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The BIOKLIM Project: Biodiversity Research between Climate Change and Wilding in a temperate montane forest – The conceptual framework

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Abstract

To understand the rapid rate of change in global biodiversity, it is necessary to analyse the present condition of ecosystems and to elucidate relationships of species to their environment. The BIOKLIM Project (Biodiversity and Climate Change Project) is intended to close this gap in our knowledge of montane and high montane forests of Central European low mountain ranges, one of the most threatened mixed montane systems worldwide. The Bavarian Forest National Park is characterised by its altitude range of ca. 800 m and a strongly developed gradient of forest structure. Relicts of old growth forests (areas of former local nature reserves) and dead stands, mostly killed by bark beetles, are accompanied by widely varying levels of woody debris and light. The gradients comprise a wide range of abiotic and forest structure factors, making the study area well suited for a multidisciplinary investigation of biodiversity. Unconstrained ordination (CA) of six taxa (vascular plants, wood inhabiting fungi, birds, carabids, spiders and molluscs) indicate the altitudinal gradient to be the main driver for distribution patterns of species assemblages.

Objectives, structure, study design and data sampling of the BIOKLIM Project are described in detail. We set up 293 sampling plots along four main straight transects following the altitudinal gradient. All abiotic and stand structure data regarded as relevant are available for each plot. Vascular plants, wood inhabiting fungi and birds were sampled or mapped on all 293 plots. For the other 22 investigated taxa we used subsamples pre-stratified according to the sampling methods. The necessity of dealing with spatial autocorrelation, arising from sampling along linear transects, is described. Finally, study approach of our biodiversity project is compared with others involving altitudinal gradients. Worldwide, only a few multidisciplinary biodiversity studies have been previously conducted on long altitudinal gradients. However, in most cases sampling techniques were similar to ours, which allows comparison of results between continents.

Keywords: Climate Change, Biodiversity, species-environment relationships

Zusammenfassung

Um die rasante Veränderung globaler Biodiversität zu verstehen, ist es erforderlich, den gegenwärtigen Zustand von Ökosystemen zu analysieren und die Zusammenhänge zwischen Arten und deren Umwelt aufzulösen. Das BIOKLIM-Projekt (Biodiversität und Klima Projekt) hat zum Ziel, diese Wissenslücken für Wälder montaner und hochmontaner Mittelgebirge zu schließen. Der Nationalpark Bayerischer Wald ist neben dem Höhengradient (ca. 800 m) durch einen starken Strukturgradient geprägt. Dieser resultiert aus Restvorkommen sehr alter Bestände (ehem. Naturschutzgebiete) sowie dem Wirken des Borkenkäfers seit ca. zwei Jahrzehnten und einem dadurch verbundenen z. T. sehr hohen Totholzvorrat. Die Gradienten umfassen eine breite Spanne von abiotischen Faktoren und Bestandesstrukturen und machen den Nationalpark zu einem gut geeigneten Untersuchungsgebiet für interdisziplinäre Biodiversitätsforschung. Korrespondenzanalysen (CA) für 6 taxonomische Gruppen (Gefäßpflanzen, Holzpilze, Vögel, Laufkäfer, Spinnen und Mollusken) machen die starke Abhängigkeit der Artengruppen vom Höhengradienten deutlich.

Es werden detailliert die Zielsetzungen, Projektaufbau, das Untersuchungsdesign sowie die Erfassungsmethoden des BIOKLIM-Projektes beschrieben. 293 Probepunkte wurden entlang von 4 Transekten, welche dem Höhengradienten folgen, eingerichtet. Zu jedem Probekreis stehen alle als relevant erachteten Daten zur Abiotik und Bestandesstruktur zur Verfügung. Gefäßpflanzen, Holzpilze und Vögel wurden auf allen 293 Probepunkten erfasst. Für die anderen 22 untersuchten Artengruppen wurde in Abhängigkeit von der Methode ein stratifiziertes Design gewählt. Lösungsansätze zum Umgang mit Autokorrelation, die durch die Anordnung von Probekreisen entlang von Linien (Transekte) bedingt ist, werden dargestellt. Schließlich wird das BIOKLIM-Projekt mit den wenigen weltweiten Biodiversitätsprojekten verglichen und diskutiert. In den meisten Fällen sind die Erhebungsmethoden ähnlich, sodass Vergleiche der Ergebnisse zwischen verschiedenen Kontinenten möglich werden.

Schlüsselwörter: Klimawandel, Biodiversität, Arten-Umwelt-Beziehung

Introduction

Loss of habitat and living space has accelerated enormously in the last few decades, caused by changes in land use and global climate. Destruction takes place faster than our understanding of natural systems improves (Wilson 1992). Global biodiversity is changing at an unprecedented rate as a complex response to several changes induced by humans in the global environment (Sala et al. 2000, Travis 2002, Hooper et al. 2005). As a result of this rapid rate of change there is a growing need to record and analyse the present state of ecosystems, to establish relationships of species to the environment, and to use this data for assessing and predicting further changes caused by anthropogenic influence (land use and climate change). It follows that a major challenge is to determine how biodiversity dynamics, ecosystem processes and abiotic factors correlate (Loreau et al. 2001). Furthermore, there is a clear need to increase our ability to predict the consequences of environmental change (Sutherland 2006). Averaged across all biomes (Boreal, Arctic, Grassland etc.), land use change and climate change are the driving factors which are expected to have the largest global impact on biodiversity by the year 2100 (Sala et al.

