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An Agenda for Austrian Biodiversity Research at the Long-Term Ecosystem Research Network (LTER)

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1. Introduction

Natural ecosystems provide a wealth of services that are useful, or even critical to humans (Daily, 1997; Millennium Ecosystem Assessment [MEA], 2003). Biodiversity, while being of intrinsic value per se, is meant to be a system property crucial to the provision of many of these services (Kremen, 2005; Luck et al., 2003). However, the link between diversity, ecosystem function and ecosystem services is still poorly understood (Hooper et al., 2005). Given the many threats to the future of biodiversity (Ehrlich & Pringle 2008), our limited knowledge of how human uses depend on and influence biodiversity is particularly alarming. Developing an agenda that links biodiversity research to socio-ecology in general, and to the study of ecosystem service provision and resource management in particular is hence an urgent issue.

In this book chapter, we present a research framework for Austrian biodiversity research under the umbrella of the Long-term Ecosystem Research (LTER) network (Mirtl, 2010; Mirtl et al., 2010). We elaborate research recommendations for the topics natural resources, resource use, energy production, climate change and pollutants, structural abiotic and biotic change, and the development of new methodological approaches. We further discuss institutional requirements for achieving a successful, efficient and competitive biodiversity research in Austria. We address the products of such research and their users as well as interlinks with the other thematic areas of LTER, namely process-oriented ecosystem research and socio-ecological research.

2. Long-Term Ecosystem Research (LTER)

The European Long-term Ecosystem Research (LTER-Europe) is a network linking 400 research sites, 100 institutions and thousands of research projects in 21 national networks, conducting research into the broad range of European terrestrial and aquatic ecosystems from arctic to Mediterranean areas and covering all major longitudinal and altitudinal gradients (Mirtl, 2010). LTER is currently going through a major restructuring (cf. www.ilternet.edu). This involves the design of infrastructure and the development of approaches focused on coupled socio-ecological systems that emerge through continuous interaction of human societies with ecosystems (Haberl et al., 2006, Singh et al., in press). Sponsored by the European Union, the European LTER infrastructure has been designed and implemented based on existing sites (Mirtl, 2010). One component of LTER-Europe, the Long-term Socio-ecological Research (LTSER) aims at the integration of natural science biodiversity research with socio-economic research (www.lter-europe.net). Referring to this umbrella, the LTER research strategy in Austria was formulated and published as the LTER-Austria White Paper (Mirtl et al., 2010). The White Paper covers basic ecosystem research, biodiversity research and conservation biology and LTSER. In Europe, LTSER will be carried out on so called LTSER Platforms which represent geo-political regions where the interaction of nature and human society can be studied. LTSER mainly investigates ecological and societal pressures on ecosystems, their driving forces, the social and economic consequences of changes in ecosystems including the development, monitoring and evaluation of biodiversity management and policies.

3. Priority research themes

Biodiversity research in the context of LTER is conducted over long periods of time, considers the full range of relevant scales, and/or relies on the LTER in situ infrastructure (Dirnböck et al., in press). The biodiversity research priorities presented here are based on several strategic documents targeting the Austrian and the European level. We used only strategic documents which had been compiled by a wide range of scientists and stakeholders to guarantee the integration of the breadth of the national research communities' priorities. The Austrian perspective is provided by documents compiled at the national level, such as the Declaration "Hardegger Erklärung", which was elaborated at the kick-off meeting of the Austrian Platform for Biodiversity Research (Plattform Biodiversität Forschung Austria – BDFA) and signed by 172 Austrians active in the field of biodiversity. We also considered a survey on the prioritization of issues in Austrian biodiversity research, which was conducted by the BDFA (Platform for Biodiversity Research in Austria, 2008), and was based on a British shortlist of the 100 most politically relevant ecological questions (Sutherland et al., 2006). In addition, the members of the conservation platform at the Federal Environment Agency – mainly including representatives of administrative bodies, NGOs, and businesses – were questioned. We focussed on research that is of outmost importance taking the Austrian biophysical conditions and land use patterns into account, i.e. high importance of mountains, forests, freshwater and agricultural ecosystems. As the Austrian biodiversity research priorities are strongly linked to the European research agenda, we included the European perspective which is provided by several strategic documents elaborated by the European Platform for Biodiversity Strategies (EPBRS); this especially applies to "Mountain Biodiversity" (EPBRS, 2006), "Biodiversity in the Wider

