity changes for the production of greenhouse gases | | X | X |
| • Compare impacts of biodiversity changes on biogeochemical cycles and regulatory functions in different ecosystems | | X | X |
| **TASK 1.6 Second generation of BEF research** | | | |
| • Synthesise limitations of the first generation of BEF research | X | X | |
| • Provide recommendations and new approaches for the next generation of BEF research | X | X | |

**Table 1** Initial Timetable of Activities for ecoSERVICES *(continued)*

| | Phase 1<br>Years 0 to 2<br>(2004-2005) | Phase 2<br>Years 3 to 5<br>(2006-2008) | Phase 3<br>Years 6 to 10<br>(2009-2014) |
|---|---|---|---|
| **Focus 2. Linking ecosystem functioning to provision of services** | | | |
| **TASK 2.1 Experimental research on links between ecosystem functioning and services** | | | |
| • Develop integrated economic-ecological models to study the effects of biodiversity changes on ecosystem services | ■ | ■ | |
| • Assess if early experimental work can be generalised to broader ecosystems and multiple trophic levels. | ■ | ■ | ■ |
| • Supplement experimental work with theoretical work on ecosystem dynamics, economic activity and service provision. | ■ | ■ | ■ |
| **TASK 2.2 Ecosystem services and environmental public goods** | | | |
| • Synthesise definitions of ecosystem goods and of their uses in different societies | ■ | | |
| • Identify ecosystem goods and services endangered by 'simplification' of managed systems | | ■ | |
| • Develop a classification of public goods based on their physical and social properties | | ■ | ■ |
| **TASK 2.3 Biodiversity, resilience and the value of ecosystem services** | | | |
| • Identify ecosystems in which catastrophic shifts to alternative attractors may occur | | ■ | |
| • Evaluate economic consequences of biodiversity regime shifts | | ■ | ■ |
| **TASK 2.4 Develop models to predict impacts of biodiversity change on ecosystem services** | | | |
| • Develop models to account for effects of biodiversity, food-web structure, community assembly and evolutionary history on ecosystem vulnerability to biodiversity change | | | ■ |
| • Model effects of human decisions on the provision of ecosystem services | | | ■ |
| **Focus 3. Human responses to changes in ecosystem services** | | | |
| **TASK 3.1 Service substitutability, local response and the single service case** | | | |
| • Formalise positive and negative feedback loops in ecological-economic models | | ■ | |
| • Identify hypotheses about channels of adaptation and choice of adaptive mode | | ■ | ■ |
| • Develop methodologies to assess the degree of substitutability of ecological services | | ■ | ■ |
| • Apply these methodologies to case studies | | ■ | ■ |
| **TASK 3.2 Service substitutability, local response and multiple services** | | | |
| • Develop theoretical models to understand the determinants of cooperation and conflict in systems with multiple users of ecosystem services | ■ | ■ | ■ |
| • Develop experimental studies to understand the determinants of cooperation and conflict in systems with multiple users of ecosystem services | | ■ | ■ |
| **TASK 3.3 Predicting changes in ecosystem services and environmental public goods** | | | |
| • Relate, through ecosystem services, biodiversity patterns to environmental public goods | | | ■ |
| • Compare the different types of models | | | ■ |
| • Compare consequences of different strategic behaviours and institutional conditions | | | ■ |
| **Project Wide** | | | |
| • Establish International Project Office (IPO) | ■ | | |
| • Provide syntheses and recommendations for the UN Convention on Biological Diversity | ■ | ■ | ■ |
| • Capacity building | ■ | ■ | ■ |

## Getting started

A limited number of short-, medium- and long-term goals have been identified and are proposed in the Initial Timetable (Table 1).

During **Phase I** of the project (Table 1; Year 0 to 2), energies will be directed toward establishing an IPO and launching a range of short-, medium- and long-term initiatives. Recognising the need for new empirical and experimental studies on biodiversity and ecosystem functioning, the Scientific Committee has identified **Task 1.6 Second generation of biodiversity-functioning research** as a top research priority. **Phase II** (Years 3 to 5) will see the delivery of the first short- and medium-term results and **Phase III** (Years 6 to 10) will focus on synthesis and data publication.

