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Scaling issues in long-term socio-ecological biodiversity research: A review of European cases

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CONTENTS

1 Abstract

International long-term ecological research (LTER) is currently going through a major restructuring that aims at improving its ability to address society's sustainability problems. This ongoing process involves the inclusion of approaches from the social sciences (Long-Term Socio-Ecological Research, LTSER). In Europe a network of regional LTSER platforms is being developed that is intended to help addressing the „biodiversity loss problem" much more efficiently than this was feasible so far. One challenge of LTSER is the consideration of relevant spatial and temporal scales because mismatches between the scale(s) of biodiversity, the scale(s) biodiversity is managed, and the scale(s) conservation policies are implemented, have been identified as a major obstacle towards halting or reducing biodiversity decline.

A total of 18 case studies was collected from five European countries (Austria, Norway, Germany, the Netherlands, and the United Kingdom), complemented by two European-wide studies. The case studies address threats to biodiversity such as climate change, land use change, eutrophication due to nitrogen enrichment and the invasion of alien plants. An evaluation was performed on the treatment of scale issues with reference to (1) biodiversity, (2) biodiversity management, and (3) biodiversity-relevant policy. Scale matches as well as cross-scale interactions were assessed. The results of this work are embedded in a review of critical scale issues in interdisciplinary biodiversity research.

The case studies surveyed exemplify characteristic spatial and temporal scale mismatches, disregards of relevant scales, and the superficial consideration of cross-scale interactions in interdisciplinary biodiversity research. The case study evaluation demonstrates that biodiversity research is still dominated by natural sciences and that scientific support at relevant scales is particularly limited for biodiversity-relevant policies and, to a lesser extent, for management.

Based on these findings we provide a set of methods which are suitable to bridge the various scales of socio-ecological systems. For LTSER, the landscape provides an inevitable link between natural and social science. Upscaling approaches from small-scale domains of classical long-term biodiversity research to the landscape scale include landscape metrics and spatial modelling. Multidisciplinary, integrated models are feasible tools for linking not only disciplines, but also for bridging scales. Those which are capable of analysing the impacts societies have on landscapes are particularly suitable for interdisciplinary biodiversity research. The involvement of stakeholders should be an integral part of these methods in order to minimise conflicts over local and regional management interventions derived from the implementations of broad-scale policies. Participatory approaches allow the linkages to be made between the specific scale domains of biodiversity, its management and policies.

Keywords:
Biodiversity; conservation; management; environmental policy; LTER; LTSER; scale; scale mismatch; cross-scale interaction

2 Introduction

Sponsored by the European Union, a framework for designing a European long-tem research infrastructure is currently being developed that is particularly focused on the integration of natural science biodiversity research with socio-economic research (www.alter-net.info). The ongoing decline of biodiversity results to a large degree from anthropogenic drivers like the intensification of the agriculture and forestry sectors or the emission of greenhouse gases (Sala et al. 2000, Thomas et al. 2004, MA 2005, Reidsma et al. 2006). How to achieve the global aim of mitigating further biodiversity loss - stated at the World Summit on Sustainable Development (CBD Decision VI/26) - is still a matter of debate, and the existing research and monitoring infrastructure seems to be inappropriate (EEA 2001, Parr et al. 2002). Long-term ecological research (LTER) is carried on by a global network of scientists engaged in long-term, site-based ecological research activities (http://www.ilternet.edu/, Hobbie et al. 2003). LTER is currently going through a major restructuring that aims at improving its ability to address society's sustainability problems (Haberl et al. 2006). 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 (Redman et al. 2004, Haberl et al. 2006). In Europe long-term socio-ecological research and monitoring (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. We here use the term "socio-ecological system" synonymously with similar notions such as "coupled human-environment systems" or "socio-environmental systems" (GLP 2005, Dearing et al. 2006). LTSER will investigate 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.

One particular challenge within the endeavour of establishing such a long-term research infrastructure is the issue of scale (Redman et al. 2004, Haberl et al. 2006) which, according to Gibson et al. (2000), is defined as "the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon". The crucial role of spatial and temporal scale for natural processes and pattern has long been recognized (Wiens 1989, Levin 1992, Peterson and Parker 1998). This issue is particularly critical when dealing with biodiversity (Tilman and Kareiva 1997, Yoccoz et a. 2001, Leibold et al. 2004, Rahbek 2005). In classical LTER, the focus was on long-term processes from thousands of years in paleoecology to annual seasons in population studies (Hobbie et al. 2003). The explicit consideration of the scale issue by social scientists is a rather novel phenomenon, but the importance of these issues is increasingly recognised (Wilbanks and Kates 1999, Cash and Moser 2000, Gibson et al. 2000, Giampietro 2004, Vermaat et al. 2005, Young et al. 2005). Mismatches between the scale(s) of the ecological processes, the scale(s) these processes are managed, and the scale(s) environmental policies are implemented have been identified as one major obstacle towards nature conservation (MA 2005, Carpenter et al. 2006, Cumming et al. 2006).

Ecological investigations usually refer to a defined study area and period of time. Both temporal and spatial scales of ecological units analysed are thus obvious. While temporal scale is often similarly explicit in the social sciences, this is less so with reference to space. Although many socio-economic analyses are also carried out with reference to a defined area, many social entities, such as households, companies, NGOs and many other social groups can hardly, if at all, be localized, and thus the concept of spatial scale cannot be applied to them. Just as for biological systems, however, society may be thought to be integrated at various levels, that may or may not be hierarchically organized (Giampietro 2003). There is a long tradition in analyzing nation-states (sociology, political sciences), local communities (social anthropology, development studies), farming systems (agricultural economics, rural development), and households (sociology, social anthropology).

Most often ecological and social processes operate at a wide variety of scales or levels and cross-scale/level interactions occur frequently (Cash and Moser 2000, MA 2003, Cash et al. 2006). Therefore, integrated research needs to be conducted at appropriate scales and levels so that efficient and goal-oriented political and management decisions can be developed. However, the ecological and socio-economic research and monitoring methods often do not match in terms of spatial and temporal scale (Carpenter et al. 2006, Cumming et al. 2006). Socio-political and socio-economic studies typically produce coarse-scale data about pressures influencing biodiversity, whereas parameters related to ecological patterns and processes are often sampled at much finer scales and hence causal links are not easily demonstrated. There is thus an urgent need for methods which are capable of bridging the various scales typical for disciplinary research.

The objectives of the paper are 1) to review critical scale issues of interdisciplinary biodiversity research, 2) to illustrate the treatment of spatial and temporal scale through a meta-analysis of 18 case studies of European biodiversity research, 3) to outline some of the methods which might be practicable interfaces for bridging the relevant spatial and temporal scales in LTSER.

3 Scale in interdisciplinary approaches

Why did scale become a critical issue in biodiversity research?

The treatment of scale in scientific disciplines has been different mainly due to differences in the subject of study, conceptual background, and the approaches towards data acquisition – and rather not due to different definitions of scale (Gibson et al. 2000, Vermaat et al. 2005).

Subject of study: Political sciences and economics are more concerned with human decision-making on different levels. These disciplines focus on agents and their behaviour, e.g. conservation area managers, local environmental administration or environmental ministries (Gezon and Paulsen 2004). These may or may not be directly related to a specific spatial unit of ecological research, like biomes, habitats or species populations (Wiens 1989). On the other hand, ecology and geography are more concerned with processes and evolving patterns, whose spatial resolution and extent may not be directly related to any relevant level of human decision-making (Levin 1992). While the concepts of scales and levels are not necessarily perceived differently, different subjects of study may still lead to mismatches in joint research.

Conceptual background: The problem of scale also arises from different conceptual foci in different disciplines. Economics is primarily concerned with aspects of allocative efficiency, i.e. how to allocate available resources in order to maximize some desired output (for instance the maximisation of conserved species subject to a budget constraint, e.g. Ando et al. 1998). While this is, of course, to a certain extent dependent on spatial aspects, the spatial distribution of the allocation itself is not of major interest. In contrast, in ecology the emerging spatial patterns and interactions bewteen processes occuring on different scales are often the primary focus of research, while less attention is often paid to the aggregate outcome (Levin 1992). Only recently, spatial aspects have become an important research topic in economics concerned with biodiversity conservation (Polasky et al. 2001, Lichtenstein and Montgomery 2003, Wätzold and Drechsler 2005).

Data availability: Some disciplinary preferences for certain scales can also be explained by data availability. As human geography, economics and political sciences heavily rely on official statistics in which data refer to areas delineated by defined administrative boundaries (Liverman et al. 1998). Their analyses are primarily focused on those spatial units and related levels of decision-making. On the other hand, the spatial resolution of many ecological and biogeophysical research approaches is determined by the observation technology, which can be a field survey technique or the available land cover data (Wiens 1989, Vermaat et al. 2005).

The challenge of scale-explicit interdisciplinary research

Much has been written on the concept and treatment of scale in different ecological disciplines (Wiens 1989, Levin 1992, Tilman and Kareiva 1997, Peterson and Parker 1998). Gibson et al. (2000) and Vermaat et al. (2003) presented a review on the treatment of scale in ecological economics and related fields. Complementary to this body of work, we here present a review of the treatment of critical aspects of scale in various research traditions within the broad field of sustainability science that are concerned with the integrated, interdisciplinary analysis of socio-ecological systems, focussing mostly on social ecology and political ecology.

In recent years, sustainability science has recognized that interaction patterns between systems of different spatial scales and different speeds are crucial in managing human-nature relationships. This is in part triggered by the interest in complex adaptive systems as composed of loosely connected hierarchical structures which exhibit self-organising, emergent phenomenon based on the concept of “holon” (Kay et al. 1999). The term “holon” was devised as an attempt to bridge the gap between individual behaviour at the micro-scale and aggregate behaviour at the macro-scale (Koestler 1967). Such socio-ecological systems have also been described as so-called “panarchies” (Holling et al. 2002, http://www.resalliance.org). This term was coined to avoid the notion of hierarchy which is often understood as a rigid, top-down structure. Using a considerable number of case studies, members of the Resilience Alliance (http://www.resalliance.org) propose that system dynamics tend to be faster on small scales which in turn are embedded in slower processes at larger scales: “Fast levels invent, experiment, and test; the slower levels stabilize and conserve accumulated memory of past, successful, surviving experiments. The whole panarchy is both creative and conserving” (Holling et al. 2002, p. 76). Eventually, however, even large-scale systems may undergo fast change, as exemplified by revolutions or the collapse of civilizations (Tainter 1988, Diamond 2005). Empirical studies of the long-term dynamics of socio-ecological systems have focused on national and local scales, while a global picture is emerging only gradually (Krausmann 2004, Krausmann and Haberl 2002, Schandl and Schulz 2002, Fischer-Kowalski and Haberl 2007). A phenomenon that still has to be integrated in this concept is that important social systems such as transnational corporations and internet discussion groups are not localized and do therefore not fit neatly into spatially delineated system descriptions.