Countryside" (EPBRS, 2007a), "Biodiversity and Ecosystem Services" (EPBRS 2007b) and "Freshwater Biodiversity" (EPBRS, 2008), being of particular relevance for the most important Austrian ecosystems. Consideration was also given to the very recently adopted EPBRS recommendations regarding ecosystem services (EPBRS, 2011) and to the "EPBRS Biodiversity Research Strategy 2010-2020" (EPBRS, 2010), which calls for a strong focus on research areas that generate the knowledge necessary to fulfil the following political goals:

- ensuring the long-term survival of species, their genetic diversity, and the ecological integrity and functionality of habitats and ecosystems
- ensuring the long-term provision of ecosystem services
- adapting to global change (including climate change)
- contributing to meeting other Grand Challenges (water, food, energy supply; population growth; human health)

The result of this survey led to three subject areas: resources and resource use, energy production, climate change and pollutants, and structural abiotic and biotic change.

3.1 Resources and resource use

This category includes the study of one or more species, of habitats and of ecosystem processes across guilds and trophic levels. LTER allows for a close alignment of biodiversity research and traditional ecosystem research, which primarily focuses on energy and material flows. Hence, the focus here is on the interaction between organisms and ecosystem processes. LTSER platforms can be used to extrapolate the gained knowledge from LTER based research to the regional, geopolitical scale. Studies about the utilization and conservation of biodiversity as well as the consequences of changes in utilization and their conservation impact are of particular importance. LTER Austria is an optimal frame to provide answers to research questions such as: To what extent do Austria's nature reserves meet a given set of goals (e.g. halting the loss of species, protecting endangered populations as well as endemic, demanding, rare or migratory species, etc.)? What are the consequences of the various (EU-guided) forms of agricultural land use on the conservation of biodiversity (Wrbka et al., 2008)? To what extent do individual forms of land management, such as hunting, fishing, forestry and farming, affect endangered populations?

Several topics that were given priority by the Austrian biodiversity research and conservation community were related to resources and resource use. These prioritized topics mainly dealt with the species themselves (taxonomy, distribution and abundance of species, population ecology, protection of species in situ), but also studies on the impact of organic farming and more investigation related to wetlands are required (Platform for Biodiversity Research in Austria, 2008). Of the research recommendations made by EPBRS, those relating to mountain and freshwater biodiversity (cf. EPBRS, 2006, 2008) are most relevant for biodiversity research at LTER Austria. Of particular interest is:

- a better understanding of the impact of human activities on the long-term sustainability of biodiversity;
- a better understanding of the role of genetic and species diversity for ecosystem dynamics, functions, and services;
- the coupling of research and long-term monitoring to assess the status, patterns and drivers of European mountain biodiversity at various scales of space and time;
- The definition of favourable states for mountain habitats and populations, as well as the identification of reference states for mountain ecosystems evaluating and taking into account ecosystem services;

- the definition of criteria, indicators, methods and processes for efficient conservation and sustainable management of mountain biodiversity;
- increased assessment of status and distribution of little-studied, ecologically important, or endangered freshwater taxa, habitats, and ecosystems;
- further development of tools to effectively conserve and sustainably use freshwater ecosystems, taking into account their specific characteristics, such as spatial and temporal dynamics and connectivity; and
- a better understanding of the functioning and role of soil biodiversity and subterranean freshwater biodiversity, especially as they relate to ecosystem services and their indicators.

