# Visions in biodiversity research

## Towards a new integrative biodiversity science

Swiss Biodiversity Forum

The Swiss Biodiversity Forum is a long-term project
of the Swiss Academy of Sciences SANW

## Imprint


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| First published | December 2002 |
| Outline | Esther Schreier, Basel, Switzerland |
| Print | druckwerkstatt, 8585 Zuben, Switzerland |
| Paper | Dominant Puro 170/120 g/m² |
| Number of copies | 1350 |
| Citation suggestion | Swiss Biodiversity Forum (2002), Visions in biodiversity research.<br>Towards a new integrative biodiversity science. |
| ISBN | ????????????? |

# Content

# Summary

In this document, members of the Swiss Biodiversity Forum present their ideas for a new and integrative approach to biodiversity research. The ultimate aim of the document is to stimulate research that improves our understanding of the processes affecting biodiversity and which enables us to conserve this vital natural resource and use it sustainably.

The specific goals of the 'Visions' referred to in the title of this paper are: (i) to describe the main areas of biodiversity research, (ii) to identify some of the major gaps and deficiencies in our knowledge, (iii) to develop strategies for strengthening biodiversity research, and (iv) to provide the baseline information needed for future discussions about funding priorities.

The proposals for new research areas are based on the considerable expertise of Forum scientists in the field of biodiversity research, and in particular on the experience gained during the ten years of the Swiss Priority Programme Environment (SPPU), which was completed in 2002.

Four principal focus areas are identified as essential for an integrated approach to biodiversity science. These are:

a The concept of biodiversity
b Natural and anthropogenic drivers of biodiversity
c Biodiversity as a driver of ecosystem functioning and the basis for human life
d The assessment of biodiversity

Each of these research fields is briefly described.

The paper provides a sound basis for the preparation of documents designed to support lobbying efforts when seeking increased funding for biodiversity research, in order to improve the ability of the scientific community to answer important questions relevant to ecology, society and economy.

As well as identifying research priorities for those working within the field of biodiversity in Switzerland, the document sets out the importance of this research in the wider context of a research strategy to tackle issues connected with sustainability and global change. The importance of such a coherent strategy was emphasised by the Swiss scientific community in a brochure published in 1997.



# Introduction

The term biodiversity was coined in the 1980s to embrace the complete diversity of life on Earth. The concept captured both public and political attention as it was realised that **biodiversity is a prerequisite for the healthy functioning of ecosystems and is thus one of the foundation stones on which human life and culture is built.** Biodiversity is declining dramatically at local, regional and global levels. The fundamental reason for this is the increasing human domination of the planet, which leads to the large-scale modification, fragmentation and destruction of habitats and to increased rates of invasions by non-native species. In the future, the loss of biodiversity could be even more severe as a result of climatic changes caused by human activities.

The Convention on Biological Diversity (CBD) – one of the most important international agreements on environmental protection – has as its objective the preservation of biodiversity. However, we cannot develop effective conservation strategies without first acquiring more information about all aspects of the diversity of life, from the genetic level to the ecosystem level. Furthermore, if this information is to make a difference, it must be available not only to the scientific community but also to all stakeholders concerned, namely all those who manage biodiversity or depend on it in some way for their livelihood. The authors believe that **sound knowledge about biodiversity must underpin the development of new policy concepts.** The advancement of high-quality research in issues related to biodiversity is therefore of importance to everyone.

In view of these needs, the Swiss Biodiversity Forum – a group of scientists within the Swiss Academy of Sciences – began a series of discussions to develop their visions in biodiversity research and to set them down on paper. The product is the brochure you have before you. It has been written **to explain the importance of biodiversity and to identify the most urgent research priorities.** The Forum hopes that it will be useful not only to scientists working in the field, but also to scientific administrators, funding agencies and decision makers.

# Objectives

The objectives of the "Visions in biodiversity research" are:

1. to assess major topics in biodiversity research (Chapter 3);
2. to describe gaps and deficits in current biodiversity research (Chapter 4);
3. to identify main trends and needs for further biodiversity research (Chapter 5);
4. to discuss strategies for developing biodiversity research (institutions, funding) (Chapter 6); and
5. to provide basic knowledge for further documents to assist biodiversity research (Chapter 7).

For the **assessment and evaluation** of current issues in biodiversity research, we were able to draw on our professional research experience in general and, more specifically, on the knowledge we gained while involved in the Integrated Project Biodiversity (IPB) of the Swiss Priority Programme Environment (SPPU). In this programme, researchers from different disciplines worked together in an interdisciplinary way, in order to answer specific questions relating to environmental issues.

Based on this knowledge, we **identified major gaps and deficits in biodiversity research,** which need to be filled in order to address complex environmental problems. We then combined these with further needs relating to the basic understanding of ecosystems, their functioning and interactions with human influences, in order to outline new research areas. These new areas have been categorized according to a function-based approach.

Finally, we devised ways in which to **seek for funding for this new kind of biodiversity research,** conscious of the fact that, to a certain degree, we are all competitors for a limited resource (money for research). However, we believe that the new integrative biodiversity research should have priority over individual research interests and that realistic methods of funding should be pursued. This involves finding new ways of promoting research topics among different target publics, including potential funding institutions and the users of future research results and expertise.

We present our visions at a time when others are also thinking about new ways to develop the basis for a **new integrative biodiversity science,** in particular DIVERSITAS, the international umbrella programme of biodiversity research. The "Advisory Commission for Environmental Research (BKUF) of the Swiss Agency for Environment, Forests and Landscape (BUWAL) also goes in the same direction with two of its four foci for Environmental Research in its publication "Forschungskonzept Umwelt für die Jahre 2004–2007", published in August 2002. As an overall goal, the BKUF wishes to strengthen the trans-disciplinary aspects of all research projects.