An important contribution to sustainability research has been the organisation of trans-disciplinary research activities. They aim at ensuring that scientific knowledge is useful and understandable for decision makers and that perceptions and interest of stakeholder are considered in deriving solutions, thus helping to develop measures and policies that are acceptable for a wider public. This in fact requires a recognition of the importance of cross-scale interaction when it comes to decision-making concerning environmental and natural resource management issues (Berkes 2006). This problem was described as a challenge of "institutional fit" (Cash et al. 2006, Young 2006). For example, a farmer's decision on which crops to plant is based on his or her knowledge of water supplies, weather, market prices, etc. but seldom by knowledge on how crop production may be influenced by future climate change. Likewise, research on global climate change rarely, if ever, considers local-level dynamics of agricultural agents. Political ecology is concerned with the study of conflicts arising from uneven distribution of natural resources among stakeholders at multiple scales (Guha and Martinez-Alier 1997, Martinez-Alier 2002, Gezon and Paulson 2004). All possible natural resource systems have direct users (those living in close spatial proximity of the resource) and indirect users (those located far away); both groups often stake claims for the same natural resource. Biodiversity and several other ecosystem services such as water resources and carbon sequestration functions of ecosystems are acknowledged to be of global value (MA 2003). Thus conflicts arise when resource use at the local scale impacts on biodiversity. It remains contested, however, what degree of participation and autonomy of local communities is most appropriate to achieve an effective management of natural resources. This may range from a mere token participation to joint management to community management, the last being a position where its proponents argue for a full control of resource management at the local level.

4 European biodiversity case studies

Methods and definitions

We use a series of case studies from 5 European countries in order to evaluate European biodiversity research with reference to the temporal and spatial scales addressed. We survey studies concerned with major threats for biodiversity such as climate and land use changes, eutrophication due to excess nitrogen deposition, and the invasion of alien plants. In order to facilitate the assessment of scale matches and cross-scale interactions we gathered case studies according to two criteria.

i) *Cross discipline criterion:* We use the "DPSIR framework" (see e.g. www.eea.europe.eu) to guarantee that not only biodiversity per se, but also biodiversity management and policy was tackled in each study. In this indicator scheme, D denotes natural and anthropogenic drivers, P their respective pressures on biodiversity, S the state of biodiversity, I impacts of biodiversity change on society, and R response measures taken to mitigate negative impacts. We select studies that use indicators for more than one part of the DPSIR framework. As a guideline for the grouping of indicators we use EEA (2003).

ii) *Collection criterion*: In order to assess the links between the applied scales we need a continuous range from local sites to landscapes, municipals, districts, provinces federal states, supra-national regions and Europe. Very few single studies adequately address these multiple scales, but the collection of case studies should do that. Each national collation of case studies should thus include local to landscape and regional to national studies. This set is then complemented by supra-national and European studies.

The processes that drive socio-ecological systems arise from different domains in terms of their temporal and spatial scales. We consider scale domains as space-time windows of observation by which the qualities of interest can be defined and studied (Wilbanks and Kates

1999). For example plant population dynamics operate locally (in most cases), whereas meteorological patterns emerge at extensive spatial scales. In order to describe these qualities of interest in terms of their extent and resolution we survey the case studies with regard to the use of the above mentioned indicators. Although often only implicit, scale domains are used intensively in ecological and socio-economic research and monitoring (e.g. Wilbanks and Kates 1999). Since no common understanding exists, we define spatial scale domains for the present study according to Table 1.

Table 1: Definitions of spatial and temporal scales applied in the present study. The same definitions are used for resolution and extent.

Spatial scale		**Temporal scale**	
Local	< 1 km, experimental plot, species, habitat, individual, household, small to medium size farmstead, etc	*Short-term*	< 3 years (e.g. common ecological experiments)
Landscape	1 - 50 km, small catchment, (small scale) landscape, large farmstead, municipal, farming system etc	*Mid-term*	3 – 10 years (e.g. conservation management plan, regional agricultural development, etc.)
Regional	> 50 km, large catchment, large scale (landscape), province, federal state, etc.	*Long-term*	> 10 years (e.g. long-term monitoring, demographic, economic development, etc.)
National	national state		
Supra-national	biogeographic regions, continental, subcontinental, unions (e.g. EU), etc.		

Scale matches are surveyed between (1) biodiversity, understood as the "the variability among living organisms […]; this includes diversity within species, between species and of ecosystems" (Article 2 of the Convention on Biological Diversity), (2) biodiversity management, i.e. the various types of local human interventions in the ecosystem, and (3) biodiversity-relevant policy, its goals and targets as well as its specific instruments (see Cash and Moser 2000 for a similar structure). We further highlight monitoring, research and evaluation acting upon each of these parts because these activities are essential to help societies in mitigating their pressures on biodiversity. We then use the criteria and definitions summarized in Table 2 to identify scale mismatches. For each case study and for each aspect of biodiversity surveyed, management and policy spatial and temporal scale domains are defined by personal judgement. These domains were then compared with the spatial and temporal scales of the indicators used in the respective study. In order to derive overall figures all scale matches, mismatches and disregards were summed up.

Table 2: Definition of scale mismatches between biodiversity, biodiversity management, and biodiversity-relevant policy (upper two rows). Definition of scale mismatches of research, monitoring, and evaluation carried out within each of these parts (third row).

	biodiversity	management	policy instrument
Management	A mismatch exists if biodiversity is studied at a temporal and spatial scale(s) which does not or only partly correspond with the particular authoritative reach of the institutional level at which biodiversity is or can be managed		
policy instrument	A mismatch exists if biodiversity is studied at a temporal and spatial scale(s) which does not or only partly correspond with particular authoritative reach of the institutional level biodiversity-relevant policy instruments operate	A mismatch exists if biodiversity is managed at an institutional level whose temporal and spatial scale(s) of authoritative reach does not or only partly correspond with the scale(s) of the authoritative reach of policy instruments	
research / monitoring / evaluation	A mismatch exists if the scale(s) of research, monitoring and evaluation of biodiversity is carried out does not or only partly correspond with the temporal and spatial scale at which biodiversity is determined	A mismatch exists if the scale(s) of research, monitoring and evaluation of biodiversity management does not or only partly correspond with the particular scale of information necessary to effectively manage biodiversity	A mismatch exists if the scale(s) of research, monitoring and evaluation with reference to particular policy instruments do not or only partly correspond with the particular scale of information necessary for political decision making

Potential cross-scale interactions of the systems surveyed were defined by personal judgement and looked for in the respective case study. We define cross-scale interactions as those in which processes and phenomena at one scale or level influence processes and phenomena at other scales or levels (see appendix for details).

Results of the case study approach

In total, 18 case studies are collected from 5 countries (Austria, Norway, Germany, The Netherlands, and United Kingdom) and 2 European-wide studies (see Appendix). Many of the case studies are composed of a series of subtopics but are embedded within a broader, mostly interdisciplinary research approach. Climate change is addressed by 8 studies, land use change by 17 studies, eutrophication due to excess nitrogen deposition by 5 studies, and the invasion of alien plants by one study. In some cases several of the threats for biodiversity are taken into account simultaneously. We do not state that the case studies are a representative sample of European biodiversity research but their disciplinary and geographical spread warrants their value as illustrative examples of how the scale issue is commonly addressed.

The spatial extent considered ranges from local to supra-national, but most studies have been conducted on the national scale. The resolution is mostly local (Figure 1). Notably, 11 studies have a long-term extent and a short-term temporal resolution prevails.

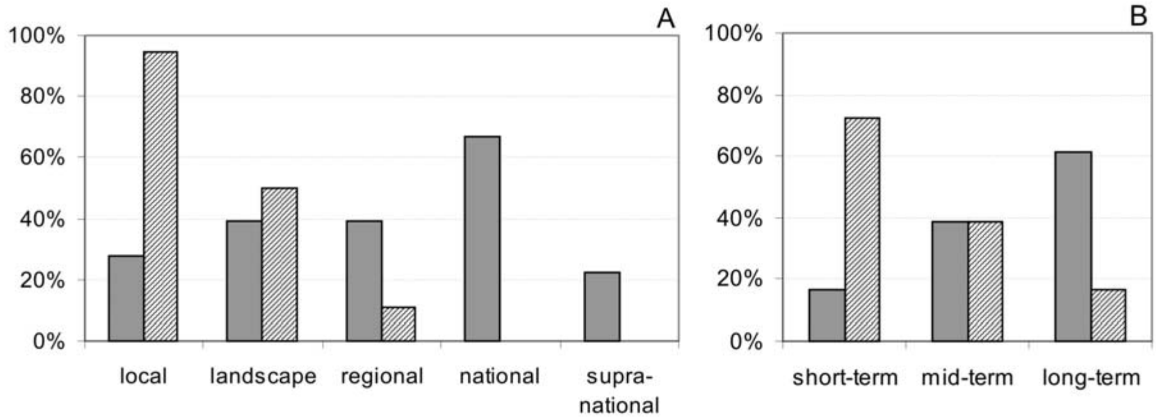

Figure 1: Distribution of spatial (A) and temporal (B) scales used in 18 European biodiversity studies. Hatched bars represent the resolution whereas grey bars represent the extent (percent of all studies). More than one scale is possible per case study. See Table 1 for the definition of scale domains.

The assessment of the case studies showes that scale mismatches are both a question of failure and of disregard. None of the 18 studies takes into account all relevant scales. The majority of studies addresses some relevant scales but disregards others (Figure 2). Often the focus is on one end of the scale range. For example, the landscape scale processes of plant or animal populations are often neglected when the focus is on local scale dynamics. In these cases the scales and levels of management and biodiversity-relevant policies are also disregarded as they are rather expressed at the landscape and even broader scales. In many case studies the variety of scales at which biodiversity-relevant policies are implemented are ignored or wrongly addressed (Figure 2). This is often true for local and regional research projects. Owing to the nested design of many European research studies, where regional case studies are embedded in a broader context, the multi-scale nature of policies is generally taken into account more carefully.

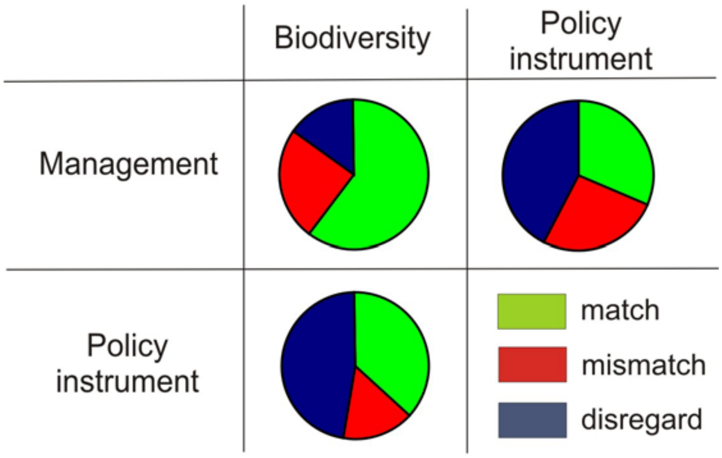

Figure 2: Distribution of spatial scale matches and mismatches between biodiversity, biodiversity management, and the biodiversity-relevant policy in 18 case studies across Europe. Scales relevant but disregarded are given as a separate group. For each case study spatial and temporal scale domains were defined for each aspect of biodiversity, management and policy. These domains were compared with the spatial and temporal scales of the used indicators of the respective case study. All matches, mismatches and disregards of all case studies were summed up to derive this overall figure.