3.2 Energy production, climate change and pollutants

The interactions between organisms, biotic communities, and the main driving forces of global change are of central interest here. The related knowledge is still very scarce and more targeted research is necessary to guide effective conservation measures. The following topics were given priority by the Austrian biodiversity researchers: climate change, climate policy, biofuels and hydropower (Platform for Biodiversity Research in Austria, 2008). Studies on ecosystem functioning are the core of LTER. Ideally, experimental and observational studies should be nested in the long-term monitoring schemes, which document changes of biodiversity and the environment over longer timeframes. This is especially true when it comes to climate change, climate policy and climate change mitigation and adaptation measures, which are currently implemented in numerous sectors such as agriculture, forestry, energy production and tourism. In view of the potentially severe effects of climate change in high mountain ecosystems (Engler et al., 2011), research in high-alpine territory is especially important (Dirnböck et al., 2011; Gottfried et al., 2011; Pauli et al., 2007). Studies on the impacts of climate change and its interaction with human land use on mountain biodiversity should constitute a core field in European research (EPBRS, 2006). The effects of fossil fuel emissions and agriculture on biodiversity (e.g. CO_2 effects, excess of reactive nitrogen, toxic substances, etc.) as well as the role of biodiversity for the functioning of ecosystems (e.g. carbon sequestration) are other highly relevant research topics.

3.3 Structural abiotic and biotic change

Structural changes of ecosystems have been massively accelerated by industrialization, land use change, habitat loss and fragmentation, and increased human mobility. The latter factor is the main driver of the invasive spread of non-native species (Pyšek et al., 2010).

The progressive loss of traditional landscape structures drives a massive crisis of farmland biodiversity that will probably not be completely realized until several decades into the future (Kuussaari et al., 2009). This opens a window of opportunity for rapid rethinking and the development of sustainable forms of utilization. Higher altitudes in the Alps still harbour many natural habitats. In the lowlands, natural and semi-natural habitats, which are important for biodiversity conservation (e.g. meadows, pastures, old-growth deciduous forests, and riverine areas) occur currently mainly as fragmented remnants of often an unfavourable status. The following topics related to the "wider countryside" (EPBRS, 2007a) and "freshwater biodiversity" (EPBRS, 2008) were recommended as research themes by EPBRS and should be included within the framework of LTER Austria:

- the importance of landscape structures, patterns and gradients for biodiversity, applied across different scales;
- effects of demographic, social, and economic trends as well as EU policies (including their national implementation) on biodiversity;
- indirect effects of climate changes (e.g. biofuel production);
- improving Agri-Environmental Schemes so that they deliver more measurable positive impacts for biodiversity; and
- the role of refugia in maintaining the long-term adaptive and evolutionary capacities.

Thus, studies related to cultural landscapes, landscape fragmentation and ecological corridors are required. Core research areas should include the effects of agriculture policies and changes in land use (e.g. land abandonment and subsequent afforestation of traditional cultural landscapes) on the species richness and composition of ecological communities (cf. Wrbka et al., 2008), the soil, and the vegetation structure. A special focus should also be given to the easily overlooked long-term effects of changing land use practices on biodiversity ("extinction debt", "invasion debt", cf. Essl et al., 2011; Kuussaari et al., 2009) which represent both a hidden threat and an opportunity for timely countermeasures. The use of genetically modified organisms and associated risks for the ecosystem will also be an essential focus of future research (e.g. Pascher & Gollmann, 1999; Pascher et al., 2011).

Transdisciplinary approaches that include stakeholders (farmers, foresters, hunters, people seeking recreation etc.) are indispensable for the restoration of the ecological integrity of cultural landscapes, traditional landscape patterns, and the ecosystem services associated therewith. While LTSER platforms provide ideal infrastructure for regional case studies, particularly in the context of transdisciplinary research (Singh et al., in press), LTER sites may serve as a pool for long-term monitoring data and sites for experimental approaches.

4. Approaches and methods

Within the framework of the "Hardegger Erklärung zur österreichischen Biodiversitätsforschung" 2008 (Platform for Biodiversity Research in Austria, 2008), the following three research questions were prioritised (compare also EPBRS, 2010):

- How do methods for evaluating the function of biodiversity in ecosystems need to be improved to capture its importance in supporting ecosystem services crucial for human wellbeing?
- How do biodiversity indicators and monitoring systems need to be improved to identify and prospectively assess the interaction between biological diversity and the drivers of global change?
- What are the most effective strategies and methods to assess, conserve, restore and sustainably use biological diversity?