An additional objective of these Visions is the biodiversity-specific product of further developing the guidelines outlined in a document on research on sustainability and global change by Swiss researchers ("Visionen der Forschenden. Forschung zu Nachhaltigkeit und Globalem Wandel – Wissenschaftspolitische Visionen der Schweizer Forschenden", June 1997, CASS/ProClim-). In this document, researchers synthesize knowledge gathered in the field of environmental research and define common hypotheses that refer to future environmental issues and their significance to society in general.

We hope that our visions will be useful to these researchers and will stimulate other scientists to participate in the worldwide effort to increase our understanding of the living world around us, of which we are part, and on which we depend and, thus, to contribute to its sustainable use and enhancement.

# Major topics in biodiversity research

The major challenge in the wide field of biodiversity research is how the different approaches and disciplines can be **combined into a new integrative biodiversity science.** The aim of a comprehensive research strategy must be to foster interactions between experts working in different areas of biodiversity research and to fill research gaps by encouraging further biodiversity research.

The following list **identifies major thematic fields,** regardless of whether they have been the subject of intense research activities so far or not. Some of the topics may have been prioritised in research agendas, whereas other may have been somewhat marginalized. They were judged to be of major importance by the members of the Forum and thus are all part of a new comprehensive and integrative biodiversity research approach. The list is the result of a brainstorming process (see Annex) and does not follow any defined hierarchy of research areas.

➔ Basic knowledge and skills:
- ~ Systematics and taxonomy
- ~ Population biology
- ~ Speciation/evolution
- ~ Ecosystem functions
- ~ Ecosystem stability
- ~ Soil fertility
- ~ Organismic interactions
- ~ (Local) adaptation
- ~ Climate change

➔ Habitat alteration and destruction:
- ~ Habitat loss
- ~ Habitat fragmentation
- ~ Land use (practices)

➔ Maintenance and promotion of biodiversity:
- ~ Monitoring
- ~ Extinctions
- ~ Reintroduction/protection of species
- ~ Management of habitats
- ~ Invasive species
- ~ Genetically modified organisms

➔ Values of biodiversity:
- ~ Ethical value (the right to exist)
- ~ Aesthetic value (beauty)
- ~ Cultural value (man-made systems of high conservation value)
- ~ Economic and social value (genes, insurance, health products)
- ~ Ecological value (ecosystem functioning, sustainable integrity, etc)

➔ Human behaviour towards biodiversity:
- ~ Perception of biodiversity
- ~ Marketing of biodiversity
- ~ Economic globalisation
- ~ Resource management
- ~ Biodiversity governance

➔ Collection and transfer of information:
- ~ Biodiversity information (databases etc.)
- ~ Knowledge transfer

This list **represents the basis for the subsequent definition of gaps and deficits in biodiversity research** by combining the topics with each other and keeping specific research questions in mind in response to today's biodiversity-research needs.

# Gaps and deficits in current biodiversity research

What information do we need in order to tackle current problems to do with biodiversity, chiefly its dramatic loss? What basic knowledge do we have and how can we assemble different aspects of this knowledge to gain new insights? Where is there a lack of perhaps even very basic data?

These questions provide the background for the identification of gaps and deficits in current biodiversity research. Based on the list of topics outlined in Chapter 3, **major needs for research have been identified,** mainly in the combination of different generally defined elements of biodiversity research.

Specifically, **collaboration should be strengthened** in the following areas and between the following levels:

- Different systematic and taxonomic areas
- Taxonomy and molecular systematics
- Organismic interactions and species distributions
- Observation, theory and experiment
- Plant, animal and microbial diversity
- Genetic diversity and species diversity
- Ecosystem ecology and population biology
- Different ecosystems (marine, grassland, woodland)
- Managed vs. unmanaged species and ecosystems
- Biology and relevant disciplines in the social sciences and humanities
- Ecology and human welfare
- Risk assessment and human activities

Generally, these areas can be categorized according to the following criteria: levels of organization (genes, species, populations, ecosystems), types of research disciplines (natural, human and social sciences), types of research instruments (observation, theory, experiment), levels of classification of organisms (taxonomic and functional units), types of interventions (environmental management, unintentional human impacts, natural disturbances) and types of importance to humanity (welfare, risk, health, food supply etc.).

**Interactions within** these categories as well as **among different categories deserve more attention** in biodiversity research. However, not all possible combinations among the categories can be addressed. Priorities must be set primarily according to their importance in solving problems relevant to society, and secondly for reasons of resource availability.

Knowledge regarding **interactions between different levels of organization,** for instance, interactions between genetic and species levels or between population and ecosystem levels, is often lacking. So far, these processes have only been investigated in very specific individual cases.
For example, it is not known if and to what extent large genetic diversity within species in species-poor ecosystems can lead to similar levels of ecosystem functioning as does lower genetic diversity within species in species-rich systems. However, knowledge of such compensatory effects would be extremely useful for agricultural management of cropland. Much more information is needed to be able to formulate hypotheses about these interdependencies.

Another major gap in knowledge concerns the **impact of different types of interventions on ecosystems and their functioning.** One challenge will be to integrate real impact scenarios into research projects, in order to gain knowledge more directly applicable in practice. For instance, harvesting practices concentrated towards large fish can lead to evolutionary shifts within species and subsequent shifts in species composition. These changes may bias an ecological community in a different way from that simulated in experiments with random extinction events and may negatively affect future harvesting potential. Establishing strict nature reserves where no harvesting takes place may be an answer to this problem, but we do not know this for certain and we do not know what size such reserves should be.

Combining recent molecular methods with traditional taxonomic and systematic methods may result in new fundamental knowledge regarding the **relationships and evolutionary aspects of organisms** and may thus serve as a base for further research topics. The current interest in charting biological information at the level of DNA and amino-acid sequences and at the level of species has developed quite independently so far, with little knowledge transfer between the two research communities.