The following example of spatial scale mismatches was particularly striking: The invasion of the alien plant *Rhododendron ponticum* in the UK, which causes considerable conservation problems, provides a good illustration of scale mismatches between the plant's spatial ecology and the methods and policies available to control it. The spatial dynamics of the plant's invasion are driven largely by the scale of seed dispersal and the pattern of habitat available for germination (e.g. Stephenson et al. 2006). Patterns of dispersal and habitat availability at a fine resolution (perhaps measured in meters) can potentially determine the rate of spread of the population at a local or landscape scale. Methods for controlling the plant are well-developed and, when properly implemented, they are effective. However, a lack of understanding of the spatial dynamics of the plants means that effective control over a spatial extent is often poor. This is already a problem within an area managed by a single landowner but becomes even more problematic when an infestation of *Rhododendron* occurs over a matrix of different estates owned by numerous individuals. Coordination of control activities at a local or a landscape scale is required for successful spatially-extended control, but this very rarely takes place. A greater understanding of the economic impacts of Rhododendron in a spatial context, including external costs associated with the probabilities that the plant spreads from one estate to another (Dehnen-Schmutz et al. 2004) will helpfully motivate a change in practice at regional scales. At the policy level, either at County, National or EU scale, a better strategic appreciation of the spatial nature of the problem would help. Currently, much of the funding for control is provided on an ad hoc basis, and there are only infrequent attempts to effectively control *Rhododendron* at a landscape or regional scale.

Long-term biodiversity research is still very rare. The information about the long-term consequences of management interventions and policies is thus very limited. This is illustrated in Figures 3 by the high proportion of scale disregards, which stem mostly from the predominance of short and mid-term studies. The relevant scales of management and of policies are thus often not addressed.

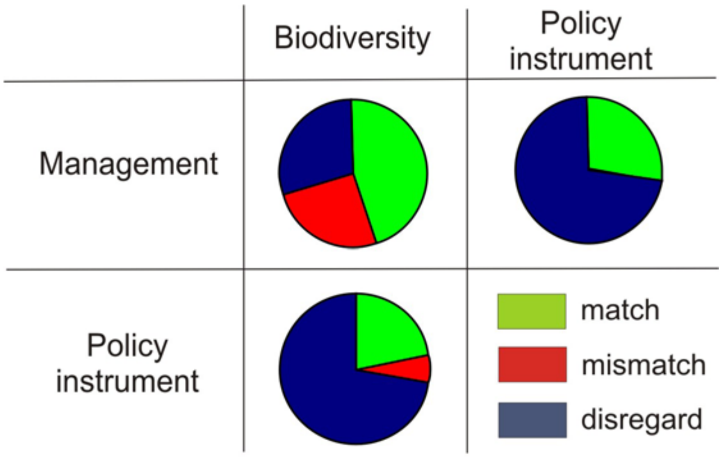

Figure 3: Distribution of temporal scale matches and mismatches between biodiversity, biodiversity management, and the biodiversity-relevant in 18 case studies across Europe. Scales relevant but disregarded are given as a separate group. For each case study spatial and temporal scale domains were defined for each aspect of biodiversity, management and policy. These domains were compared with the spatial and temporal scales of the used indicators of the respective case study. All matches, mismatches and disregards of all case studies were summed up to derive this overall figure.

The following example is useful to demonstrate mismatches of temporal scales: An extensive and costly experimental study was carried out in the UK, the farm-scale evaluation (FSE), in order to assess the effects of differences in the management – especially the type of herbicides used and the timing of their application – of conventional and genetically modified herbicide-tolerant crops on the diversity and abundance of plants and invertebrates (Firbank et al. 2003). In general, the study demonstrated a series of direct or indirect effects. Notably, various discussion papers appeared with some of them explicitly criticising the limited usefulness of FSE due to neglected temporal and spatial scales: "The most serious limitation of the FSE from the standpoint of public policy is that the study has no predictive component. Forecasts of the likely impacts on biodiversity 10, 20, or even 50 years into the future and at a landscape scale are needed if policy decisions are to be made. However, the FSE was not designed with the goal of estimating parameters for the development of predictive models, but was tied to a rather narrow hypothesis test and constrained to a field scale. Therefore, the current results are inadequate to make long-term policy evaluations." (Freckleton et al. 2003).

Ecological research, monitoring and evaluation focussing only on biological aspects of biodiversity has largely taken the relevant spatial, and to a reasonable degree also the temporal scales, into account. However, the case studies highlight that scientific support at relevant scales is particularly limited for biodiversity-relevant policies and, to a lesser extent, for management (Figure 4). This result may be biased by the selection of case studies. Nevertheless, it illustrates that biodiversity research is still dominated by natural sciences with its specific scales of research. Though exceptions exist, in many case studies, social, economic and political topics are mere accessory matters.

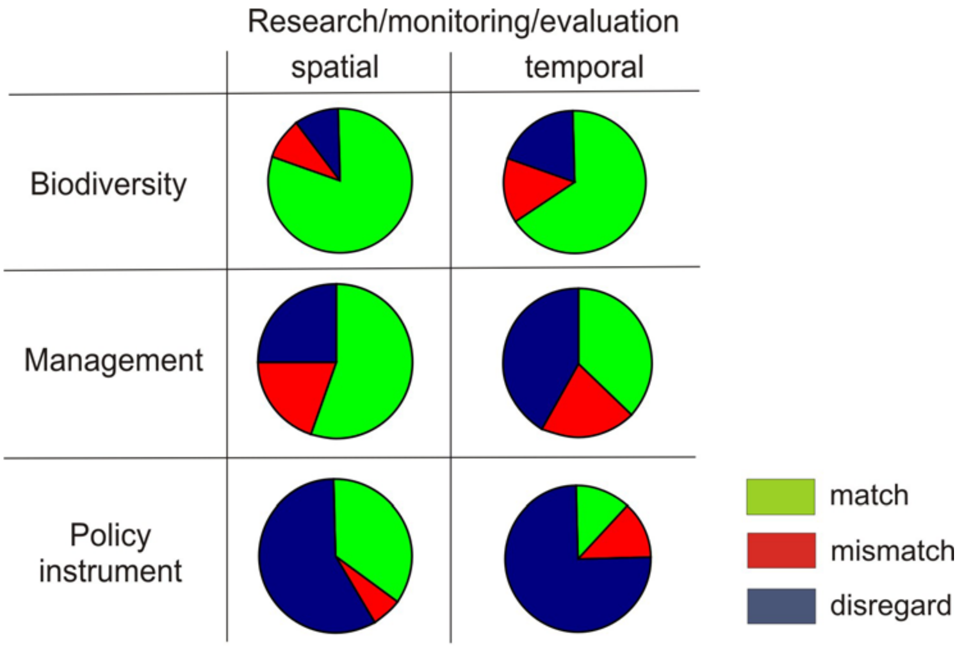

Figure 4: Distribution of spatial and temporal scale matches, mismatches, and disregards between the biodiversity, biodiversity management, the biodiversity-relevant policy and monitoring, research and evaluation acting upon each of these parts. Data from 18 case studies across Europe. Scales relevant but disregarded are given as a separate group. For each case study spatial and temporal scale domains were defined for each aspect of biodiversity, management and policy. These domains were compared with the spatial and temporal scales of the used indicators of the respective case study. All matches, mismatches and disregards of all case studies were summed up to derive this overall figure.

In the total of 18 case studies, 55 potential cross-scale interactions between aspects of biodiversity, biodiversity management and policies were identified by personal judgement. Only 23 of these had been explicitly taken into account in the respective case study, at least as far as this could be judged from reading the written material. In addition, 15 cross-scale interactions had been considered implictly in one way or another.

The following study is a useful example for an attempt to account for cross-scale interactions: Schmitzberger et al. (2005) investigated the relationship between biodiversity and farming activities in selected Austrian agricultural landscapes. The concept of farming styles, which integrates human attitudes, farming objectives and economic success was used. A close link between farmer mentality, land-use intensity and biodiversity could be demonstrated. The farming styles also differed in their dependency on agro-environmental subsidies. Agro-environmental subsidies were thus amenable to assessment from the viewpoint of biodiversity conservation by linking a range of scales and levels. However with this first step study, the relationship between scales remains rather descriptive and correlative and the mechanisms of interactions between socio-ecological processes at different spatial scales cannot be inferred.

5 Towards scale-explicit LTSER approaches

European LTSER platforms are currently being implemented at the regional scale as a long-lasting research infrastructures and a network of such platforms is currently emerging across Europe (www.alter-net.info). The case studies analyzed above exemplify that ecological research often misses the broader scales at which social science can be linked to ecological research in order to provide useful support for biodiversity managers and policy makers. For LTSER the landscape provides an inevitable link between natural and social science since its structure and processes are the variable outcome of the interplay of nature and society (Haberl et al. 2006). The landscape is therefore integrating several scales of this interaction (Farina 2000, Naveh 2000a, b). Biodiversity too, is profoundly impacted by processes and structures of landscapes (Leibold et al. 2004, Young et al. 2005). LTSER is devoted to long-term research due to the fact that many ecological and social processes are inherently slow. The case studies illustrate that long-term - particularly interdisciplinary - research is still very rare. Long-term landscape scale research which will thus be one main focus at most LTSER platforms and innovative metaanalysis methods will be needed to analyze and interpret the results across the LTSER network (Young et al. 2006). Ecological research and modelling also offer several approaches that help in upscaling findings from small-scale studies to the landscape scale.

Moreover, several modelling techniques are currently emerging that are able to link natural and social drivers at different scales and – with a given uncertainty – can predict the likely outcome of management actions and policy decisions at various scales. Few interdisciplinary studies so far address the various scales of management interventions and policies. Participatory approaches, could help in mitigating conflicts that arise when broad scale goods like biodiversity are to be conserved locally. These methods are thus basic necessities for the design of a scale-explicit interdisciplinary biodiversity research at LTSER platforms.

Upscaling site-based research to the landscape scale and the long-term

The scale at which landscape studies are conducted may profoundly influence the conclusions (Turner 1989). Patterns and processes important at one scale are frequently not important or predictive other scales (e.g. Zechmeister and Moser 2001, Moser et al. 2002, Wrbka et al. 2004), and information is often lost when spatial data are considered at coarser scales, i.e. low resolution (Meentemeyer and Box 1987). Ecological problems may also require the extrapolation of measurement gathered at a plot level to the landscape scale (Peterseil et al. 2004). Likewise, it is often necessary to assess the relevance of broad scale trajectories in socioeconomic data or indicators on finer scales. This task is often difficult, if at all feasible, since the data available in official statistics represents aggregate figures for large, heterogenous areas such as the territory of municipalities, districts or even provinces.