4.1 Ecosystem functions and services

The concept of ecosystem functions and services (Boyd & Banzhaf, 2007; Costanza et al., 1997; Daily, 1997; De Groot et al., 2002) has been increasingly employed during recent years, since it facilitates an approach to evaluating the importance of intact ecosystems for humans. In the "Millennium Ecosystem Assessment" (MEA, 2003) and "The Economics of Ecosystems and Biodiversity" (TEEB, 2009), the importance of biodiversity and the corresponding ecosystem services was analysed and evaluated. 23 ecosystem functions were

determined, based on an even larger set of ecosystem goods and services (De Groot et al., 2002, see also Hermann et al., 2011 for a recent review). The contribution of biodiversity to ecosystem services and the influence of drivers and pressures on conservation and use of ecosystems are research aspects of particular importance (Kremen, 2005; EPBRS, 2007b, 2011). In the frame of a recent meeting under the Hungarian EU presidency that took place 27-29 of April 2011, the EPBRS (2011) adopted research recommendations regarding ecosystem services with the following ones being specifically relevant in the context of Austrian biodiversity research in the frame of LTER and LTSER:

- Develop standardized methods and criteria for the measurements, mapping and monitoring of biodiversity and ecosystem services at various temporal and spatial scales;
- Understand the ecological, economic and social aspects of the multiplicity of ecosystem services, identify trade-offs and synergies occurring between services, and develop management mechanisms and innovative uses;
- Identify and characterize linear and non-linear social and ecological dynamics (including tipping points) and their interactions, to foster ecosystem service resilience;
- Improve existing and develop innovative management techniques to reduce or eliminate drivers of dangerous change in ecosystem services or disservices such as biological invasions, chemical pollution including pharmaceuticals, and eutrophication;
- Assess the impacts on ecosystem services of novel or emerging pressures, such as alternative energy production, abrupt changes in management regimes in an oilconstrained world, and pollution by light and noise, nano-particles and micro-plastics;
- Better understand the disruption of ecosystem services, at various scales in time and space, caused by natural and anthropogenic drivers operating through phenomena such as mismatch in processes related to phenology, trophic interactions, and migration;
- Take into account uncertainty, complexity, and all relevant knowledge including local and traditional knowledge, in developing tools and methods to support the integration of ecosystem services into management and decision making in public and private sectors;
- Take into account the potential for changes in values under future scenarios, and the variability of values in various spatial, temporal and cultural contexts;
- Understand and evaluate ecosystem services provided by poorly known ecosystems such as glaciers, groundwater, and aquatic microbial communities;
- Identify the main threats to soil biodiversity (including to specific functional groups) and quantify their impacts on ecosystem processes and services;

4.2 Indicators

Indicators simplify, quantify, and communicate information on ecosystem processes that are too complex to be measured directly (Hammond et al., 1995). Biodiversity and sustainability in their entirety require very complex methods of measurement, which is why indicators are usually applied (Walpole et al., 2009). The indicators that are most relevant in terms of environmental policy are those that are easy to survey, efficient, cost-effective, sensitive to processes of change and robust against other influences (e.g. EEA, 2007; Gregory et al., 2009; Kati et al., 2010; Pauli et al., 2007; Renetzeder et al., 2010; Schindler et al., 2008; Tasser et al.,

2008). Frequently, environmental indicators are related to habitat and species diversity, land use and land cover, and invasive species. Biodiversity indication is a difficult task and the development of standardized methods to harmonize and supplement indicators for biodiversity as well as for its driving forces and the causes of endangerment is a European biodiversity research focus (EPBRS, 2007a). Well established indicators, such as the IUCN Red List Index, can undermine their own indicator performance as conservation actions become targeted towards Red List species (Newton, 2011). To ensure that naturally species-poor habitats (e.g. mires or acidic beech forests) are adequately represented, the contribution of such areas to overall biodiversity must be considered. Current indicators of species diversity have to be expanded towards genetic diversity and ecosystem diversity (Walpole et al., 2009), and multi-taxa approaches must be applied more frequently in conservation practise (Edenius & Mikuszinski, 2006; Poirazidis et al., 2010). Increasing the taxonomic, geographic and temporal area of biodiversity indicators has to be a paramount goal of biodiversity research. Due to long time series, simultaneous in-situ data of environmental and human pressures and its effects and integrative approaches, LTER Austria provides an outstanding opportunity for testing and improving indicators for biodiversity, sustainability, and climate change. In particular the LTSER platforms provide the possibility to relate such indicators to socioeconomics and ecosystem services, which constitutes another important research topic (Sachs et al., 2009).