**Table 2 Immediate Activities for ecoSERVICES**

| TASK | Activity | Dates/Locations |
|---|---|---|
| TASK 1.5 | Workshop: Biodiversity and carbon sequestration | September 2005, Borneo |
| TASK 1.6 | Workshop: Second generation of experiments on the relationships between biodiversity and ecosystem functioning | September 2005, Borneo |
| TASK 2.1 | 7th Annual BIOECON Conference: Economics and the analysis of biology and biodiversity | 20-21 September 2005 Cambridge, UK |
| TASK 2.1 | Workshop: Integrated modelling of economies and ecosystems | 3-5 November 2004 Paris, France |
| Other | Establish International Project Office (IPO) | |

## Management structure and execution

The work of ecoSERVICES is guided by a Scientific Committee[4] (SC) comprising scientists who demonstrate expertise in the main research areas of the various Foci. This Committee is appointed by the DIVERSITAS Scientific Committee. Duties of the SC-ecoSERVICES include:

- Provide scientific guidance and oversee the development, planning and implementation of ecoSERVICES.
- Encourage national governments and funding agencies to support research at the national, regional and international level, relevant to the overall goals of ecoSERVICES.
- Seek collaboration between ecoSERVICES activities and other international programmes.
- Take on responsibilities within the work programme of ecoSERVICES.

## International Project Office

ecoSERVICES will be supported by an International Project Office (IPO) which will be responsible for raising funds for proposed activities, organising these activities and seeking involvement from the wider community. The IPO will also work to establish links with relevant national and international programmes. In addition, it will communicate results of activities through various media including its website.

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[4] Scientific Committee (see list, page 4)

## Partnerships

As described in the Introduction, the activities carried out by ecoSERVICES will both enhance and advance the work being carried out by the sister Core Projects of DIVERSITAS: bioDISCOVERY and bioSUSTAINABILITY. They will also contribute to the Cross-cutting Networks on mountain biodiversity, agro-biodiversity, freshwater biodiversity and global invasive species. In addition, ecoSERVICES will interact with various programmes with which DIVERSITAS already has strong links.

For instance, ecoSERVICES will build on the legacy of its partnership with the former Global Change and Terrestrial Ecosystems (GCTE) Project of IGBP, particularly under the focus of "biodiversity and ecosystem functioning". ecoSERVICES will now engage in the Global Land Project, which is being jointly established by IGBP and IHDP as a successor of GCTE and Land-Use and Land-Cover Change (LUCC).

ecoSERVICES also anticipates opportunities for collaboration with the new Integrated Marine Biogeochemistry and Ecosystem Research (IMBER), a joint project of IGBP and the Scientific Committee on Oceanic Research (SCOR). In addition, ecoSERVICES will actively pursue partnerships with the Global Carbon Project and, potentially, with other initiatives of the Earth System Science Partnership (ESSP) as well as with other organisations and committees such as the Scientific Committee on Problems of the Environment (SCOPE) and the Resilience Alliance.

ecoSERVICES also aims to collaborate with relevant conventions and assessments, such as the UN Convention on Biological Diversity (CBD), with which DIVERSITAS has a Memorandum of Understanding, and address the priorities of the Millennium Ecosystem Assessment (MA).

### Getting involved

As outlined in the inside back cover of this publication, there are many ways to participate in DIVERSITAS—as an individual scientist, by establishing a National Committee, or as a funder.

The ecoSERVICES International Project Office (IPO) encourages scientists to propose additional activities that support the goals of this Science Plan including:

- proposals for collaborative research
- workshops
- syntheses.

ecoSERVICES also welcomes requests for endorsement of activities that embrace its goals. Such proposals should be submitted to the IPO in the early planning stages of the event or initiative.

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# Concluding Remarks

# V


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*DIVERSITAS SC Chair Michel Loreau delivers a declaration on behalf of the science community at the International Conference on Biodiversity: Science and Governance (Paris, January 2005).*

As this ecoSERVICES Science Plan was going to press, more than 2000 scientists and policy makers from 100 countries assembled for the *International Conference on Biodiversity: Science and Governance* (24-28 January 2005, Paris). In the Closing Session, DIVERSITAS SC Chair Michel Loreau delivered a Declaration on behalf of the international science community emphasising that unless humankind takes strong action to sustain existing biodiversity, we risk losing forever the ecosystem services on which human societies depend.