Recent research approaches in the field of biodiversity and environmental issues unite experts from different disciplines, in order to **tackle complex problems that concern environment and society in an inseparable way.** Concepts of inter- and transdisciplinarity have been developed, with a variety of experts and stakeholders involved in the whole research process. One issue in international policies is, for example, how a high diversity in ecosystems may be counted as a nation's contribution towards mitigation of the $CO_2$ problem (Kyoto protocol). Similarly, basic research into ecosystem services can help justify and put real price tags on compensation areas in managed terrestrial landscapes. This requires close collaboration with economists, managers, and politicians. In the recent foot-and-mouth-disease case in Britain, the damage to the agricultural "product" tourism was probably about ten times more costly than the damage to direct agricultural production.

Some of the research areas outlined in Chapter 5 may be of particular interest to institutions dealing specifically with inter- and trans-disciplinary issues, such as the new focal points of the Swiss Academy of Sciences (SANW): "Trans-Disciplinarity-Net" and "Ecosystem Research". Questions re garding different perceptions of and values attributed to biodiversity on the part of human beings could be addressed within this institutional framework and reveal new insights into the importance that is attributed to biodiversity by different members of society. This may lead to the development of new strategies for the conservation and sustainable use of this natural resource.

# Main trends and needs for further biodiversity research

The objective of a comprehensive biodiversity research programme is to establish new biodiversity research groups and to support researchers and research groups in their efforts to form networks of specialists. The promotion of the mobility of researchers across disciplines and between research institutes and the improvement of facilities to investigate the international problems of biodiversity protection will assist in developing a new integrative biodiversity science. The programme should promote cooperation among universities, other institutions carrying out research and private enterprises.

Taxonomy and systematics are the tools needed to answer the basic question of how much biodiversity there is. However, over the past 10–15 years, in Switzerland many professorships in taxonomy and organismic biology have been replaced by professorships in other biological disciplines that were, at the time, considered to be more important. Today, the negative consequences of this development can be seen in many areas of basic and applied research. It is hard or impossible to find experts in the identification and classification of organisms belonging to such important groups as microbes, fungi, algae, nematodes, mites, and insects, to name just a few. This not only makes the monitoring of many taxa impossible, it also prevents research and the development of management strategies, for example to protect species and avoid unwanted ecological disequilibria, such as pest outbreaks in agriculture or the spread of invasive species. **In order not to lose further taxonomic knowledge and skills, we need a new direction in the education sector and a change in recruitment policies.** Swiss universities and natural history museums need to build up, once again, the much-needed expert knowledge in biodiversity. The education of the next generation of experts is also of key importance.

In the end, **we need knowledge relating to all aspects of biodiversity, their interdependencies, and their relationships with the physical world and human society,** in particular given the current trend of global change. Such biodiversity research must bridge the gap between basic and applied research. In accordance with the Convention on Biological Diversity, the ultimate applied goal is the protection of biodiversity in a self-sustaining long-term perspective. **The social, economic, and applied aspects of biodiversity research, such as management and quality control, require an interdisciplinary approach.** Future integrative projects should aim at parallel, cross-linked research into these aspects and the full participation of all contributors from the beginning, with equal importance given to all. Three types of knowledge needed in such integrated projects have been identified: system, target and transformation knowledge. These are relevant to all aspects of biodiversity research. For example, system knowledge may show how policies and governance affect biodiversity, target knowledge how they should affect it, and transformation knowledge how they could be changed to reach the target. These types of knowledge are also the objective of the catalogue of environmental research proposed by the BKUF (see Chapter 7), where priority, however, is given to transformation knowledge.

There are **several possible ways to structure biodiversity research.** We have chosen **function-based categories.** Two **additional categories** in the introductory and final section of this chapter refer to the concept of biodiversity and the assessment of biodiversity, respectively. Other ways of structuring biodiversity research could be based on habitat type (terrestrial, fresh water, marine; surface, soil/sediment, water, air), groups of organisms (animals, plants, microbes), research discipline (biology, geography, economy, management, psychology, etc.), or types of application (communication, conservation, human dimension, management, perception, policy, sustainable use, valuation).

## 5a The concept of biodiversity

Discussions about definitions of biodiversity have paralleled the development of biodiversity research from its beginnings. There are many different uses of the word "biodiversity", yet despite the lack of terminological coherence, the term has become a "thick concept" in the sense that it is being used widely, that people identify with it and that considerable efforts are being made towards the stewardship of biodiversity. Rather than finding new definitions of the term, it should be a scientific task in its own right to **study the history and development of meanings of the concept in different contexts and see how they could be integrated.** Such a study of biodiversity as a concept will itself feed back into the science, valuation and management of biodiversity and the funding of these activities. Outside the life sciences, it has been postulated that the concept of biodiversity has a strong cultural dimension and, hence, is also a political as well as a scientific reality. Most of the motivation to protect biodiversity is driven by culture and economics, and based on a fascination with rarity and a fear of losing it. Biodiversity as a concept is given a positive normative meaning by most people, based on the paradigm "more is better." What are the consequences of this, and how do different groups in society shape the concept of biodiversity as a construct or semantic expression?

Specific questions concerning the concept of biodiversity are:

- ➔ Which aspects of nature are conjured up the concept?
- ➔ How do we quantify and valuate biodiversity in a way agreed on by most?
- ➔ How can we increase public awareness of biodiversity?
- ➔ Are there "success stories" that would enable us to better communicate conservation policies?
- ➔ How can biodiversity knowledge be transferred among interest groups and regions?

## 5b Natural and anthropogenic drivers of biodiversity

The number of organisms at a particular locality is determined by the types of habitat, their condition, structure and size, by speciation and extinction, and by immigration and local loss. This local biodiversity represents the result of gains and losses, which is influenced by natural and anthropogenic drivers. However, little is known about the **relative importance of these drivers and about their interactions and possible feedback mechanisms.** For example, the introduction of new species or genes may initially increase biodiversity, but may lead to a decline in the longer term if the new organisms cause the loss of a higher number of existing ones. Furthermore, one driver may increase one component of biodiversity and at the same time reduce another, thereby changing the composition of biodiversity rather than its level. Some natural drivers of biodiversity are internal to biodiversity itself, such as evolutionary potential and interactions between organisms, while others, such as environmental conditions, are external. Human activities change both internal and external conditions affecting biodiversity, either intentionally or unintentionally.