One set of methods that can help in this respect have emerged in the last decades within landscape ecology, a research field with a largely natural-scientific origin. Landscape ecology examines the relationship between landscape patterns and ecological processes (Forman and Godron 1986, Turner, 1989, Gustafson 1998), using landscape metrics to quantify and describe characteristics of the landscape structure (McGarigal and Marks 1994, Haines-Young and Chopping 1996, Gustafson 1998, Hargis et al. 1998). Many of the indicators used in landscape-ecological analyses refer to abstract holistic features of the landscape, such as heterogeneity, diversity, complexity, or fragmentation. The purpose of landscape metrics is to obtain sets of quantitative data that allow a more objective comparison of different landscapes

(Gustafson 1998, Antrop 2000). The question of scale with reference to resolution and extent is very important for the calculation of many landscape metrics (Cullinan and Thomas 1992, O'Neill et al. 1996). O'Neill et al. (1996) suggest as a rule of thumb that the resolution of data should be two to five times smaller than the spatial features of interest, and that the extent should be two to five times larger than the landscape patches to avoid bias in calculating the indices. However, the necessity to use rules of thumb instead of solid, evidence-based knowledge illustrates well the poor scientific state of the art with reference to mechanisms that drive the abundance and distribution of species. Vos et al. (2001) thus proposed a framework of ecologically scaled landscape indices (ELSIs) that take this variation into account. A combination of ELSIs and ecological species profiles is used to facilitate this concept in practice. Other approaches are to identify species-specific and scale-specific thresholds of indices for assessing the effect of e.g. habitat fragmentation on the survival of species (Jaeger 2000, Tischendorf and Fahrig 2000).

Modelling approaches have been developed using theoretical frameworks such as the species-area-relationship - which predicts that species diversity increases with increasing area available - to model diversity at the landscape scale (Pereira and Daily 2006). Another widely applied technique in this context is that of habitat distribution models which use an array of spatial environmental data in order to predict species, communities or species diversity (Guisan and Zimmermann 2001). Both techniques have been applied successfully. However, they lack significant determinants of species diversity - like the dispersal of species in fragmented landscapes – which are particularly crucial when effects of environmental change are to be investigated (Ibáñez et al. 2006).

The abundance and distribution of species result from elementary principles such as fecundity, mortality and migration. The complexity ecologists face regarding biodiversity arise because (1) the respective importance of these factors are likely to vary depending on ecosystems, taxonomic groups, species, populations, (2) and the impact of these factors may vary with time; for example, a loss of genetic diversity may have delayed impact on populations, whereas the destruction of habitats or individuals may have more immediate effects on populations. Population Viability Analysis (PVA) is used to get better insights into these mechanisms by combining life-history data, demographic and sometimes genetic data and data on environmental variability. PVA predicts the probability that a plant or animal population will persist for a given period of time in a given area with a given setting of suitable habitats (habitats where a species can potentially survive). Spatially-explicit PVA's have been used for just over 10 years (Akcakaya et al. 1995), and their use is becoming increasingly commonplace (Akcakaya et al. 2004, Larson et al. 2004). Typically, they use GIS technology to create maps of suitable breeding and dispersal habitat for the target species. A stochastic population model then sits on top of the GIS-created matrix and is run to assess the probability that the population persists in a given landscape. In standard PVA, the whole population is assumed to be freely-mixing, and spatial structure and dispersal is ignored. Once one moves to a spatial PVA, however, dispersal becomes crucial, and both the rate at which individuals disperse and the spatial scale of movement emerge as vital parameters. Provided that spatial data about the distribution of habitats is available, PVA can be applied to relatively large spatial scales. Interactions can be analyzed between different environmental changes. For example range shifts of species resulting from climate change are predicted in that way. The migration process can be limited by a lack of suitable habitats in highly fragmented landscapes so that the species potentially goes extinct due to the synergetic interaction of both forces (Travis 2003). PVA thus is a promising tool for evaluating such processes at the landscape scale, i.e. at the scale at which it can be linked to policy instruments and management. So far, however, these tools exist only for a limited number of taxonomic groups and species.

Long-term ecological experiments and monitoring still provide the most reliable information on ecological processes and are indispensable for evaluating modelling results and improving model structure (Rees et al. 2001, Rastetter et al. 2003). They thus remain a necessary complement within any other strategy for bridging the spatial and temporal scales needed in interdisciplinary LTSER.

While this review has shown that a plethora of tools is meanwhile becoming available to analyze interrelations between spatial scales in natural systems, an even wider question remains unresolved: How to deal with scale issues in analyzing human-dominated landscapes, i.e. the spatially organized, integrated socio-ecological systems that emerge through the interaction of social systems with natural processes (Berglund 1991, Farina 2000). As such analyses also require the inclusion of human demography, institutions, economic structures, government regulations, technology and numerous other social and economic factors, in addition to the above-discussed ecological factors, their complexity is still higher, and methods to tackle scale issues in integrated land system analyses are still in their infancy (Liverman et al. 1998, Young et al. 2005, Haberl et al. 2006, Young et al. 2006, see also the chapter below).

Developing multidisciplinary modelling approaches for bridging scales

A key future task in LTSER will be to join together spatio-temporal modelling approaches already developed for disciplinary studies. This will not be trivial due to different predominant scale domains of biodiversity, management and policies. Take for example the conflict between game management and raptor conservation (Thirgood and Redpath 2005). Raptors are scarce and legally protected, but at the same time threaten the livelihoods of gamekeepers and economic returns for private estates. This conflict covers a number of scales and resolutions. An ecological model of the dynamics of the predator and the prey may be built with a resolution set to the size of a single raptor's territory. An economic approach may be set at the resolution of a private estate, which could encompass a number of predator territories. An agent-based model could be set at a regional scale at which the gamekeepers interact. All of these scales and levels are subject to the legal-political framework that operates at a national or even international scale.

The most promising way in model integration at least for a site-based LTSER network - is a nested structure of various models working at different scales (Schroeter et al. 2005, Reidsma et al. 2006). Broad-scale models, e.g. international trade models and macroeconomic models (Hertel 1997, Edenhofer et al. 2005), should provide the general background against which regional and local decisions and actions are analysed. An international trade model, for instance, would define the regional and local level of food and energy demand which is a crucial determinant of land use changes and, finally, landscape structure and processes. To make the processes at different levels more consistent, these models can be used in an iterative way by feeding inputs and outputs back and forth (Root and Schneider 2002). Of course, not all real-world feedback mechanisms can be considered. Depending on the complexity of the models, coupled modeling systems may thus not always converge to a unique solution and results from different models may not be consistent.

One of the major problems is data availability across different scale domains. As mentioned, many disciplines have, for good reasons, developed tools and models around the available data. Hence, economics is mostly concerned with aggregated data for nation states (Hertel 1997), while global models on vegetation cover and climate change usually work on a 0.5 degree grid, which is compatible with standard satellite remote sensing information (Bondeau et al. in press). Modeling paradigms may also influence the degree of complexity in terms of spatial resolution. For instance, dynamic optimization models in economics are constructed at a rather aggregated level, in order to allow for solutions at reasonable computational costs. These models are usually less detailed in terms of spatial, temporal and institutional resolution than climate or hydrological models. The properties and the challenges of integrated modeling have been summarized by the SustainabilityA-Test EU project (www.sustainabilitya-test.net). Wätzold et al. (2006) and Drechsler et al. (in press) give a general discussion of challenges of ecologic-economic-modeling including scale issues.

Approaches and models that are capable of analysing society's impacts societies on landscape structure and processes are particularly relevant for interdisciplinary biodiversity research. The socio-economic metabolism approach, pioneered in the 1970's (Boulding 1973, Ayres and Kneese 1969), analyzes society's stocks and flows of materials, energy or substances (e.g., carbon, nitrogen, lead, copper, etc.). These flows are thought to be simultaneously influenced by biogeophysical patterns and processes including climate, geomorphology, soils, biota, etc. one the one hand, and by social interactions and relations such as economic transactions, power relations, legal and political frameworks on the other hand. This "double compatibility" towards ecological and socio-economical models and data enables the socio-economic metabolism approach to establish a link between socio-economic variables, and biophysical patterns and processes with both groups characterised by their predominant scales (Haberl et al. 2004). Land use intensity can – at least partially – be analyzed using indicators such as the "human appropriation of net primary production" (HANPP). HANPP has been defined as the difference between the amount of net primary production (NPP) that would be available each year in an ecosystem in the absence of land use and the amount of netto primary production that actually remains in the ecosystem after harvest (Haberl 1997, Haberl et al. 2001). HANPP can be consistently integrated with studies of socio-economic metabolism (Haberl et al. 2004). HANPP studies have been conducted on global scale (Vitousek et al. 1986, Wright 1990, Rojstaczer 2001, Imhoff et al. 2004), on the national scale (Haberl et al. 2001) and on a village scale (Grünbühel et al. 2003, Krausmann 2004). GIS techniques allow to calculate HANPP with the resolution that satellite imagery or aerial photography allows (Haberl et al. 2001, Wrbka et al. 2004). Other land-use related indicators, e.g., indicators relating to carbon stocks or nitrogen flows could also be calculated using the socio-economic metabolism approach on any spatial scale for which land-use and land-cover data with sufficient resolution can be generated (Erb 2004). Ultimately, by combining tools to analyze ecological material and energy flows (e.g., biogeochemical process models) with socioeconomic metabolism studies, integrated assessments of socio-ecological metabolism could be made that would allow the study of the respective effects of natural and socioeconomic drivers on patterns and processes in integrated socio-ecological systems (Haberl et al. 2006).

Researchers increasingly use models that combine agent-based modules that simulate decisions of and interactions between agents land use as well as biophysical stocks and flows (Axtell 2002, Janssen 2004). Agents are not only individuals, but also social or economic units such as farmsteads or households. In these models the behaviour of agents depends not only on natural, social, economic or political factors, but also on the behaviour of other agents. The agent's decisions may have important biophysical effects like changes in land use and these changes may also feed back on agents and modify their behaviour. These models are currently mostly being explored on local to regional scales and are thus readily suitable for LTSER platforms. Nevertheless, modelers are aware that processes on broader scales may critically affect trajectories. Such models could be coupled to larger-scale models and help to develop dynamic multi-scale approaches that would allow to analyze scale interactions much more comprehensively (Janssen and Ostrom 2006).

Implementing the scales of decision making of management and policies

It is widely recognized that key stakeholder groups should participate in decision-making, especially when these decisions have an impact on stakeholder economic or social well-being (Western and Wright 1994, Hulme and Murphree 2001). The latter case often arises when common goods like biodiversity are to be conserved locally. Participatory approaches have been developed to address this issue. One way of assessing the acceptability of different management options is to quantify the views of stakeholders through the use of a variety of Multicriteria Analyses (Edwards-Jones et al. 2000). Such approaches have been used to assess opinions over land management decisions, the use of mountain and water resources and the management of human-wildlife conflicts (Moss et al. 1996, McDaniels et al. 1999, Bayfield et al. 2000, Gregory 2000, Redpath et al. 2004). In the management of biodiversity conflicts, the general principle of quantifying the perceptions of stakeholders as a means of searching for acceptable solutions has broad relevance (Messmer 2000, Conover 2002).

An example for an integrated approach provides Multi-Scale Integrated Analysis (MSIA, Giampietro 2004). There socio-economic options are checked against biophysical constraints for a given area, and against cultural constraints associated with the local context, regional context and supra-regional context (Giampietro and Mayumi 2000, Giampietro 2004, Giampietro and Ramos-Martin 2005). An integral part of the Multi-Scale Integrated Analysis is the use of Societal Multi-criteria Evaluation (SMCE) that engages stakeholders in discussion, negotiation and agreement about possible alternatives to established paths of development (Munda 2004). The scenarios as envisioned by the stakeholders are put to test scientifically using MSIA, the results of which are then fed to the stakeholders via a structured process for decision making (Giampietro et al. 2006).