The Declaration underlined the need for a major co-ordinated international effort that would mobilise scientists from all necessary disciplines to extend scientific knowledge, particularly on ecosystem services. The Declaration urgently called for an ambitious research programme in order, *inter alia*, to integrate biodiversity into the criteria considered in economic and policy decisions, as well as environmental management (see page 36 for full text of Declaration).

The ecoSERVICES Science Plan, and the community which contributed to its development, stand ready to address the above challenge.

The interdisciplinary approach presented in the ecoSERVICES Science Plan is vital precisely because of the need to consider the interplay of two complex and changing systems—ecological and economic—on local, regional and global scales. Predicting ecosystem resource limits and societal impacts requires a better understanding of the numerous variables in both systems: policies directed toward economic activity impact ecosystems and policies directed toward ecosystems impact economic activity. At present, economists, ecologists and decision makers have very incomplete knowledge about this reciprocity; therefore, they cannot reasonably determine how ecosystem impacts will affect economic welfare.

The Research Objectives and Tasks outlined in this Science Plan will help to improve understanding of the biological processes that support human well-being while also revealing important information about the economic, social and cultural value various stakeholders accord to ecosystem goods and services. Gathering this knowledge will constitute an important step in developing effective and efficient methods to promote conservation and sustainable use of biodiversity and in formulating key principles to guide policy makers on appropriate approaches under various circumstances.

As stated in the Preface, this research agenda is not exhaustive. It will evolve in the light of future research findings and as environmental circumstances change. Enacting this research agenda will require funding at national, regional and international levels. Several initiatives to secure such funding are already underway.

This Science Plan is founded on two distinct characteristics that underpin all of the work DIVERSITAS pursues. First, its overriding enthusiasm for, and insistence upon, bridging the traditional disciplines of biology, ecology and social science. Second, its intense efforts to ensure truly international participation in all aspects of the science programme. In achieving both these goals, ecoSERVICES aspires to make a major contribution to the future of the Earth's biodiversity and the people who use it.

# Paris Declaration on Biodiversity

# VI

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The scientists assembled in the International Conference Biodiversity Science and Governance (Paris, 24-28 January 2005) agreed on the following Declaration:

### 1. Biodiversity is a natural heritage and a vital resource for all humankind

The Earth is home to tremendous biological diversity, which not only includes the millions of different species that inhabit our planet, but also the diversity of their genes, physiologies, and behaviours, the multitude of their ecological interactions with each other and with their physical environment, and the variety of the complex ecosystems they constitute. This biodiversity, which is the product of more than 3 billion years of evolution, is an irreplaceable natural heritage and a vital resource upon which humankind depends in many ways.

- It is a source of aesthetic, spiritual, cultural, and recreational values.
- It provides goods that have direct use values, such as food, wood, textiles and pharmaceuticals.
- It supports and enhances ecosystem services on which human societies depend often indirectly, such as plant and animal production, crop pollination, maintenance of water quality and soil fertility, carbon sequestration, nutrient cycling, protection against pathogens and diseases, and resistance of ecosystems to disturbances and environmental changes.
- It provides opportunities for human societies to adapt to changing needs and circumstances, and to discover new products and technologies.

### 2. Biodiversity is being destroyed irreversibly by human activities

Human alteration of their environment is having unprecedented effects on distribution and abundance of species, ecosystems, and the genetic variability of organisms.

Species are currently being lost globally at a rate that is about 100 times faster than the average natural rate, and tens of thousands of other species are already committed to future extinction because of the recent worldwide loss of their habitats.

The primary causes underlying the loss of biodiversity are demographic, economic, and institutional factors, including increasing demands for land and biological resources due to the growth in the human population, world production, consumption and trade, associated with a failure of people and markets to take into account the long-term consequences of environmental changes and the full array of biodiversity values.

These causes manifest themselves in the loss, fragmentation, and degradation of habitats; the overexploitation of biological resources; the introduction of non-native species; the pollution of soil, water, and atmosphere; and more recently, signs of long-term climate change.

The loss of species and genetic biodiversity is essentially irreversible, and therefore poses serious threats to sustainable development and the quality of life of future generations.