Natural drivers of biodiversity:

- ➔ Evolutionary processes **A** and ecological interactions **B**
- ➔ Abiotic environmental factors **C**

Anthropogenic drivers of biodiversity

- ➔ unintentional **D**
- ➔ intentional (by management) **E**

## A Evolutionary processes and biodiversity

Speciation is the creative process leading to the build-up of species diversity and is therefore the ultimate motor driving biodiversity. The protection of biodiversity for the future is mainly the **protection of the evolutionary potential** of organisms by ensuring processes like sexual reproduction, dispersal and migration, which lead to or maintain genetic diversity within species. Open questions regarding the conservation of the evolutionary potential of organisms are:

- ➔ Is genetic diversity positively correlated with species persistence and evolutionary potential?
- ➔ In which species groups do we find a correlation between species richness and intraspecific (genetic) diversity?
- ➔ How does the population viability of a species depend on size and connectedness of habitat?

Understanding the general patterns and processes of speciation is fundamental when seeking to explain the diversity of life. Central questions in this research field include:

- ➔ What are the general causes of speciation, and how do rates of speciation vary over time and among taxonomic groups and geographical regions?
- ➔ What are the factors that influence rates of speciation?
- ➔ Is there a feedback, positive or negative, between species numbers and the generation of new taxa?
- ➔ In which historical and environmental contexts do evolutionary processes lead to increased biodiversity?
- ➔ To what extent is the history of biodiversity influenced by adaptive radiation, chance, and integration (e.g. non-Mendelian processes)?

## B Ecological interactions and biodiversity

In nature, no organism lives in isolation, separated from other individuals of its own or other species. There is no life without biotic interaction. **Organismic interactions** include genetic exchange, disease and cultural transmission, while **trophic interactions** (predation, parasitism, herbivory) include competition, facilitation, mutualism or symbiosis. At the **population level,** interactions are related to resource consumption, space-occupancy, and reproduction. At the **community level,** interactions between individuals of different taxa (e.g. host–pa thogen interactions) are a major force in maintaining diversity.

Open questions about the driving function in biodiversity of ecological interactions are:

- ➔ How strongly is animal and microbe diversity linked to plant diversity, and can we expect consistent biodiversity ratios?
- ➔ How does the population viability of species depend on the presence of interacting species?

## C Abiotic environmental impacts on biodiversty

Abiotic factors are **environmental drivers of biodiversity** and represent the **matrix for natural selection.** The main hypothesis to be tested is, whether there is only one steady-state biodiversity level (within a given pool of species) for a given constellation of resource availabilities, environmental conditions and disturbance regimes. There is currently very little information about the absolute and relative impacts of the various environmental factors such as climate and climate variability, soil fertility, water availability, growing-season length, and stress factors (e.g. climatic or fire) on the quantity and quality of biodiversity. As a consequence, discussion continues between those who assume biodiversity is mainly regulated by abiotic environment and those who believe that biodiversity itself is the major driver of its own development and of the abiotic factors that are thought to drive biodiversity.

Specific questions about abiotic environmental impacts on biodiversity are:

- ➔ To what extent is this relationship dependent on the spatial and temporal scale being considered, and are there situations leading to positive or negative feedback loops between abiotic factors and biodiversity?
- ➔ Is current global change so rapid that it leads to the extinction of all but the most generalist species, which in turn has a further negative impact on the environment?

## D Unintentional human impacts on biodiversity

Most of the factors influencing biodiversity and the current high **rates of extinction are induced or influenced by human activities.** The immediate reasons for the decline in biodiversity due to human activity may vary between ecosystems and also within ecosystems across a larger area. In aquatic systems, pollution, acidification and eutrophication have serious negative effects on biodiversity. In terrestrial environments, the single most important factor reducing biodiversity is human land use and changes in land use, especially if they lead to the loss of important habitat types. Where traditional, small-scale land use often increased biodiversity locally, conventional modern agriculture, intensification of land use or abandonment usually has the opposite effect. In terms of effects on biodiversity, the quantitative changes in species (or gene, ecotype, trait, functional group, landscape type) abundances warrant increased attention, because they may already occur when the qualitative changes in richness (e.g. loss of certain species, traits, etc.) are not yet apparent. The quantitative changes in abundance can have important consequences for ecosystems long before richness is threatened by extinction; at the same time, they may create an extinction depth leading to richness loss in the long term.

Specific questions about unintentional impacts of human activities on biodiversity are:

- ➔ Is the microbial diversity so large and flexible that it is not affected by human-triggered environmental changes?
- ➔ To what extent is the dispersal of organisms reduced by the fragmentation of landscapes?
- ➔ What are the consequences of limited dispersal abilities, e.g. in the case of climate change, on biodiversity?
- ➔ Is global warming affecting biodiversity at present levels of human activity?
- ➔ How do governmental subsidies affect biodiversity?

**E** Intentional human impacts on biodiversity: management of biodiversity

The deliberate management of biodiversity by humans is, in most cases, related to the management of particular ecosystems or species, either wanted and unwanted (invasive species, pests and diseases). With the increased value ascribed to biodiversity, independent of its particular composition, new information is needed on **management tools to enhance biodiversity in a locality**. This also requires tools for the assessment and monitoring of biodiversity and tools to assess the effectiveness of the management (see Chapter 2d: Assessment of biodiversity). To maintain species diversity (which is a key measure in the public perception of biodiversity), all other levels of biodiversity are necessary preconditions. The direct management of biodiversity occurs by introducing measures of nature conservation, restoration ecology or the management of resources that are commercially exploited (e.g. in agriculture, fisheries, game management, tourism, etc). On a level above these particular measures, frame rules may be set by environmental policy to obtain more integrated biodiversity governance.

