MONITORING OF BIODIVERSITY

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Contents

Summary

Biodiversity is – by its nature - not a constant but a dynamic feature of ecosystems, changing its composition, structures and functional properties in response to a wide variety of external and internal influences. Monitoring of biodiversity is defined as the systematic and focused observation and measurement of present changes of biodiversity in its various forms (genes, taxa, structures, functions, ecosystems) usually within a defined context defined by e.g. a research question or a management goal.

During the past decades global environmental changes accelerated the intensity and speed of change of biodiversity at an unprecedented rate. In response, monitoring of such global changes became an important need. New methods and additional complexity resulted from the necessary integration of biodiversity monitoring into a wider Earth System perspective.

1. Introduction

Biodiversity is – by its nature - not a constant but a dynamic element of ecosystems, changing its composition, structures and functional properties in response to a wide variety of external and internal forces. During evolutionary time scales, biodiversity is even changing its basic entities, i.e. the species and other taxonomic levels and functional abilities. During shorter time scales, existing taxa and species pools are altered controlled by a wide variety of abiotic and biotic environmental factors. In the opposite direction, biodiversity alters the environmental parameters, due to the functional properties of the organisms.

In summary, the dynamics of biodiversity play a key role with regard to the indication, measurement, understanding and prediction of changes within living ecosystems. Based on this context, monitoring, i.e. the measurement of recent changes of biodiversity, is providing important information for an understanding of the properties and dynamics of each system. Especially, all efforts to manage biodiversity require measurement of the dynamics of the system with regard to four basic goals:

1. Measurement of the direction and speed of present change within a system are of basic importance. Monitoring of the status of availability of natural resources (e.g. hunted game etc.) or natural threats (e.g. occurrence of dangerous animals, diseases, etc.) are simple examples for observation of more or less natural systems. Within managed systems (farm systems, conservation plans) monitoring is required for the measurement of status in comparison to defined targets.
2. In many cases several external forces are considered to be responsible for an observed change of biodiversity, e.g. climate change versus land use change. Monitoring of both, the change of biodiversity and the course of the potential driving forces allows identification of the relative importance of each of several drivers.
3. Change, at a closer look, is based on a wide spectrum of mechanisms and processes, often including cascading effects. Monitoring allows an understanding of such mechanisms.
4. The above mentioned observations and analyses also enable to predict future changes. The quality of prediction greatly depends on the investment in scientific analysis.

All these quite different basic motivations to implement monitoring activities, have to take into account the complexity of biodiversity, given by the scales (ecosystem diversity, species diversity, genetic diversity), the aspects (taxonomic, structural, functional) and by the multitude of interactions between the large number of organisms and environmental conditions. This complexity entails the necessity to make clear decisions about the number of parameters to be measured and the methods to be involved. This is of special importance if monitoring results from different systems and sites shall allow comparison and spatial modeling.

While this complexity of goals, subjects and methods is discouraging for all efforts to set up major monitoring activities, on the other hand the dramatic global change of biodiversity defines the urgent need to supply reliable and scientifically sound data on the rate and direction of change of biodiversity, even at a global scale, i.e. beyond the boundaries of ecosystems, countries and cultures. Therefore, the roadmap towards an adequate global observation system of the change of biodiversity is an important discussion topic within the scientific community and the international environmental treaty structures, especially the Convention on Biological Diversity.

2. Multiple Goals of Biodiversity Monitoring

Monitoring of biodiversity serves many goals. Monitoring the population sizes of protected species in their conservation areas gives feedback on the success of conservation measures. Monitoring the spread of a toxic invading species or of an infectious organism can feed into an early warning system for farmers or for medical services. Monitoring systems at game farms allow optimization of population

management systems. These are just a few examples for the wide spectrum of applications.

In a more systematic way, the following list presents different approaches to monitoring as the response to very basic questions or motivations:

1. Neutral observation ("What happens?")
This approach of *pure* observation at first glance seems to be of little scientific value as no hypothesis is tested. On the other hand, we do not know for sure that all important drivers and processes involved in change of biodiversity are identified. We should still consider surprising new observations e.g. on the impact of rare events. Such a *pure* observation approach can also document the consequences of change, particularly if properties of the ecosystem form part of the observation program (e.g. soil quality, microclimate, land use).

2. Early warning system ("When must we take action?")
Change of biodiversity can have important consequences for ecosystem function and use of resources. Such changes seldom follow linear relationships. There are positive and negative feedback loops. Single events can cause cascades of secondary effects, and transitions from one meta-stabile phase of a system into another new phase may take place suddenly once thresholds have been passed (e.g. state of an ecosystem, size of a population or area of distribution). Therefore, an observation system should serve as an early warning system, which allows action to be taken well before irreversible damage has taken place.

3. Indicators of biodiversity change ("What is important?")
Observation of a large number of parameters and processes often requires large investments of time and manpower, which often are not available. An alternative solution is the observation or measurement of only a limited set of specific qualities and/or quantities which qualify as indicators for certain properties or states of a system. Such indicators may also serve for benchmarking progress towards defined targets in the frame of normative institutional efforts. For a detailed treatment please refer to *Search for Indicators for Biodiversity Assessments*

4. Causality approach ("Why does change happen?")
Observation of the type and intensity of change within a given ecosystem can allow identification of the drivers of change, if the measurement of such potential driving forces (e.g. specific climatic changes, specific land use practices) is integrated into the observation system. All listed approaches are suitable for identifying effects of climate change and/or other drivers and to analyze the role of different drivers.