The value of participatory approaches with respect to the scale issue is that they allow linkages to be made between the specific scale domains of biodiversity, its management and policies and the recognition of the importance of cross-scale interaction when it comes to decision making.

6 Conclusions

Existing policy-relevant interdisciplinary biodiversity research is still in its infancy. The ideal case of a long-term inter- and transdisciplinary research tackling all relevant scales of biodiversity, its management and the biodiversity-relevant policies rarely takes place. The case studies surveyed exemplify characteristic scale mismatches, disregards of relevant scales, and the superficial consideration of cross-scale interactions. A major reason is probably the disciplinary focus in education and research and, hence, the lack of appropriate interdisciplinary theories, methods and expertise. In biological conservation, to date we are confronted with a patchwork of studies which brought about a growing number of results covering important issues but often lack usefulness for effective management of biodiversity and goal-oriented political decision making.

The future European LTSER network - and it will most probably be analogous in other international efforts towards LTSER - will be based on already existing LTER infrastructure, thus is confronted with exactly the above situation of many disciplinary studies which can not be integrated straightforward into interdisciplinary efforts. Mismatches in the scales taken into account in disciplinary studies are but one reason. Gaps with regard to relevant scales, which become apparent when screening existing studies in the area of a LTSER platform, should be addressed by a scale-explicit research agenda. Such an agenda will be most effective when including the participation of stakeholders from different scale domains. Studies at the regional scale of LTSER platforms could then be systematically integrated into large-scale modeling exercises or metaanalyses. Making information from the whole LTSER network representative a suitable sampling strategy will however be necessary.

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7 Literature Cited

Akcakaya, H. R., M. A. McCarthy, and J. L. Pearce. 1995. Linking landscape data with population viability analysis: Management options for the helmeted honeyeater. *Biological Conservation* **73**:169-176.

Akcakaya, H. R., V. C. Radeloff, and H. S. Mladenhoff. 2004. Integrating landscape and metapopulation modeling approaches: Viability of the sharp-tailed grouse in a dynamic landscape. *Conservation Biology* **18**:526-537.

Ando, A., J. Camm, S. Polasky, and A. Solow. 1998. Species Distributions, Land Values, and Efficient Conservation. *Science* **279**:2126-2128.

Antrop, M. 2000. Background concepts for integrated landscape analysis. *Agriculture, Ecosystems and Environment* **77**:17-28.

Axtell, R. L., C.J. Andrews, and M. J. Small. 2002. Agent-Based Modeling and Industrial Ecology. *Journal of Industrial Ecology* **5**:10-13.

Ayres, R. U., and A. Kneese. 1969. Production, consumption and externalities. *American Economic Review* **59**(3):282-297.

Bayfield, N. G., G. M. McGowan, and F. Fillat. 2000. Using specialists or stakeholders to select indicators of environmental change for mountain areas in Scotland and Spain. *Oecologia Montana* **9**:29-35.

Berkes, F. 2006. From community-based resource management to complex systems: the scale issue and marine commons. *Ecology and Society* **11**(1):45. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art45.

Bondeau, A., P. C. Smith, S. Zaehle, S. Schaphoff, W. Lucht, W. Cramer, D. Gerten, H. Lotze-Campen, Chr. Müller, M. Reichstein, and B. Smith. *Modelling the role of agriculture for the 20th century global terrestrial carbon balance*. Global Change Biology, *in press.*

Boulding, K. E. 1973. The Economics of the Coming Spaceship Earth. Pages 3-14 in H. E. Daly, editor. *Towards a Steady State Economy*. Freeman, San Francisco, US.

Carpenter, S. R., R. DeFries, T. Dietz, H. A. Mooney, S. Polasky, W. V. Reid, and R. J. Scholes. 2006. Millenium Ecosystem Assessment: Research needs. *Science* **314**:257-258.

Cash, D. W. and S. C. Moser. 2000. Linking global and local scales: designing dynamic assessment and management processes. *Global Environmental Change* **10**:109-120

Cash, D. W., W. N. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard, and O. Young. 2006. Scale and Cross-Scale Dynamics: Governance and Information in a Multi-Level World. *Ecology and Society* **11**(2): 8 [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art8

Conover, M. 2002. *Resolving human-wildlife conflicts: The science of wildlife damage management.* CRC Press, Boca Raton, Florida.

Cullinan, V. I. and J. M. Thomas. 1992. A comparison of quantitative methods for examining landscape pattern and scale. *Landscape Ecology* **7**:211-227.

Cumming, G. S., D. H. Cumming, and C. L. Redman. 2006. Scale mismatches in socio-ecological systems: causes, consequences, and solutions. *Ecology and Society* **11**(2):14. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art14

Dearing, J. A., L. J. Graumlich, R. Grove, A. Grübler, H. Haberl, F. Hole, C. Pfister, and S. E. van der Leeuw. 2006. *Integrating socio-environment interactions over centennial timescales: needs and issues.* The MIT Press, Cambridge, US.

Dehnen-Schmutz, K., C. Perrings, and W. Williamson. 2004. Controlling Rhododendron ponticum in the British Isles: an economic analysis. *Journal of Environmental Management* **70**:323-332.

Diamond, J. M. 2005. *Collapse: How societies choose to fail or succeed*. Viking, New York, NY.

Drechsler, M., V. Grimm, J. Mysiak, and F. Wätzold, F. *Differences and similarities between economic and ecological models for biodiversity conservation*. Ecological Economics, *in press.*

Edenhofer, O., N. Bauer, and E. Kriegler. 2005. The Impact of Technological Change on Climate Protection and Welfare: Insights from the Model MIND. *Ecological Economics* **54**:277-292.

Edwards-Jones, G., B. Davies, and S. Hussian. 2000. *Ecological economics: an introduction*. Blackwell Science Ltd., Oxford, UK.

EEA. 2001. *Late lessons from early warnings: the Precautionary Principle 1896–2000.* Environmental Issue Report 22, European Environment Agency, Copenhagen, DE. [online] URL: http://reports.eea.europa.eu/environmental_issue_report_2001_22/en.

EEA. 2003. *An inventory of biodiversity indicators in Europe, 2002*. Technical Report 92, European Environment Agency, Copenhagen, DE. [online] URL: http://reports.eea.europa.eu/technical_report_2004_92/en.

Erb, K.-H. 2004. Land-use Related Changes in Aboveground Carbon Stocks of Austria's Terrestrial Ecosystems. *Ecosystems* **7**:563-572.

Farina, A. 2000. The cultural landscape as a model fort he integration of ecology and economics. *BioScience* **50**:313-320.

Firbank, L. G., M. S. Heard, I. P. Woiwod, C. Hawes, A. J. Haughton, G. T. Champion, R. J. Scott, M. O. Hill, A. M. Dewar, G. R. Squire, M. J. May, D. R. Brooks, A. D. Bohan, R. E. Daniels, J. L. Osborne, D. B. Roy, H. I. J. Black, P. Rothery, and J. N. Perry. 2003. An introduction to the farm-scale evaluations of genetically modified herbicide tolerant crops. *Journal of Applied Ecology* **40**:2-16.

Fischer-Kowalski, M. and H. Haberl, editors. 2007. *Socioecological Transitions and Global Change. Trajectories of Social Metabolism and Land Use.* Edward Elgar, Cheltenham, UK, Northampton, US, in press.

Forman, R. T. T. and M. Godron. 1986. *Landscape Ecology*. John Wiley & Sons, New York, US.

Freckleton, R. P., W. J. Sutherland, and A. R. Watkinson. 2003. Deciding the future of GM crops in Europe. *Science* **302**:994-996.

Gezon, L. L. and S. Paulson 2004, editors. *Political Ecology across spaces, scales and social groups*. Rutgers University Press, New Jersey, US.

Giampietro, M. 2004. *Multi-scale integrated analysis of agroecosystems*. CRC Press, Boca Raton, Florida, US.

Gibson, C. C., E. Ostrom, T. K. Ahn. 2000. The concept of scale and the human dimension of global change: a survey. *Ecological Economics* **32**:217-239.

GLP. 2005. *Global Land Project. Science Plan and Implementation Strategy*. IGBP Secretariat, Stockholm. [online] URL: http://www.globallandproject.org.

Grünbühel, C. M., H. Haberl, H. Schandl, and V. Winiwarter. 2003. Socio-economic Metabolism and Colonization of Natural Processes in SangSaeng Village: Material and Energy Flows, Land Use, and Cultural Change in Northeast Thailand. *Human Ecology* **31**:53-86.

Guha, R. and J. Martinez-Alier. 1997. *Varieties of Environmentalism. Essays on North and South.* Earthscan, London.

Guisan, A. and N. E. Zimmermann. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* **135**:147-186.

Gustafson, E. J. 1998. Quantifying landscape spatial pattern: What is the state of art? *Ecosystems* **1**:143-156.

Haberl, H. 1997. Human Appropriation of Net Primary Production as an Environmental Indicator: Implications for Sustainable Development. *Ambio* **26**:143-146.

Haberl, H., K. H. Erb, F. Krausmann, W. Loibl, N. Schulz, and H. Weisz. 2001. Changes in Ecosystem Processes Induced by Land Use: Human Appropriation of Net Primary Production and Its Influence on Standing Crop in Austria. *Global Biogeochemical Cycles* **15**:929-942.

Haberl, H., M. Fischer-Kowalski, F. Krausmann, H. Weisz, and V. Winiwarter. 2004. Progress Towards Sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. *Land Use Policy* **21**:199-213.

Haberl, H., V. Winiwarter, K. Andersson, R. Ayres, C. Boone, A. Castillo, G. Cunfer, M. Fischer-Kowalski, W. R. Freudenburg, E. Furman, R. Kaufmann, F. Krausmann, E. Langthaler, H. Lotze-Campen, M. Mirtl, C.L. Redman, A. Reenberg, A. Wardell, B. Warr, and H. Zechmeister. 2006. From LTER to LTSER: Conceptualizing the socio-economic dimension of long-term socio-ecological research. *Ecology and Society* **11**(2):13. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art13

Hertel, T. W. editor. 1997. *Global Trade Analysis – Modeling and applications*. Cambridge University Press, UK.

Hobbie, J. E., S.R. Carpenter, N. B. Grimm, J. R. Grosz, and T. R. Seastedt. 2003. The US Long Term Ecological Research Program. *BioScience* **53**:21-32.

Holling, C. S., L. H. Gunderson, and G. D. Peterson. 2002. Sustainability and panarchies. Pages 63-102 in L.H. Gunderson and C.S. Holling, editors. Panarchy: *understanding transformations in human and natural systems*. Island Press, Washington, DC.

Hulme, D., and M. Murphree, editors. 2001. *African wildlife and livelihoods: the promise and performance of community conservation*. James Currey, Oxford, UK.

Ibáñez, I., J. S. Clark, M. C. Dietze, K. Feeley, M. Hersh, S. LaDeau, A. McBride, N. E. Welch, and M. S. Wolosin. 2006. Predicting biodiversity change: outside the climate envelope, beyond the species–area curve. *Ecology* **87**:1896-1906.

Imhoff, M. L., L. Bounoua, T. Ricketts, C. Loucks, R. Harriss, and W. T. Lawrence. 2004. Global patterns in human consumption of net primary production. *Nature* **429**:870-873.