Possible management tools that need to be developed are:

- ➔ "Species management": intentional eradication of "unwanted" species such as weeds, pests, pathogens, diseases; reintroduction of species in their natural habitats, where they have become extinct
- ➔ Restoration or conservation of characteristic, rare or species-rich habitat types (river embankments, hedges, forest edges), creation of ecological compensation areas
- ➔ Policy instruments to reduce negative effects on biodiversity exerted by transportation, accessibility of pristine areas, population pressure on natural ecosystems (land degradation), homogenisation of land use

The following research questions must be addressed in an effort to develop the science-based management of biodiversity:

- ➔ At what level and distance between habitats can lost biodiversity be restored by natural dispersal?
- ➔ Can minimum viable population sizes and minimum population-specific genetic diversities be estimated?
- ➔ Can natural disturbance be simulated by management?
- ➔ How much "wilderness area" is needed to keep the existing biodiversity?
- ➔ Does focusing on regional economic activities enhance biodiversity?
- ➔ What would be the overall economic consequences be of a re-orientation in agricultural policies (e.g. payments for providing ecosystem services such as clean water, intact landscapes, biodiversity protection)?

## 5c Biodiversity as a driver of ecosystem functioning and basis for human life

Despite its thin layer, the biosphere influences the composition of atmosphere, soils and sediments substantially. To what extent is this influence modified by different levels of biodiversity? How important are changes in biodiversity in relation to other kinds of change? The biosphere, with its ecosystems of living organisms, is still a big black box in our understanding of global physical and chemical processes. This understanding is not only a scientific challenge. We also need to know to what extent the **influences of biodiversity on ecosystem functioning and environmental conditions affect the basis for human life.** Besides our dependence on these "ecosystem services", we human beings belong to the living world and are therefore naturally part of the ecological web. We directly depend on or are influenced by other organisms for nutrition, health (beneficial symbionts, pathogens and diseases living within or on the human body; organisms providing medicinal substances) and habitat (including clothing and building materials). This interdependency among the elements of specific environmental systems and the interactions of different types of systems, called "biocomplexity", takes into account that the individual components of environmental systems provide only limited information about the behaviour of the systems themselves.

Biodiversity and ecosystem functioning:

- ➔ Biodiversity as a driver of the level of ecosystem variables A
- ➔ Biodiversity as a driver of the stability and predictability of ecosystem variables B

Biodiversity and human life:

- ➔ Ecosystem functioning and ecosystem services C
- ➔ Direct effects of biodiversity on human life D

**A** Biodiversity as a driver of the level of ecosystem variables

Functional groups of organisms or even single species may **affect ecosystem variables** directly by modifying pathways of energy and material flow (C-, N-cycles), or indirectly by altering abiotic conditions that regulate these flows. Affected ecosystem variables include productivity, soil formation, carbon and nitrogen storage, water filtration, hydrology and microclimate, to name just a few. Additionally, some ecosystem variables are driven by the "information flow" of biodiversity itself, e.g. levels of pollination, pests and diseases (e.g. invasion control by niche occupation, pest control by antagonistic interactions or by dilution of the host species). As human activities influence the abundance of species more frequently than the presence of species, changes in species evenness warrant increased attention in particular.

Research questions in addition to the direct investigation of the driver function of biodiversity on the level of ecosystem variables (perhaps at the moment the most intensively addressed topic in biodiversity research) are:

- ➔ What are the mechanisms behind demonstrated biodiversity–ecosystem functioning relationships? (Selection, complementarity, facilitation?)
- ➔ What is the relative contribution of plasticity and genetic variation in ecological–functional traits within and among species to biodiversity effects on ecosystem processes?
- ➔ Are processes that lead to biodiversity change correlated with resulting changes in ecosystem functioning (random versus non-random extinction scenarios)?

### B Biodiversity as a driver of the stability and predictability of ecosystem variables

Biodiversity may represent **a form of biological insurance against the loss or poor performance of particular species.** Therefore, high biodiversity should enhance ecosystem reliability, where reliability refers to the probability that a system will provide a consistent level of performance over a given unit of time. It implies that redundancy (in the sense of having multiple species with similar traits) is a stabilising component of biodiversity.

The main questions in this research field are

- ➔ Is biodiversity correlated with ecological resilience?
- ➔ Does biodiversity provide system insurance against environmental extremes?
- ➔ Are there minimum levels of biodiversity for sustained ecosystem integrity?
- ➔ How can we save the insurance potential of biodiversity against future environmental change?

### C Ecosystem functioning and ecosystem services

The effects of biodiversity on ecosystem functioning are particularly relevant if the affected variables can be considered **as services provided by ecosystems and the biosphere at large to support human life.** There is a great need to develop economic analysis tools to measure the impact of these services on the well-being and wealth of individuals and society.

Central questions are

- ➔ Can real economic values be attributed to ecosystem services?
- ➔ How can the stewards of biodiversity (farmers, foresters, fishers, hunters, land owners) be rewarded for providing ecosystem services through the prudent management of biodiversity?

### D Direct effects of biodiversity

Biodiversity contributes in various ways to **useful products for mankind,** e.g. the production of food, fibre, building materials, energy, medicine, cosmetics, fragrances, ornamental plants and domestic animals. We use the rich diversity of genetic information in modern biotechnology. Furthermore, the extinction of, for example, one quarter of all the species in Switzerland (the rarest 25% per taxonomic class) may, at the very least, have a dramatic psychological impact, because we value the aesthetic, educational and scientific aspects of biodiversity (e.g. biodiversity as a source of knowledge and as an indicator for the state of our natural and cultural environment).

Research priorities in this area include

- ➔ Methods and impacts of prospecting biodiversity for genes and material compounds
- ➔ Benefit sharing, property rights, access to genetic resources

## 5d The assessment of biodiversity

Applying knowledge about drivers of biodiversity, and about biodiversity as a driver itself, **requires assessment tools to measure the different components of biodiversity efficiently and reliably.** Aspects of biodiversity for which improved measurement methods should be developed are the number of units, the distribution of units, the genetic or phenotypic difference between units, and the number and strength of interactions between units. An important consideration when measuring biodiversity is the scale and level of organisation (e.g. genes, species or on the ecosystem or landscape level). The comparability of measurements and therefore the development of internationally agreed standards is of particular importance. Nevertheless, there will be no single measure that can be used for all purposes or even to completely describe biodiversity, a problem that makes comparability and standardisation even more challenging. It should also be made clear whether measurement units of biodiversity contain a valuation. For example, giving priority to high small-scale (alpha) diversity may imply beneficial effects on ecological resilience ("balance of nature" implication), whereas giving priority to high large-scale (gamma) diversity may imply better preservation of endangered species.