4.3 Approaches for conservation and sustainable use of biodiversity

To conserve rare natural goods in the long term, research today increasingly has to address not only autecological problems but also synecological aspects on population and metapopulation levels. In this context, the methodological question of choosing the "right" spatial and temporal scale is of crucial importance for the design of new concepts of evidence based conservation and sustainability (Dirnböck et al. in press). The larger the areas designated for research, the more feasible it is to conduct studies on the level of the (meta¬)population (e.g. gene flow). At larger spatial scales, it is normally not feasible to gather field data across the whole investigation area, and ecological modelling is used instead (Elith et al., 2006; Guisan & Thuiller, 2005). Long time series of in-situ data are necessary to increase the precision of models that aim for instance at detecting changes of the composition of communities and population trends. The importance of indicators and modeling is also increasing, as a growing number of research questions is met with ever decreasing budgets, making it more important than ever to use funds economically. Ecological modeling, however, is not only a means of reducing cost, but is actually a field of research in itself. Further methods that, until recently, were still in their infancy regarding their application in biodiversity research (e.g. genetics, remote sensing) are now valuable options, opening up new fields of research (Avise, 2008; Gillespie et al., 2008; Grill et al., 2007; Schindler et al., 2010).

The human use of ecosystems is omnipresent. The socioeconomic component of LTER, namely LTSER, and relevant biodiversity research has gained tremendously in importance over the last two decades (Mirtl et al., 2010; Singh et al., 2010). LTSER platforms provide an optimal infrastructure to meet this new requirement, enabling research that links biophysical processes to governance and communication, consider patterns and processes across several spatial and temporal scales, combines data from in-situ measurements with statistical data, cadastral surveys, and soft knowledge from the humanities (Haberl et al.,

2006). The inclusion of society into the existing research infrastructure facilitates transdisciplinary approaches. These approaches, which include the participation and mutual learning of stakeholders, are crucial when the research focus lies on the indirect drivers of biodiversity loss (Balian et al., 2011; EPBRS, 2010, 2011), or when the gap between science (e.g. conservation planning and research based conservation recommendations) and action (e.g. implementation of conservation actions) should be bridged (Reyes et al., 2010; Schindler et al., 2011). Stakeholder involvement can also be of advantage when defining conservation priorities. For this purpose, transnational conservation initiatives such as the European Habitat and Birds Directives as well as biodiversity-related Multilateral Environmental Agreements have to be innovatively applied (Mauerhofer 2010, 2011) along with local or national assessments (e.g. national red lists, assessment of global conservation responsibilities).

5. Requirements

5.1 Structural requirements

Concerted research efforts are absolutely crucial for developing scientifically substantiated approaches to solving current problems related to biodiversity and ecosystems. Therefore, a research program founded upon a general consensus of the Austrian research community and approved at an international level is of great importance. To further strengthen research efforts, an even more efficient network of existing research facilities, initiatives, nature reserves and conservation programs is needed. A closer connection to European and international ecosystem research (e.g. LTER-Europe) is desirable; education in schools and universities must be encouraged and research institutions such as museums or universities need increased long-term financing. Cooperation and communication between science and the interested public needs to be specifically promoted.

5.2 Institutional requirements

Implementing the above-mentioned structural requirements implies institutional changes. Within the framework of the EPBRS biodiversity research strategy 2010-2020, five fields are presented for developing the research environment that is needed (EPBRS, 2010):

- continuous identification, revision and "horizon scanning" (i.e. wide, interdisciplinary early recognition of future developments; cf. Sutherland et al., 2010, 2011) of research foci;
- support of European and international platforms (e.g. GEO Bon, ILTER, GBIF, Biodiversity-Knowledge);
- increasing capacity through general and advanced education;
- creation of links between research and politics (e.g. via the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES); and
- regular evaluation of European biodiversity research with particular reference to its practicability and the applicability of research findings.