### 3. A major effort is needed to discover, understand, conserve and sustainably use biodiversity

Strong actions must be taken now to inventory, understand and project biodiversity in order to meet the Millennium Development goals, and ensure food security, human health and the quality of life. If humankind fails to do this, we risk losing forever the ecosystems services supported by existing biodiversity as well as the opportunity of reaping its full potential benefits to humankind in the future.

Most of the biodiversity that surrounds us on our Planet, its current changes, many of its impacts on ecological processes and services on which we depend, and many of its potential uses, are still unknown to science. The ecosystems in which most of the Earth's biodiversity is concentrated are still poorly understood because they constitute very complex assemblages of species and interactions with the physical environment. Extending the scientific knowledge of biodiversity requires a major co-ordinated effort internationally that mobilises scientists from all disciplines and geographical regions. The vision and effort that have been put into space exploration are now needed for exploring and understanding life on Earth. This objective can rely, among others, on technological advances that offer novel opportunities to discover and identify living organisms.

The conservation and sustainable use of biodiversity need to become an integral component of social and economic development by correcting past policy market failures. Innovative social, economic, institutional and legal frameworks are needed to develop more ecologically based management systems that take into account the multiple values of biodiversity and to ensure that conservation and sustainable use of natural resources are integrated successfully into public and private decision making. New production and consumption technologies are essential so that economic development and poverty alleviation favour a long-term preservation of living resources and ecosystems.

The broad lines of the statements presented here were already known 13 years ago at the time of The Earth Summit (Rio de Janeiro, 1992), and the scientific knowledge accumulated since then has amply confirmed them. Yet, in spite of some protection efforts, the threats to biodiversity have clearly increased without significant and effective response to them.

Therefore we urge governments, policy makers, and citizens to take the necessary actions to support development of the scientific knowledge, as well as the conservation and sustainable and equitable use of biodiversity.

• Ambitious interdisciplinary research programmes must be set up to discover, understand and predict biodiversity, its status, trends, and the causes and consequences of its loss, and to develop effective science-based decision tools for its conservation, and sustainable use.

• Biodiversity must be integrated without delay, based on existing knowledge, into the criteria considered in all economic and policy decisions as well as environmental management.

• Education of citizens and public awareness programmes must be greatly strengthened and improved to reach these objectives.

• A major effort must be made to build the capacity, especially in developing countries, to undertake biodiversity research and implement biodiversity protection.

Lastly, we call for the establishment of an international mechanism that includes intergovernmental and non-governmental elements, and that builds on existing initiatives and institutions, with a view to:

• providing scientifically validated information on the status, trends, and services of biodiversity;
• identifying priorities and recommendations for biodiversity protection;
• informing the relevant international conventions, especially the Convention on Biological Diversity, as their parties.

The mechanism should enhance the effectiveness of existing organisations through the integration and coordination of shared and complementary efforts.

# VII

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# Acknowledgements

# VIII

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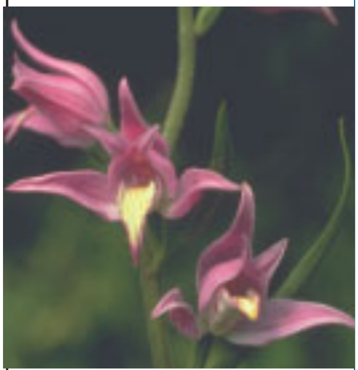
# List of Acronyms