Motives for measuring largely relate to management policies (e.g. implementation of the Convention on Biodiversity, the identification of targets and actions for conservation, the need to understand changes). Because of the great urgency to measure biodiversity, also in situations and places where human and financial resources are limited, **the measurement methods should be efficient, easy to apply and robust.** As not all components of biodiversity can thus be measured, there is a need to develop indicators of biodiversity. Indicators need to be representative (of what they intend to measure), robust (against variability caused by temporal dynamics and spatial heterogeneity), sensitive (to changes in what they intend to measure), measurable, cost effective and relevant to their end-users (indicators selected according to management or policy objectives).

A national biodiversity monitoring programme (www.biodiversitymonitoring.ch) was started in Switzerland in 2001 and aims to provide long-term data on selected indicators that record biodiversity. This programme concentrates on documenting common and widespread species (plants, birds, molluscs and mosses), as it is based on large sampling grids covering the whole of Switzerland. However, biodiversity is not distributed equally in the landscape and small structures in particular, like hedges, rock faces or springs, show high biodiversity and often bear very rare species. Therefore, large sampling grids miss many rare (but important) species, for which a special monitoring programme should be added.

Specific research tasks that need to be addressed are:

- ➔ Suitability of genetic markers to define taxonomic units in asexual organisms
- ➔ Assessment of microbial diversity in the different media (soil, sediment, water, air, other organisms)
- ➔ Factors influencing biodiversity–area relationships
- ➔ Systematics of all groups of organisms
- ➔ Biodiversity inventories in neglected taxa, habitats and areas
- ➔ Development of biodiversity information facilities (e.g. databanks containing information about species and collections)
- ➔ Development of quick measurement tools for biodiversity (involving the question of how constant biodiversity ratios between different taxa are)

# Strategies for developing biodiversity research

What instruments lead to action in biodiversity research? There is a **need for lobbying** groups to secure support for biodiversity research in academic institutions, along with increased support for basic life sciences. The basic and applied value of integrative biodiversity research should be shown in a policy paper. Toolboxes are needed and new ways of funding must be found. Although we are, to a certain degree, competitors for funds, we should identify common interests first and lobby for biodiversity research before focusing on particular interests. The present document should help to develop further documents that meet the specific requirements of the identified lobbying targets.

## Development of Swiss Research Programmes (NRP)

Based on the ideas assembled in the Visions, new research programmes should be developed and submitted to the relevant authorities. The Swiss Biodiversity Forum proposes **two new national research programmes (NRP):** "Genetically modified plants: benefits and risks" and "Nature as a resource: the potential of and threat to the diversity of life in Switzerland". These issues have been made the focus of international programmes as well. Although the research activity suggestions made have not been taken up in a first round in 2002, they should be further developed and presented again to the funding institutions in the years to come.

## Cooperation with DIVERSITAS and other international research initiatives

Expertise summarized in the new research areas can serve as important input to the international biodiversity umbrella programme DIVERSITAS. According to its new science plan, DIVERSITAS wants to **promote integrative biodiversity science,** linking different disciplines in order to gain socially relevant knowledge and to provide the scientific basis for the conservation and sustainable use of biodiversity. The science plan is divided into three core projects, whose elements are defined in accordance with research areas presented in this document.

Information made available on an international level can trigger new research ideas in the global research community and foster the setting up of common research projects. Other potential research partners are international research programmes such as the IGBP and may also involve international funding agencies like DFG (Germany), NSF (USA) and NERC (UK).

## Dialogue with nature conservation authorities

Authorities have to implement legal frameworks and thus need scientific expertise. The results of biodiversity research outlined here **should lead to applicable management guidelines** and provide basic information for quality control systems (e.g. in the ecological compensation system of the Swiss agricultural policy). One of the mid-term goals of the Swiss Biodiversity Forum is the development of a preventive early-warning mechanism, which anticipates future problems in nature and landscape conservation. This should be achieved by close collaboration between practitioners, such as the cantonal conference of the authorities for nature and landscape conservation (KBNL).

## Cooperation between research institutions in Switzerland

Opportunities defined in the present document include lobbying at the university level aimed at the creation of new professorships in the field of biodiversity, the **strengthening of links** between research institutions and the development of PhD programmes in biodiversity.

Based on the visions, new research projects at the inter-institutional level should be designed and thus bring researchers from different disciplines together. The research areas outlined in this document require research activities across institutional and disciplinary borders.

## General lobbying for biodiversity research by concerted action

The setting up of a lobby group for biodiversity in general requires coordinated actions in different areas on a long-term basis. We think that an effective lobbying for biodiversity research requires the **establishment of biodiversity as an essential concept of life within society.** Only if people accept and recognize biodiversity as an important and thus interesting issue, can broad support for research activities in the service of society be achieved. This will be a long-term task.

The topic of mainstreaming was raised in the Forum's new project on "Education and Public Awareness", which was developed in a thematic workshop in May 2002. Some fundamental questions raised in these Visions can serve as means to stress the importance of biodiversity research and to identify questions of major interest for the general public.

Biodiversity should not only be the subject of intense research activities; it should also become a commonly accepted concept in society. The **mainstreaming** required to achieve this aim will have to take place on different levels and be aimed at different target publics, policy makers being one of these. For this purpose, specific information transfer should be institutionalised. Well-timed presentations about specific topics and fact sheets dealing with issues reflecting the political agenda could play an important role in this knowledge transfer system. In addition to these institutionalised means, media-relevant events should be organized, such as biodiversity days or open days at biodiversity research institutes.