Jaeger, J. A. G. 2000. Landscape division, splitting index and effective meshsize: new measures of landscape fragmentation. *Landscape Ecology* **15**:115-130.

Janssen, A. M. 2004. Agent-Based Models. Pages 155-172 in: Proops, J. and Safonov, P., editors, *Modelling in Ecological Economics*. Edgar Elgar, Cheltenham, UK, Northampton, MA, US.

Janssen M. A. and E. Ostrom. 2006. Empirically based, agent-based models. *Ecology and Society* **11**(2): 37. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art37

Kay, J. J., H. A. Regier, M. Boyle, and G. Francis. 1999. An ecosystem approach for sustainability: addressing the challenge of complexity. *Futures* **31**:721-742.

Koestler, A. 1967. *The Ghost in the machine*. Arkana, London, UK.

Krausmann, F. 2004. Milk, manure and muscular power. Livestock and the transformation of pre-industrial agriculture in Central Europe. *Human Ecology* **32**:735-772.

Krausmann, F. and H. Haberl. 2002. The process of industrialization from the perspective of energetic metabolism, Socioeconomic energy flows in Austria 1830-1995. *Ecological Economics* **41**:177-201.

Larson, M. A., F. R. Thompson, J. J. Millspaugh, W. D. Dijak, and S. R. Shifley. 2004. Linking population viability, habitat suitability, and landscape simulation models for conservation planning. *Ecological Modelling* **180**:103-118.

Leibold, M. A., M. Holyoak, N. Mouquet, P. Amarasekare, J. M. Chase, M. F. Hoopes, M. F., R. D. Holt, J. B. Shurin, R. Law, D. Tilman, M. Loreau, M. and A. Gonzalez. 2004. The metacommunity concept: a framework or multi-scale community ecology. *Ecology Letters* **7**:601-613.

Levin, S. A. 1992. The problem of pattern and scale in ecology. *Ecology* **73**:1943-1967.

Lichtenstein, M. E., and C. A. Montgomery. 2003. Biodiversity and timber in the Coast Range of Oregon: inside the production possibility frontier. *Land Economics* **79**:56-73.

Liverman, D., E. F. Moran, R. R. Rindfuss, and P. C. Stern. 1998. *People and Pixels, Linking Remote Sensing and Social Science.* National Academy Press, Washington DC.

Martinez-Alier, J. 2002. *The Environmentalism of the Poor. A Study of Ecological Conflicts and Valuation.* Edward Elgar, Cheltenham, UK.

McDaniels, T., R. Gregory, and D. Fields. 1999. Democratising risk management: successful public involvement in local water management decisions. *Risk Analysis* **19**:497-510.

Meentemeyer, V. and E. O. Box. 1987. Scale effects in landscape studies. Pages 15-34 in Turner, M.G., editor. *Landscape heterogeneity and disturbance*. Springer Verlag, New York, US.

Messmer, T.A. 2000. The emergence of human-wildlife conflict management: turning challenges into opportunities. *International Biodeterioration & Biodegradation* **43**:97-102.

Millenium Ecosystem Assessment (MA). 2005. *Ecosystems and Human Well-being: Biodiversity Synthesis.* World Resources Institute, Washington, DC. [online] URL: http://www.millenniumassessment.org/proxy/Document.354.aspx.

Millenium Ecosystem Assessment (MA). 2003. *Ecosystems and human well-being, a framework for assessment.* Millennium Ecosystem Assessment Series. Island Press. Washington DC.

Moser, D., H. G. Zechmeister, C. Plutzar, N. Sauberer, T. Wrbka, G. Grabherr. 2002. Landscape patch shape complexity as an effective measure for plant species richness in rural landscapes. *Landscape Ecology* **17**:657-669

Moss, R., D. C. Catt, N. G. Bayfield, and D. D. French. 1996. The application of decision theory to sustainable management of an upland Scottish estate. *Journal of Applied Statistics* **23**:211-229.

Naveh, Z. 2000a. The Total Human Ecosystem: Integrating Ecology and Economics. *BioScience* **50**:357-361.

Naveh, Z. 2000b. What is holistic landscape ecology? A conceptual introduction. *Landscape and Urban Planning* **50**:7-26.

O'Neill, R. V., C. T. Hunsaker, S. P. Timmins, B. L. Jackson, K. B. Jones, K. H. Riiters, and J. D. Wickham. 1996. Scale problems in reporting landscape pattern at the regional scale. *Landscape Ecology* **11**:169-180.

Parr, T. W., M. Ferretti, I. C. Simpson, M. Forsius, E. Kovács-Lang. 2002. Towards a long-term integrated monitoring programme in Europe: network design in theory and practice. *Environmental Monitoring and Assessment* **78**:253-290.

Pereira, H. M. and G. D. Daily. 2006. Modeling biodiversity dynamics in countryside landscapes. *Ecology* **87**:1877-1885.

Peterseil, J., T. Wrbka, C. Plutzar, I. Schmitzberger, A. Kiss, E. Szerencsits, K. Reiter, W. Schneider, F. Suppan, and H. Beismann. 2004. Evaluating the ecological sustainability of Austrian cultural landscapes – the SINUS approach. *Land Use Policy* **21**:307-320.

Peterson, D. L. and V. T. Parker. 1998. *Ecological scale: theory and application*. Columbia University Press, New York, US.

Polasky, S, J. D. Camm, and B. Garber-Yonts. 2001. Selecting biological reserves cost-effectively: an application to terrestrial vertebrate conservation in Oregon. *Land Economics* **77**:68-78.

Rahbek, C. 2005. The role of spatial scale and the perception of large-scale species-richness patterns. *Ecology Letters* **8**:224-239.

Rastetter, E. B., J.D. Aber, D. P. C Peters, D. S. Ojima, and I. C Burke. 2003. Using mechanistic models to scale ecological processes across space and time. *BioScience* **53**:68-76.

Redman, C. L., J. M, Grove, and L. L. H Kuby. 2002. Integrating social science into the long-term ecological research (LTER) network: social dimensions of ecological change and ecological dimensions of social change. *Ecosystems* **7**:161-171.

Redpath, S. M., B. E., Arroyo, F, M. Leckie, P. Bacon, N. Bayfield, R. J. Gutiérrez, and S. J. Thirgood. 2004. Using decision modelling with stakeholders to reduce human-wildlife conflict: a raptor - grouse case study. *Conservation Biology*:**18**:350-359.

Rees, M., R. Condit, M. Crawley, S. Pacala, and D. Tilman. 2001. Long-term studies of vegetation dynamics. *Science* **293**:650-655.

Reidsma, P., T. Tekelenburg, M. van den Berg, and R. Alkemade. 2006. Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Agriculture, Ecosystems and Environment* **114**:86–102.

Rojstaczer, S., S. M. Sterling, and N. Moore. 2001. Human Appropriation of Photosynthesis Products. *Science* **294**:2549-2552.

Root, T. and S. H. Schneider. 2002. Strategic cycling scaling: bridging five orders of magnitude scale gaps in climatic and ecological studies. *Integrated Assessment* **3**:188-200.

Sala, O. E., F. S. Chapin, J. J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L. F. Huenneke, R. B. Jackson, A. Kinzig, R. Leemans, D. M. Lodge, H. A. Mooney, M. Oesterheld, N. LeRoy Poff, M. T. Sykes, B. H. Walker, M. Walker, and D. H. Wall. 2000. Global biodiversity scenarios for the year 2100. *Science* **287**:1770-1774.

Schandl, H., and N. B. Schulz. 2002. Changes in United Kingdom´s natural relations in terms of society's metabolism and land use from 1850 to the present day. *Ecological Economics* **41**:203-221.

Schmitzberger, I., Th. Wrbka, B. Steurer, G. Aschenbrenner, J. Peterseil, and H. G. Zechmeister. 2005. How farming styles influence biodiversity maintenance in Austrian agricultural landscapes. *Agriculture, Ecosystems and Environment* **108**:274–290.

Schröter, D., W. Cramer, R. Leemans, I. C. Prentice, M. B. Araújo, N. W. Arnell, A. Bondeau, H. Bugmann, T. R. Carter, C. A. Gracia, A. C. de la Vega-Leinert, M. Erhard, F. Ewert, M. Glendining, J. I. House, S. Kankaanpää, R. J. T. Klein, S. Lavorel, M. Lindner, M. J. Metzger, J. Meyer, T. D. Mitchell, I. Reginster, M. Rounsevell, S. Sabaté, S. Sitch, B. Smith, J. Smith, P. Smith, M. T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, S. Zaehle, and B. Zierl. 2005. Ecosystem service supply and vulnerability to global change in Europe. *Science* **310**:1333-1337.

Stephenson, C. M., M. L. MacKenzie, C. Edwards, and J. M. J. Travis. 2006. Modelling establishment probabilities of an exotic plant, Rhododendron ponticum, invading a heterogeneous, woodland landscape using logistic regression with spatial autocorrelation. *Ecological Modelling* **193**:747-758.

Tainter, J.A. 1988. *The collapse of complex societies*. Cambridge University Press. New York, US.

Thirgood, S. J. and S. M. Redpath. 2005. Science, politics and human-wildlife conflicts: harriers and grouse in the UK. Pages 192-208 in Woodroffe, R., S. Thirgood, and A. Rabinowitz, editors. *People or Wildlife: Conflict or Coexistence*. Cambridge University Press, London, UK.

Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. Townsend Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. *Nature* **427**:145-148.

Tilman, D. and P. Kareiva. 1997. *Spatial ecology: the role of space in population dynamics and interspecific interaction.* Princeton University Press, Princeton, New Jersey.

Tischendorf, L. and E. Fahrig. 2000. How should we measure landscape connectivity? *Landscape Ecology* **15**:633-641.

Travis, J. M. J. 2003. Climate change and habitat destruction: a deadly anthropogenic cocktail. *Proceedings of the Royal Society B: Biological Sciences* **270**:1471-2954.

Turner, M. G. 1989. Landscape ecology: The effect of pattern and process. *Annual Review of Ecology and Systematics* **20**:171-197.

Vermaat, J. E., F. Eppink, J. C. J. M. van den Bergh, A. Barendregt, and J. van Belle. 2005. Aggregation and the matching of scales in spatial economics and landscape ecology: empirical evidence and prospects for integration. *Ecological Economics* **52**:229-237.

Vitousek, P. M., P. R. Ehrlich, A. H. Ehrlich and P. A. Matson. 1986. Human Appropriation of the Products of Photosynthesis. *BioScience* **36**:368-373.

Vos, C. C., J. Verboom, P. F. M. Opdam, and C. J. F. Ter Braak. 2001. Toward ecologically scaled landscape indices. *The American Naturalist* **183**:24-41.

Western, D., and R. M. Wright, editors. 1994. *Natural Connections: Perspectives in Community-based Conservation.* Island Press, Washington DC.

Wiens, J. A. 1989. Spatial scaling in ecology. *Functional Ecology* **3**:385-397.

Wilbanks, T. J., R. W. Kates. 1999. Global change in local places: how scale matters. *Climatic Change* **43**:601-628.

Wrbka, T., K.-H. Erb, N. B. Schulz, J. Peterseil, C. Hahn, and H. Haberl. 2004. Linking pattern and process in cultural landscapes. An empirical study based on spatially explicit indicators. *Land Use Policy* **21**:289-306.