From the Austrian research community`s point of view, highest priority should be given to a better access to biodiversity-relevant information and databases (e.g. geodata, biodiversity data, environmental data); the long-term nature and continuity of networks and projects; integration/networking with international biodiversity research and other international initiatives; as well as improved access to research funding (Platform for Biodiversity

Research in Austria, 2008). A central data collection hub that is easily accessible for LTER-researchers, the "Data Center for Biodiversity and Conservation Research", is to function as an infrastructural institution in support of research activities and as such is seen as a vital prerequisite for improving the quality of research. Another key factor is ensuring the long-term support of existing institutions contributing to biodiversity and conservation research (e.g. nature reserves, museums and collections) as well as access to the data stored at these facilities. A consensual approach to the establishment of future research foci also seems to be of particular importance. This is where the concept of LTER comes into play, without which it would be almost impossible for selected LTER sites to bring together manageable amounts of data in a competent way, i.e. linked and made accessible to individual research groups.
The transnational LTER network offers the advantage of access to international data collections related to sites, where a wide range of potential drivers of biodiversity are measured simultaneously. As a first step, it provides meta-information on the existence of data sets and their holders and supports Austrian research teams to present their data and studies to the international research community – a fact that is highly relevant with respect to acquiring European funding. From a present-day perspective, mapping the research foci seems to be imperative and would give funding bodies a better overview of the entire research landscape. Identifying teams worthy of funding could thus be carried out in a balanced way across all sectors, to the benefit of current research foci.
In this context the ESFRI project LifeWatch is of high relevance (www.lifewatch.eu). It links "resources" (elements producing biodiversity related data like LTER Sites or collections) with the scientific users of such resources by supporing data mining, access and workflows related to complex analyses. LTER-Europe represents one of the major in-situ components of LifeWatch. Communities as well as national organisations engaged in LTER-Europe and LifeWatch are highly overlapping in about 50% of all LifeWatch countries, securing efficient lobbying and maximum use of synergies. In Austria a national LifeWatch strategy has been adopted (Mirtl et al., 2011), integrating LTER-Austria, the BDFA and the Austrian Biodiversity Documentation (museums and collections organized as national GBIF consortium).

6. Products and users

The driving forces of global change force public officials and conservation bodies to deal with complex questions, such as "Where do conservation measures make sense from an ecological or economic standpoint?" or "On which spatial scale are they likely to provide positive results?".
The more precisely it is possible to assess future developments, the easier it is to successfully counteract undesirable developments. Reflecting the wide spectrum of expertise involved, the range of results from biodiversity and conservation research is immensely varied. Their products should be made available to the research community, but should also serve policy makers and society as a basis for future planning and decision-making. Precisely because of the many interfaces between them and the various land use sectors, agriculture, forestry and recreational industries, the transdisciplinary results of biodiversity and conservation research provide practical approaches to the sustainable exploitation of traditionally-used resources. Decision-makers and in many cases the custodians of essential goods (e.g. water) are thus direct beneficiaries.

7. Conclusion

The global loss of natural habitats, biodiversity and ecosystem services represent one of the biggest challenges facing mankind. Emerging issues that could have substantial impacts on the conservation of biological diversity may become reality in the near future (Sutherland et al., 2010, 2011). By combining research and long-term monitoring and creating the necessary infrastructure for this, LTER Austria – in cooperation with LTER networks in other countries – can provide science based answers to the problems arising at an ever increasing rate due to global change.

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Research in Biodiversity - Models and Applications

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The book covers several topics of biodiversity researches and uses, containing 17 chapters grouped into 5 sections. It begins with an interesting chapter considering the ways in which the very biodiversity could be thought about. Noteworthy is the chapter expounding pretty original "creativity theory of ecosystem". There are several chapters concerning models describing relation between ecological niches and diversity maintenance, the factors underlying avian species imperilment, and diversity turnover rate of a local beetle group. Of special importance is the chapter outlining a theoretical model for morphological disparity in its most widened treatment. Several chapters consider regional aspects of biodiversity in Europe, Asia, Central and South America, among them an approach for monitoring conservation of the regional tropical phytodiversity in India is of special importance. Of interest is also a chapter considering the history of the very idea of biodiversity emergence in ecological researches.

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