In the long term, a policy observation service should be established, in order to be able to bring in scientific expertise preventively, in response to evolving political issues rather than in reaction to decisions already taken.

# Role of the "Visions in biodiversity research"

The writing of the "Visions in biodiversity research" was partly prompted by a document on research into sustainability and global change written by Swiss researchers in the field of environmental research ("Visionen der Forschenden. Forschung zu Nachhaltigkeit und Globalem Wandel – Wissenschaftspolitische Visionen der Schweizer Forschenden", June 1997, CASS/ProClim-). In that document, the authors analyse the complexity of problems concerning sustainability and describe the environmental research needed to address those problems. The contribution of science to sustainable development is described as being as the integration of three different types of knowledge: system knowledge, target knowledge and transformation knowledge. The "visions in biodiversity research" presented here represent an **integrative, biodiversity-specific contribution** to this overall role of science and respect the more globally defined guidelines of visions in the areas of sustainability and global change. The fields of future biodiversity research proposed here integrate the different types of knowledge identified in the CASS document.

DIVERSITAS, the international programme of biodiversity science, has recently elaborated a new science plan, which is divided into three different core projects. These projects (Discovering biodiversity and predicting its changes, Assessing impacts of biodiversity changes, Developing the science of conservation and sustainable use of biodiversity) match to a great extent the issues raised here and can therefore be a basis for enhanced future collaboration between Swiss scientists and DIVERSITAS.

In the **concept for environmental research** (Forschungskonzept Umwelt für die Jahre 2004–2007) by the Advisory Commission on Environmental Research (BKUF) of the SAEFL (BUWAL), three of the four focal research points defined deal either directly or indirectly with aspects of biodiversity. One of them, directly linked to biodiversity, is "Loss of natural resources and the biological and the landscape diversity" (e.g. biodiversity, biodiversity monitoring). According to the description, this focal point sets very similar priorities to those defined here. Among them are:

- System knowledge of biodiversity and landscape:
  Identification of the role of biodiversity in the functioning of ecosystems, quantification of the impact of human activities on extinction processes and interference with competition effects, maintenance of regeneration of ecosystems
- System knowledge of indicators and monitoring:
  Development and testing of indicator systems for the monitoring of complex processes, enhancement of knowledge through monitoring, accessibility of data gathered
- Target knowledge of biodiversity and landscape:
  Knowledge of how to use ecosystems in a sustainable way, modelling, definition of conservation goals, perspectives of landscape evolution.
- Transformation knowledge of incentive measures:
  Incentive models aiming at conserving intact landscapes, new forms of cooperation in order to reconcile different soil and landscape use requirements, development of participative use systems

Two other priorities, indirectly related to biodiversity, are 'Handling of risks by society (integral risk management related, for example, to natural hazards or genetic engineering)' and 'Climate change and its effects on nature and society' are partly related to biodiversity research.

The report makes special mention of the overall need for transformation knowledge, in addition to enhanced system and target knowledge. Furthermore, the BKUF demands the enhancement of transdisciplinarity and its common acknowledgment as an appropriate research approach. The BKUF suggests several incentive measures to achieve this goal, among others the provision of finances, a redefinition of submission systems for environmental research projects and the reorganisation of educational structures.

## Future needs for biodiversity research

Although several issues related to inter- and transdisciplinarity have been raised in this document without explicit mention, the Swiss Biodiversity Forum as a scientific group sees its role mainly as one of creating basic knowledge to fill the gaps identified by its scientific members. The overall goal is to **develop new research programmes** in collaboration with experts from other research disciplines.

Additional target knowledge and transformation knowledge should be gained in specific inter- or transdisciplinary research and discussion groups, such as the focal point on 'Ecosystem Research' or the 'Trans-Disciplinarity Net', both of which are future projects of the Swiss Academy of Sciences (SANW). These inter-academic platforms will be ideal institutions within which to discuss and develop further research topics related to biodiversity in the context of society, the economy and the environment.

The document "Visions in biodiversity research" outlines research needs in the field of biodiversity at the beginning of the decade. However, in order to evaluate future needs for research in this fast moving field, the process leading to these visions should be repeated every 5–10 years. This will make it possible to integrate recent research results and to identify future needs of biodiversity research.

The visions presented here mark the starting point of a periodical evaluation process, based on the experience of researchers in the field of biodiversity in Switzerland.

# Authorship

Switzerland was one of the first countries with a national interdisciplinary research programme on biodiversity (Integrated Project Biodiversity of the Swiss Priority Programme Environment, 1993–2001). Several authors of the present document took part in that programme and are now members of the Swiss Biodiversity Forum, a long-term project of the Swiss Academy of Science (SANW).

The Swiss Biodiversity Forum provides a national network of experts and a platform for information exchange in the field of biodiversity research. It was created in order to continue and strengthen collaboration, integrate and share knowledge within the biodiversity research community, stimulate interdisciplinary and transdisciplinary research projects and intensify communication between scientists and land-users, conservation agencies, administrative authorities and the public. The Swiss Biodiversity Forum is the national committee of DIVERSITAS in Switzerland.

The members of the Swiss Biodiversity Forum work in a wide variety of biodiversity research fields and the consortium as a whole can therefore claim to have a comprehensive view of biodiversity science as a whole. At the end of 2000, the Forum circulated among its members an open-ended questionnaire with the aid of which it gathered ideas for the "Visions in biodiversity research" (see Annex). These ideas were then discussed at a workshop in March 2001 and assembled in a structure draft document. The document was subsequently edited by the project leader Eva Spehn and then discussed and reviewed in further rounds by e-mail and at a meeting in November 2001. It was further developed by integrating new aspects concerning the future role of the Forum as a novel institution of the SANW. The following people contributed to the document:

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# Acronym index

| | |
|---|---|
| **BKUF** | Beratende Kommission Umweltforschung (Consulting Commission on Environmental Research) |
| **BUWAL** | Bundesamt für Umwelt, Wald und Landschaft (Swiss Agency for Environment, Forest and Landscape) |
| **CASS** | Conseil des Académies Scientifiques Suisses (Council of the Swiss Scientific Academies) |
| **DFG** | Deutsche Forschungsgemeinschaft (German Research Council) |
| **ESF** | European Science Foundation |
| **IGBP** | International Geosphere-Biosphere Program |
| **IPB** | Integriertes Projekt Biodiversität (Integrated Project Biodiversity) |
| **GCTE/IGBP** | Global Change and Terrestrial Ecosystem of the International Geosphere Biosphere Program |
| **KBNL** | Konferenz der kantonalen Beauftragten für Natur- und Landschaftsschutz (Conference of the cantonal deputies for nature- and landscape conservation) |
| **NERC** | Natural Environment Research Council |
| **NSF** | National Science Foundation |
| **SAGW** | Schweizerische Akademie der Geistes- und Sozialwissenschaften (Swiss Academy of Humanities and Social Sciences) |
| **SANW** | Schweizerische Akademie der Naturwissenschaften (Swiss Academy of Sciences) |
| **SNF** | Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung (Swiss National Science Foundation) |
| **SPPU** | SchwerPunktProgramm Umwelt (Priority Programme Environment) |

# References and links

DIVERSITAS Newsletter Nr.1 (July 2002); **http://www.icsu.org/diversitas**

Forschungskonzept Umwelt für die Jahre 2004 - 2007, Beratende Kommission Umweltforschung des BUWAL, (2002); **http://www.umwelt-schweiz.ch/buwal/de/fachgebiete/forsch/ur2_grund/forschungskonzept_themen/index.html**

Visionen der Forschenden. Forschung zu Nachhaltigkeit und Globalem Wandel – Wissenschaftspolitische Visionen der Schweizer Forschenden, CASS/ProClim- (June 1997); **http://www.proclim.ch/Reports/SP/Visions/Visions_E.html**

# Methods / synthesis process leading to the "Visions in biodiversity research"

## 1. Questionnaire

In order to assess and evaluate the current issues and gaps in biodiversity research, a questionnaire was sent to all members of the Swiss Biodiversity Forum (23 experts). Thirteen questionnaires were filled out and returned. The questionnaire included both closed and open questions. Experts were also asked to rank items on a proposed a list of biodiversity areas according to the need for further research.

## 2. Workshop

A workshop of the members of the Swiss Biodiversity Forum was held on 14–15 March 2001 in Montézillon, Switzerland. The first day started with a presentation of the questionnaire results and a discussion of the aims and possible products of the workshop. A variety of lobbying strategies for biodiversity research was then assembled, after which there was a session aimed at defining a "new integrated biodiversity science". Finally, individual research questions (hypotheses) arising from the questionnaire were clustered under the following subtitles:

- Concept of biodiversity
- Assessment of biodiversity
- Influence of biodiversity on ecosystems
- Benefits of biodiversity
- Natural drivers of biodiversity
- Human drivers of biodiversity

On the second day, the participants at the workshop divided into three subgroups, each of which worked on two of the clusters. This work resulted in the three areas of research that we believe can serve as a basis for larger research programme proposals:

- Assessment of biodiversity, concept of biodiversity
- Influence of biodiversity on ecosystems, benefits of biodiversity
- Natural drivers, human drivers of biodiversity

After the presentation and discussion of the results of each subgroup, the participants at the workshop drew up an outline of the present document and discussed further steps to be taken after the workshop.

## 3. Further Steps (conducted and ongoing)

- ➔ Synthesis of the workshop: "Visions in biodiversity research" (Eva Spehn)
- ➔ Feedback from participants, filling of gaps, further elaboration of topics
- ➔ Further development of chapters and positioning of the Visions within the institutional framework of the Swiss academies of science (SANW, SAGW) and comparison with other national and international research plans
- ➔ Distribution of the final synthesis paper to target groups:
  - ~ The Swiss and international scientific community and international research networks (IGBP, DIVERSITAS)
  - ~ Swiss funding agencies (SNF, federal agencies, universities)
  - ~ Other national funding agencies (DFG, Germany; NSF, USA; NERC, UK)
  - ~ European funding agencies (ESF, EU Commission)
  - ~ Societies (Ecological Society of America, British Ecological Society)
  - ~ Research implementors (environmental agencies, Swiss Science Council, Swiss University Commission)
  - ~ The media and the general public
- ➔ Production of further documents to be used when lobbying for biodiversity research

# Visions in biodiversity research

## Towards a new integrative biodiversity science

In this document, members of the Swiss Biodiversity Forum present their ideas for a new and integrative approach to biodiversity research. The ultimate aim of the document is to stimulate research that improves our understanding of the processes affecting biodiversity and which enables us to conserve this vital natural resource and use it sustainably.

The specific goals of the 'Visions' referred to in the title of this paper are: (i) to describe the main areas of biodiversity research, (ii) to identify some of the major gaps and deficiencies in our knowledge, (iii) to develop strategies for strengthening biodiversity research, and (iv) to provide the baseline information needed for future discussions about funding priorities.

The proposals for new research areas are based on the considerable expertise of Forum scientists in the field of biodiversity research, and in particular on the experience gained during the ten years of the Swiss Priority Programme Environment (SPPU), which was completed in 2002.

Four principal focus areas are identified as essential for an integrated approach to biodiversity science. These are:

a The concept of biodiversity
b Natural and anthropogenic drivers of biodiversity
c Biodiversity as a driver of ecosystem functioning and the basis for human life
d The assessment of biodiversity

Each of these research fields is briefly described.

The paper provides a sound basis for the preparation of documents designed to support lobbying efforts when seeking increased funding for Biodiversity research, in order to improve the ability of the scientific community to answer important questions relevant to ecology, society and economy.

As well as identifying research priorities for those working within the field of biodiversity in Switzerland, the document sets out the importance of this research in the wider context of a research strategy to tackle issues connected with sustainability and global change. The importance of such a coherent strategy was emphasised by the Swiss scientific community in a brochure published in 1997.

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