Wright, D. H. 1990. Human impacts on the energy flow through natural ecosystems, and implications for species endangerment. *Ambio* **19**:189-194.

Wätzold, F. and M. Drechsler. 2005. Spatially uniform versus spatially differentiated compensation payments for biodiversity-enhancing land-use measures. *Environmental and Resource Economics* **31**:73-93.

Wätzold, F., M. Drechsler, C. W. Armstrong, S. Baumgärtner, V. Grimm, A. Huth, C. Perrings, H. P. Possingham, J. F. Shogren, A. Skonhoft, J. Verboom-Vasiljev, C. Wissel. 2006. Ecological-economic modeling for biodiversity management: Potential, pitfalls, prospects. *Conservation Biology* **20**:1034-1041.

Yoccoz, N. G., J. D. Nichols, T. Boulinier. 2001. Monitoring of biological diversity in space and time. *Trends in Ecology and Evolution* **16**:446-453.

Young, J., A. Báldi, L. Benedetti-Cecchi, A. Bergamini, K. Hiscock, S. van den Hove, T. Koetz, E. van Ierland, A. Lányi, G. Pataki, C. Scheidegger, L. Tötök, and A. D. Watt. 2005. *Landscape scale biodiversity assessment: the problem of scale*. EPBRS meeting, Budapest, Hungary, 31 March - 4 April 2005. Institute of Ecology and Botany of the Hungarian Academy of Sciences, Vacratot, Hungary.

Young, O.R. 2006. *The institutional dimensions of environmental change: fit, interplay, and scale*. The MIT Press, US.

Young, O., E. F. Lambin, F., Alcock, H., Haberl, S.I. Karlsson, W. J. McConnell, T. Myint, C. Pahl-Wostl, C. Polsky, P. S. Ramakrishnan, M. Scouvart, H. Schröder, P. Verburg. 2006. A Portfolio Approach to Analyzing Complex Human-Environment Interactions: Institutions and Land Change. *Ecology and Society* **11(2)**:31. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art31/

Zechmeister, H. G. and D. Moser. 2001. The influence of agricultural land-use intensity on bryophyte species richness. *Biodiversity and Conservation* **10**:1609-1625.

8 Appendix

1 United Kingdom: Farm-Scale Evaluations

The FSE assesses the effects of differences in the management – especially the type of herbicides used and the timing of their application – of conventional and genetically modified herbicide-tolerant crops on the diversity and abundance of arable vascular plants and invertebrates in the UK. Responses are analyzed in terms of population changes of individual species, changes of abundances of higher taxa and of functional groupings. For each of the crops studied – beet, spring oilseed rape and maize (winter oilseed rape is not considered here) – between 60 and 80 agricultural fields spread across England are used as experimental plots in a randomized block design (conventional and GMHT-crops allocated at random to half-fields). Fields were selected as to represent the whole range of environmental conditions and management practices (intensities) currently represented in the UK - with the explicit intention of achieving results that can be extrapolated to a situation where GMHTs were of widespread use over the whole UK.

Firbank, L. G., M. S. Heard, I. P. Woiwod, C., Hawes, A. J. Haughton, G. T. Champion, R. J. Scott, M. O. Hill, A. M. Dewar, G. R. Squire, M. J. May, D. R. Brooks, A. D. Bohan, R. E. Daniels, J. L. Osborne, D. B. Roy, H. I. J. Black, P. Rothery and J. N. Perry. 2003. An introduction to the farm-scale evaluations of genetically modified herbicide tolerant crops. *Journal of Applied Ecology* **40**: 2-16.

2 United Kingdom: Mapping predator-human conflicts

Hen harriers *Circus cyaneus* are a rare bird of prey in the UK, protected by EU legislation. However, they breed in upland habitats where they are an important predator of the managed game bird, the red grouse *Lagopus l. scoticus*. This brings them into conflict with managers of grouse populations and harriers are illegally killed as a consequence. Harriers and grouse overlap considerably in their habitat requirements – notably they both require heather *Calluna vulgaris.* Information is available at a variety of spatial scales. Data on the distribution of harriers is present for the whole EU, and on variation in abundance for the whole UK (100km^2 grain). Variation in abundance to habitat and prey is related at a km^2 grain within six study areas in Scotland. Data on red grouse abundance are present for approx 40 1km^2 study areas across the UK. In addition data on the number of grouse shot are present for hundreds of land management units (100km^2 grain) across the UK. Data on illegal killing is present for different land use classes across the UK (national scale). Data on land use is collected at 100km^2 scale. The study attempts to use this information to map out the distribution of grouse and harriers in upland Britain to highlight regions of conflict and consider alternative management techniques. This is done by first mapping out the potential distribution of harriers in absence of illegal killing in the UK then exploring gaps between predicted and real distribution. Numerical and functional responses of the predator to its prey are built in and ultimately an individual based harrier model is derived to explore alternative management options.

Redpath, S. M., B. E. Arroyo, F. M. Leckie, P. Bacon, N. Bayfield, R. J. Gutiérrez and S. J. Thirgood. 2004. Using decision modelling with stakeholders to reduce human-wildlife conflict: a raptor - grouse case study. *Conservation Biology*: **18**: 350-359.

Thirgood S. J. and S. M. Redpath 2005. Science, politics and human-wildlife conflicts: harriers and grouse in the UK. In: Woodroffe, R., S. Thirgood and Rabinowitz. editors. *People or Wildlife: Conflict or Coexistence.* A. ZSL. London.

3 United Kingdom: Managing *Rhododendron* invasion under environmental change

See body text for a description

Stephenson, C.M., M.L. MacKenzie, C. Edwards, J.M.J. Travis. 2006. Modelling establishment probabilities of an exotic plant, *Rhododendron ponticum*, invading a heterogeneous, woodland landscape using logistic regression with spatial autocorrelation. *Ecological Modelling* **193**: 747-758.

Dehnen-Schmutz, K., C., Perrings, M. Williamson. 2004. Controlling *Rhododendron ponticum* in the British Isles: an economic analysis. *Journal of Environmental Management* **70**: 323-332.

4 Germany: Functions and services of biodiversity

The study assesses the effects of land use dynamics and habitat structure on plant species diversity in grassland. Focused on the local scale (habitat level), it considers interactions with larger scale factors only implicitly.

Otte, A., V. Wolters, R. Waldhardt and D. Simmering. 2002. *Funktionen und Leistungen floristischer Biodiversität für zukünftige Landschaftsentwicklungen.* URL: http://www.uni-giessen.de/waldhardt/SFB299_TeilprojektB3.1_Bericht2002.pdf

5 Germany: Response of freshwater copepods to warm summers

The authors investigated how a recent period of warm springs and summers has affected the population dynamics of various cyclopoid copepods in a central European lake. They compared (i) the duration of the period when the species were present in the water column, and (ii) their annual peak density in a period dominated by cool summers (1980–91) and one dominated by warm summers (1992–99). This study demonstrates clear impacts of recent (1992–99) spring and summer warming on the population dynamics of cyclopoid copepods. The active phase of all species was prolonged in spring and autumn in the warm years. This observation complements growing evidence that the seasonal phenology of many flora and fauna are currently advancing in both aquatic and terrestrial ecosystems as a consequence of climate warming. In addition, the population size of the most thermophilic species increased in the warm years. The results provide further support for the hypothesis that single species rather than taxonomic or functional groups act as highly sensitive harbingers of climate change. The study explicitly considers the issue of scale interaction between global warming and its local impacts. It is an almost pure freshwater ecological study and therefore does not aim at more comprehensive scale consideration.

Gerten, D. and R. Adrian. 2002. Species-specific changes in the phenology and peak abundance of freshwater copepods in response to warm summers. *Freshwater Biology* **47**, 1-11

6 Germany: Forest soil inventory

The aim of the study is to survey the state of the soil in the German forest in order to gain knowledge about forest soils. This information shall help protecting the forest from harmful future influences. About 2000 sample points in an 8 by 8 km German wide network will be investigated during 2006 – 2008. This survey is a repetition of the first inventory of forest soils 1987 – 1993.

BMELV. 2005. *Zweite Bodenzustandserhebung im Wald.* URL:
http://www.bmelv.de/cln_044/nn_753670/SharedDocs/downloads/06-

Forstwirtschaft/Bodenzustandserhebung/ZielsetzungKonzeptionBZE,templateId=raw,property=publicationFile.pdf/ZielsetzungKonzeptionBZE.pdf

7 Austria: The Pasque Flower in Austria between 1991 and 2005

Pulsatilla vulgaris is a rare and endangered flagship species of managed (mowing regime) semi dry meadows in Central Europe. In Austria, which is the spatial extent of the study, as in other regions of Europe, the species is highly threatened owing to habitat loss following to land use changes. The study evaluates trends of *Pulsatilla* populations in relation to habitat preferences agricultural management practices, and conservation efforts. Scale issues are addressed only implicitly by matching habitat patches to the actual management: Record of all existing populations of various sizes (ca. 5 to 2000 individuals) in Austria in 1991, 1997-2001, and 2003-2004. For each site and time flowering individuals were counted. Population growth or decrease was directly inferred from a comparison of 1991 and 2003-2004. Habitat preferences were investigated using vegetation relevès with a size of 25 to 300 m². The total area of the habitat was measured and ranges between 1 to >10.000 m². Management practices (mowing, gracing, abandoned) were recorded in each investigation year together with exiting disturbances (fertilization, shrub encroachment, etc.). The results show a dramatic population loss and now few larger populations predominate over some very small ones. The main reason is that *Pulsatilla vulgaris* has extremely narrow habitat preferences. A change from mowing to grazing or even abandonment is followed by marked population losses. The maintenance or reestablishment of the beneficial mowing regime was almost exclusively a direct response to local conservation actions.

Essl, F. 2005. Population development, habitat preferences and causes of endangerment of the Pasque Flower (Pulsatilla vulgaris MILL.) in Austria between 1991 and 2005. *Linzer biologische Beiträge* **37**: 1145-1176.

8 Austria: Simulation of Ecological Compatibility of Regional Development

This project aims at the development of an integrated model which will be able to simulate changes in income and workload of farmsteads, land use, social/economic/ecological material/substance flows as well as selected ecological indicators. The model (acronym SERD: Simulation of Ecological Compatibility of Regional Development) will consist of an agent-based actor model which is coupled with a social/economic/ecological material/substance flow model. Agents of the model are single farms and population groups of the municipality of Reichraming (Upper Austria). Climate changes as well as changes in the global price markets will be part of the model. Dynamics in the model will be driven by assumptions on changes in socio-economic framework conditions as well as climate The model will allow the simulation of future scenarios, e.g. on the effects of improved collaboration between agriculture, tourism and the National Park „Kalkalpen“ (Limestone Alps) which is partly situated on Reichraming’s territory. Also effects of changes of EU subsidies and national policy decisions will be analyzed.