5. Process analysis ("How does change happen?")
If observation is designed to provide additional scientific understanding of the mechanisms and processes of change, more detailed studies of dynamics of biocoenoses and populations have to be integrated. The resulting knowledge can also form the basis for the prediction of future developments:

6. Model-based approach ("Do we understand the full picture?")

Observations can be used to test (verify or falsify) and validate modeling results, if observation and model development are jointly established.

7. Experimental approach ("How can we intervene?")
One of the ultimate goals of biodiversity research is the implementation of sustainable use and conservation of biodiversity. For this purpose, observation can integrate a variety of experimental approaches for testing and measuring vulnerability, resilience, restorability and other system properties. If successful, this approach allows the derivation of management recommendations.

3. Monitoring of Biodiversity in a Global Change Context

Recently, within the context of human-made global environmental change, rates of change of biodiversity have reached a dimension far beyond natural processes. The resulting changes within the biosphere have strong effects on ecosystem functions and on human use of biodiversity. Considering the global dimension of such a human-made "reconstruction" of the biosphere, the sum of these changes obviously has a serious impact on the life support system.

Over the past millennia and centuries, human activities on our planet developed to an intensity and dimension which meanwhile can be described as a thorough reconstruction of the earths biosphere. Human influence on all existing ecosystems causes rapid changes of biodiversity, including extinction of phylogenetic lineages, invasion of exotic taxa and even the spread of artificially constructed genetically manipulated organisms (GMO´s) or part of their genome.

Many of these changes are not neutral in their functional consequences. Some are beneficial, others have negative impact on ecosystem functions, on other organisms and on goods and services, consumed by humans. Considering the dimension of change, many important elements of our life support system are altered and the consequences of all these changes, sometimes triggering cascades of changes in interrelated compartments, are not predictable.

Against this background, conservation and management of biodiversity gained a new dimension of importance and, therefore, also monitoring of biodiversity is of far higher relevance for biodiversity and for sustainable development.

Therefore, within the context of the international research programs dealing with global environmental change, monitoring of the change of biodiversity gained additional importance. Change is no longer seen as a local phenomenon or as a slowly developing trend. In the contrary: it is likely that complex feedback mechanisms and sudden and irreversible transitions of biological systems from one state to another should be expected in addition to slow changes within these systems.

With rising awareness of such global environmental changes, monitoring data are needed for a variety of goals, including (a) to understand the role and impact of drivers and causes of change, (b) to be able to analyze processes and mechanisms of change, (c) to lay the foundation for modeling and prediction of future changes, etc. Within a

defined strategy of adequate measurements and of transformation of the results, structured monitoring activities can play an important role for the planning of sustainable management and development. The open question is, which strategies and techniques for biodiversity monitoring are most adequate to analyze global environmental change of biodiversity in a context of sustainable development of human societies.

Nevertheless, the basic rationale of monitoring remained the same, as it was traditionally understood: To monitor a process or a dynamic system (origin: from Latin "*monere*" = "to remind", "to warn"; "monitor" = "reminder", "supervisor") means to observe or measure the relevant parameters which describe the change of a system adequately. Normally, the activity will be defined in a framework of strategic planning and it will serve a purpose: It will either be based on a hypothesis on the drivers and mechanisms of change, which need to be tested, or targets will be defined, which again require a monitoring activity as a control tool which measures the progress along the road towards the intended goal.

Results of monitoring can also be of direct relevance to policy-making. Especially, if the measurement of a current state in relation to either a starting point or a threshold or a defined target are of interest, the discussion is often dominated by the definition of an (or a set of several) indicator(s). This approach is discussed in detail by R. Scholes in *Search for Indicators for Biodiversity Assessments*. However, besides the use of monitoring for direct transformation into policy and decision-making, there is a vast scientific interest in monitoring, as well. In the context of research programs on global environmental change and with regard to the political efforts to define feasible approaches towards conservation and sustainable development of biodiversity, the definition of adequate monitoring systems is of high importance and forms one of the foci of the bioDISCOVERY core project with in the DIVERSITAS program.

Especially the political decision taken at the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 and within the UNCBD, to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth" has stimulated the discussion on adequate measures (compare *Search for Indicators for Biodiversity Assessments*) and on observation systems. Simultaneously, the interest in observation systems in other fields of interest, has stimulated the formation of the Global Earth Observation System of Systems (GEOSS). In this larger context, monitoring of biodiversity forms only one of many elements within an integrated observation system.

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Biographical Sketch

Norbert Jürgens: born 28.6.1953 in Rotenburg, Lower Saxony, Northern Germany.

1973 – 1980: University education in Biology at the University of Hamburg

1980: Diploma

1986: PhD / Dr. rer.nat. (Thesis: Ecology of African Succulent Plants)

1987-1992: Postdoc Research, Topic: Arid vegetation in the Namib region in South Africa and Namibia.

1992: Habilitation at the Faculty of Biology, University of Hamburg. (Thesis: Biogeography of plants of the Namib Desert Region)

1994: Full Professor of Botany (Systematics and Vegetation Ecology) at the

University of Cologne.

Since 1999: Chair of the National Secretariat of DIVERSITAS Germany

Since 2000: Head of Department of Plant Evolution and Systematics, Director of the Herbarium Hamburgense and supervisor of the Botanical Garden at the University of Hamburg

Since 2000: Chair of the BIOTA AFRICA Project network

2001: Member of the DIVERSITAS International Task Force

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Since 2002: Co-Chair of the German National Committee on Global Change Research

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