# IX



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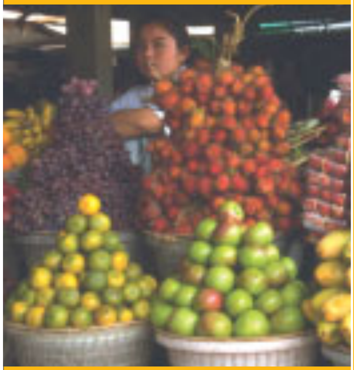
| | |
|---|---|
| APN | Asia-Pacific Network for global change research |
| BIOECON | BIOdiversity and Economics for CONservation |
| BIOTREE | BIOdiversity and ecosystem processes in experimental TREE stands |
| BMBF | German Federal Ministry of Education and Research |
| CBD | Convention on Biological Diversity |
| CONACYT | National Council on Science and Technology, Mexico |
| DFG | German Research Foundation |
| DIWPA | DIVERSITAS in Western Pacific and Asia |
| ESSP | Earth System Science Partnership (DIVERSITAS, IGBP, IHDP, WCRP) |
| GCP | Global Carbon Project (ESSP) |
| GCTE | Global Change and Terrestrial Ecosystems (IGBP) |
| GECAFS | Global Environmental Change and Food Systems (ESSP) |
| GISP | Global Invasive Species Programme |
| GLP | Global Land Project |
| GMBA | Global Mountain Biodiversity Assessment (DIVERSITAS) |
| GTI | Global Taxonomy Initiative |
| GWSP | Global Water System Project (ESSP) |
| IAI | Inter-American Institute for global change research |
| ICIMOD | International Centre for Integrated Mountain Development |
| 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 |
| IMBER | Integrated Marine Biogeochemistry and Ecosystem Research |
| INBIO | National Biodiversity Institute (Costa Rica) |
| IUBS | International Union of Biological Sciences |
| IUCN | The World Conservation Union |
| IUMS | International Union of Microbiological Societies |
| KNAW | Royal Netherlands Society of Arts and Sciences |
| LUCC | Land Use and Land Cover Change |
| MA | Millennium Ecosystem Assessment |
| MAB | Man and Biosphere (UNESCO) |
| NAS | US National Academy of Sciences |
| NERC | Natural Environment Research Council, UK |
| NFR | Swedish Natural Science Research Council |
| NSF | National Science Foundation, USA |
| NWO | The Netherlands Organisation for Scientific Research |
| RA | Resilience Alliance |
| SBSTTA | Subsidiary Body for Scientific, Technical and Technological Advice (UN CBD) |
| SCOPE | Scientific Committee on Problems of the Environment |
| SCOR | Scientific Committee on Oceanic Research |
| SNF | Swiss National Science Foundation |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| WCRP | World Climate Research Programme |

# Getting involved…



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The success of DIVERSITAS is directly related to the voluntary involvement of scientists and organisations from around the world. The following paragraphs briefly describe the primary means of contributing to this dynamic network of integrated biodiversity science. More detailed information is available in the **Getting involved** section of our web site: www.diversitas-international.org

## as a Scientist

DIVERSITAS invites individual scientists to make the Secretariat aware of their ongoing research and to suggest ways to integrate local and international initiatives. The DIVERSITAS Secretariat, as well as the Core Project and Cross-cutting Network offices, welcome proposals for collaborative activities (research projects, workshops, syntheses, etc.) that support the implementation of the DIVERSITAS Science Plan.

## as a National Committee

DIVERSITAS encourages the establishment of National Committees as a means of building a truly international network to support integrated biodiversity science. These Committees play an important role in linking national and international programmes, as well as interacting with policy makers and other stakeholders in their home countries.

## as a Funder

Funding DIVERSITAS initiatives provides an excellent opportunity for individuals and organisations to demonstrate a strong commitment to conservation and sustainable use of biodiversity—issues that often have strong appeal for their own stakeholders and publics. DIVERSITAS welcomes the opportunity to collaborate with private industry, non-governmental/inter-governmental organizations, foundations and associations.

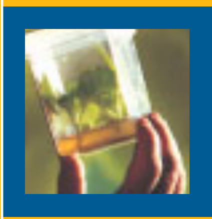
# Our Mission

**DIVERSITAS**
is an international, non-governmental programme with a dual mission:

- To promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge.

- To provide the scientific basis for the conservation and sustainable use of biodiversity.

**Collectively, DIVERSITAS Core Projects comprise a cycle of discovery, analysis and information sharing that supports the application of socially relevant knowledge. The ecoSERVICES Science Plan complements efforts in related areas of:**



## bioDISCOVERY

Assessing current levels of biodiversity; developing the scientific basis for monitoring and observation; understanding and predicting changes.

## bioSUSTAINABILITY

Developing new knowledge to guide policy and decision making that support sustainable use of biodiversity; evaluating the effectiveness of current conservation measures; studying the social, political and economic drivers of biodiversity loss, as well as social choice and decision making.

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IUBS
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SCOPE
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DIVERSITAS
an international programme of biodiversity science

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