9 Austria: Biodiversity indicators in agricultural landscapes

The study tests the quality of eight indicator taxa in the agricultural landscape in eastern Austria as biodiversity surrogates and the influence of land use parameters on species richness. Scale issues are addressed implicitly by (1) developing a comparable sampling design for organism groups with widely different spatial distribution and behavior, by (2) matching the local grain to the actual land use and abiotic variables on a coarser scale, and by (3) exploring indicators derived from socio-economic metabolism (HANPP). Ad (1): Within each of the 38 sites 10 sampling points are investigated, using an identical scheme for all sites. At each sampling point eight taxa are censused: bryophytes, vascular plants, gastropods, spiders, orthopterans, carabid beetles, ants and birds. The species identified across the ten sampling points per site is pooled for respective taxa. Ad (2): Land use was mapped in the field and abiotic variables (i.e. climate) were intersected with the 38 sample sites. E.g. climate variables were derived from climatic surfaces that had been interpolated based on a digital elevation model. Ad (3): HANPP was found to be a significant indicator for diversity. The results demonstrate (1) the possibility do develop accurate biodiversity indicators, (2) the preponderance of land use parameters over climatic and other abiotic variables in explaining species richness patterns in agricultural landscapes, and the usefulness of indicators derived from socio-economic metabolism.

Sauberer, N., K.-P. Zulka, M. Abensperg-Traun, H.-M. Berg, G. Bieringer, N. Milasowszky, D. Moser, C. Plutzar, M. Pollheimer, C. Storch, R. Tröstl, H. G. Zechmeister and G. Grabherr. 2004. Surrogate taxa for biodiversity in agricultural landscapes of eastern Austria. *Biological Conservation* **117**: 181-190.

Zechmeister, H. G. and D. Moser. 2001. The influence of agricultural land-use intensity on bryophyte species richness. *Biodiversity and Conservation* **10**: 1609-1625.

Haberl, H., N. B. Schulz, C. Plutzar, K. H. Erb, F. Krausmann, W. Loibl, D. Moser, N. Sauberer, H. Weisz, H. G. Zechmeister, P. Zulka. 2004. Human appropriation of net primary production and species diversity in agricultural landscapes. *Agriculture, Ecosystems and Environment* **102**: 213–218.

Haberl, H., C. Plutzar, K.-H. Erb, V. Gaube, M. Pollheimer and N. B. Schulz. 2005. Human appropriation of net primary production as determinant of avifauna diversity in Austria. *Agriculture, Ecosystems and Environment* **110**: 119–131.

Moser, D., S. Dullinger, T. Englisch, H. Niklfeld, C. Plutzar, N. Sauberer, H. G. Zechmeister and G. Grabherr. 2005. Environmental determinants of vascular plant species richness in the Austrian Alps. *Journal of Biogeography* **32**: 1117–1127.

10 Austria: How farming styles influence biodiversity

See body text for a description

Schmitzberger, I., Th. Wrbka, B. Steurer, G. Aschenbrenner, J. Peterseil and H. G. Zechmeister 2005. How farming styles influence biodiversity maintenance in Austrian agricultural landscapes. *Agriculture, Ecosystems and Environment* **108**: 274–290

11 Netherlands: Changes of plant diversity in the Netherlands

In this study changes in Dutch flora in the last century are related to climate change, land use change and deposition of air pollutants through the analysis of plant attributes (Ellenberg indicators for temperature, continentality, nutrients, moisture, salinity, acidity and urbanity indicator) from nationwide monitoring database since 1900. Results indicate an impact due to climate change, since urbanization can only partially explain the rapid change. Main effects also come from deposition.

Tamis, W.L.M., M. van ‘t Zelfde, R. van der Meiden and H. A. U.de Haes. 2005. Changes in Vascular plant biodiversity in the Netherlands in the 20th century explained by their climatic and other environmental characteristics. *Climate Change* **72**:37-56.

12 Netherlands: Dead wood and biodiversity

This study focuses on the presence and quantity of dead wood in Dutch forests in relation to changing forest management practices through changing perspectives and policy incentives. The study is based on national forest monitoring system in addition with more detailed data from the Dutch Forest Reserve Network. The consequences of dead wood quality and quantity are assed for arthropods, fungi and mosses by means of a literature study only. Dead wood amounts were assessed explicitly for the national scale, the local (stand) and the landscape scale (forest reserves). Forest ownership was taken into account. Temporal scales of change in dead wood were used through data from the 1980ties to 2002.

Jagers op Akkerhuis, G.A.J.M., S.M.J. Wijdeven, L.G. Moraal, M.T. Veerkamp and R.J. Bijlsma. 2005. *Dood hout en biodiversiteit; een literatuurstudie naar het voorkomen van dood hout in het Nederlandse bos en het belang ervan voor de duurzame instandhouding van geleedpotigen, paddenstoelen en mossen*. Alterra report 1320, Wageningen, The Netherlands.

13 Netherlands: Forest development, ungulate grazing and forest management regimes

This study focuses on the effects of actual and potential grazing densities and forest management regimes on an actual forested area. A model-scenario approach was used to test the effects in a spatially explicit manner. A detailed vegetation map of the 11.000ha area was produced and used as input, together with the actual population densities of ungulates and present (differing) management regimes of the various forest owners. In this study a spatially explicit forest development simulation model is developed and used. Within this model: interaction between individual trees through competition for resources determines forest development. Forest management scenarios with detailed forest maps and ownership of entire region are then superimposed, consisting of spatially explicit thinning, group selection and shelter and clear cutting favouring certain forest composition, structures or dynamics. Seed dispersal of tree species differentially enables species to colonize sites. The amount and composition of edible food in patches then determines the ungulate grazing pressure, roaming through the landscape. In this study of forest development in dynamic interaction with grazing pressure and management regimes uses spatial scales from tree to region and temporal scales from monthly to 50 years.

Bruinderink, G.W.T.A., R.J. Bijlsma, J. den Ouden, C.A. van den Berg, A.J. Griffioen, I.T.M. Jorritsma, R. Kluiver, K. Kramer, A.T. Kuiters, D.R. Lammertsma, H.H.T. Prins, G.J. Spek and S.E. van Wieren 2004. *De relatie tussen bosontwikkeling op de Zuidoost Veluwe en de aantallen edelherten, damherten, reeën, wilde zwijnen, runderen en paarden; onderzoek naar de realisatiemogelijkheden van beheerdoelstellingen.* Wageningen, Alterra, The Netherlands.

14 Netherlands: Plant distribution on open forest landscapes

Present distribution of ancient forest plants is mapped in detail in a forested landscape. Distribution patterns are related to historical land use patterns and practices and changes therein. The study offers insight in potential conservation of threatened species, not only linking these to present habitats but primarily to land use practices and changes therein.

J. Clerkx, S. and R.J. Bijlsma 2003. *Veluwse heide blijkt open boslandschap na ecologische interpretatie van het kadastrale archief van 1832.* De Levende Natuur.

15 Netherlands: Recreation and Natura 2000 on the Veluwe

This study focuses on the effects of recreation areas on Natura 2000 sites (a network of European conservation areas) in a large Natura 2000 designated area (90000 ha). In this area the provincial policy objective is to combine improved recreation areas with Natura 2000 conditions. The question is whether certain recreation areas pose a threat to Natura 2000 (shrinkage) and where expansion of recreation areas is possible without damaging Natura 2000 – aiming at a neutral total shrinkage-expansion scenario. This study presents a general framework for evaluation of recreation policy. The study focuses at an actual area of 90000 ha, and identifies general threats for Natura 2000 species and habitats and identifies potential spatial influences of certain types of recreation area.

Janssen, J.A.M. and R.J. Bijlsma 2005. *Recreatie en Natura 2000 op de Veluwe; Voorstel voor een strategisch kader 'Groei & Krimp' in relatie tot de Vogel-en Habitatrichtlijn.* Alterra report 1184, Wageningen, Alterra, The Netherlands.

16 Norway: Monitoring programme for terrestrial ecosystems

The Monitoring Programme for Terrestrial Ecosystems (TOV) of the Directorate for Nature Management (DN) aims to document changes in flora and fauna of common boreal and alpine ecosystems and to discover possible effects of human activities, especially long-range atmospheric pollution. The programme includes integrated studies at 7 permanent monitoring sites, spanning a range of conditions in climate and pollution loads, from the southwest to the north. The studies cover ecosystem components which may reflect effects of long-range atmospheric pollution, such as ground vegetation, epiphytes, population levels and reproduction of predatory and passerine birds. The studies also include populations of 'key species' like small rodents and grouses which may heavily influence the natural dynamics of other ecosystem components. The project is thus designed to monitor how regional influence (acid rain deposition, climate) affects different ecosystems and species on a local scale. Each reference area is visited each every five years for the vegetation part but annually for other species. Status and detected changes are reported annually to the Directorate of Nature Management.

Økland, T., V. Bakkestuen, R.H. Økland, and O. Eilertsen. 2004. Changes in forest understory vegetation in Norway related to long-term soil acidification and climatic change. *Journal of Vegetation Science* **15**: 437-448.

17 Europe: Impacts of land-use change on biodiversity

The objective of this study is to assess land-use intensity and the related biodiversity in agricultural landscapes of the EU25 for the current situation (2000), and explore future trends, based on the four EURURALIS scenarios up to 2030. Data from the Farm Accountancy Data Network (FADN) were used to classify farm types in 100 regions of the EU15, according to agricultural intensity. For the ten New Member States (EU10), which are not yet considered by the FADN, country level data were used to obtain similar farm types. Three processes were considered for the assessment of future trends in agricultural land-use intensity: (1) land-use change, (2) conversion into organic farming, and (3) changes in productivity of crop and grassland production. An ecosystem quality value was attributed to each farm type according to dose-effect relationships between pressure factors and biodiversity compared to the value for an undisturbed situation. The biodiversity in agricultural landscapes was then calculated as the average ecosystem quality multiplied by the relative area size of each farm type within a region. A similar method of attributing ecosystem quality values to other land-use types allowed comparison between different land-use types.

Reidsma, P., T. Tekelenburg, M. van den Berg and R. Alkemade. 2006. Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Agriculture, Ecosystems and Environment* **114**: 86-102.

18 Europe: Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM)

ATEAM's primary objective was to assess the vulnerability of human sectors relying on ecosystem services with respect to global change. They consider vulnerability to be a function of potential impacts and adaptive capacity to global change. Multiple, internally consistent scenarios of potential impacts and vulnerabilities of the sectors agriculture, forestry, carbon storage, water, nature conservation and mountain tourism in the 21st century were mapped for Europe at a regional scale for four time slices (1990, 2020, 2050, 2080).

Schröter, D. et. al. 2004. ATEAM Final report 2004. Potsdam, Germany: Potsdam Institute for Climate Impact Research. URL: http://www.pik-potsdam.de/ateam/ateam_final_report_sections_5_to_6.pdf

Schröter, D., W. Cramer, R. Leemans, I. C. Prentice, M. B. Araújo, N. W. Arnell, A. Bondeau, H. Bugmann, T. R. Carter, C. A. Gracia, A. C. de la Vega-Leinert, M. Erhard, F. Ewert, M. Glendining, J. I. House, S. Kankaanpää, R. J. T. Klein, S. Lavorel, M. Lindner, M. J. Metzger, J. Meyer, T. D. Mitchell, I. Reginster, M. Rounsevell, S. Sabaté, S. Sitch, B. Smith, J. Smith, P. Smith, M. T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, S. Zaehle, and B. Zierl. 2005. Ecosystem service supply and vulnerability to global change in Europe. *Science* **310**:1333-1337.

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