2000). Global air temperature increased in the 20th century by about 0.74K. The global trend is reflected in rapid atmospheric warming during the last decades. 11 of the last 12 years were the warmest since the measurement of climate parameters began (Ipcc 2007b). This development has most probably been caused by anthropogenic greenhouse gas emissions, especially carbon dioxide (Ipcc 2007b). Latest scenarios predict further warming (Ipcc 2007b). The probable value for the lowest scenario until the end of this century is an increase of 1.8 K (1.1 – 2.9 K) and for the highest 4.0 K (2.4 – 6.4 K). According to this assessment, the northern hemisphere has been most affected by the past temperature increase and will be strongly affected in future. It is difficult to measure the impacts of increasing air temperature on biodiversity. Despite this, there is broad evidence that anthropogenic climate change will lead to massive species extinction (Bakkenes et al. 2002, Leuschner & Schipka 2004, Schröter et al. 2004, Thomas et al. 2004, Ipcc 2007a). Changes in plant or animal phenology as a result of climate change have already been made clearly evident by reliable long-term data (Beebee 1995, Crick et al. 1997, Ahas 1999, Crick & Sparks 1999, Menzel & Fabian 1999, Parmesan et al. 1999, Sparks 1999, Walther et al. 2002, Menzel 2003, Menzel et al. 2006). Many studies reveal a coherent shift in distribution of species (Parmesan et al. 1999, Frahm & Klaus 2000, Hill et al. 2002, Parmesan 2003, Walther et al. 2005), but the potential effect on complex communities is little understood. The conventional approach of making assumptions and deriving models to make predictions about the consequences of environmental change is often unsatisfactory for complex problems and includes considerable uncertainties (Harrington et al. 1999, Ipcc 2001, Sutherland 2006). We need significantly improved models of the effects of climate change on the distribution of species and habitats. To achieve this, ecological research on climatic tolerances of species and habitats needs to be intensified (Sutherland et al. 2006). Furthermore, according to the latter study there is an urgent need to find out which species are the best indicators of the effects of climate change on natural communities, which habitats and species might be lost completely because of climate change, what time lags can be expected between climate change and ecological change, and what the likely relationship will be between the extent of climate change and the pattern of species extinction.

Current climate change predictions for the study area at a regional scale show increasing temperatures until the end of the 21st century. Hence a temperature increase of 1.7 – 2.1 K is expected (mean 2071 – 2100 compared to mean 1961 – 1990) (Spekat et al. 2007). Changes in precipitation will be moderate, decreasing by a maximum of about 6 % (Spekat et al. 2007).

More than half of Central Europe consists of mountain areas and most of these are low ranges covered by forest (Cipra 2007). The aim of our studies is to contribute to the knowledge of expected effects of climate change on these low mountain range forest ecosystems in Central Europe. The biodiversity and climate-change project described here includes an altitudinal gradient representative of a considerable part of Central European forests (Cipra 2007). Despite much discussion and a high level of research activity on assessing the impact of global change caused by temperature increase on biodiversity and natural systems in various disciplines there is still a major lack of knowledge on temporal and spatial scales as described by Sutherland et al. 2006. To remedy this, biodiversity projects have recently been started worldwide. Despite its relevance to policy makers, only a few studies involve integrated, multidisciplinary biodiversity research along altitudinal gradients (Epa 2007, Ibisca 2007, Doran et al. 2003).Because mainly of the expected increase in temperature, a powerful effect on biological systems is very likely (Ipcc 2007a) and the most significant effects of climate change will occur on a regional scale in the next 50 years.

1 Aims and structure of the BIOKLIM Project

The fundamental objective of our study is to quantify the dependency of various taxa on the environmental factors which are main determinants of their local distribution. The two dominant spatial gradients in the study area are altitude and frequency of forest structures. By the latter we mean characteristic structures that emerged through the protection of natural processes, such as areas rich in dead wood or alterations in canopy structure mainly created by the activity of bark beetles. The subjects addressed by the project may be divided into the complexes “Climate Change” and “Habitat Factors”.

The steep altitudinal gradient recommends the study area for research work on the impacts of climate change, because changes will take place within a small area. Geographical variation in species assemblages is known to be tied strongly to climate (Wildenow 1805). Distribution of many species is limited by altitude, as an expression of response to climate parameters or limitation of resources (Grabherr et al. 1994, Theurillat & Guisan 2001). The main priority of our study is to identify, through intensive study of the widest possible range of organisms, which species or groups are responding with greatest sensitivity to climate change. In this context the first step is to identify climate sensitive zones, in order to then focus on areas which are most sensitive to temperature increase. Climate sensitive zones are climate-induced ecological thresholds (Muradin 2001) represented by defined altitudinal zones. The monitoring of these zones allows for early quantification of climate change effects because the most obvious changes take place here first as warming proceeds. On the basis of the data gathered we can model the impacts of climate change and verify scenarios by conducting effective monitoring in the region. Prediction of the extinction risk for high montane species using habitat modelling techniques (e.g. generalized linear models, for more detail see Lawler et al. 2006) is one example of the possible uses for such data.

The second main objective of the project is to assess habitat factors responsible for species response variation; in particular, gradients in forest structure resulting from different types of management (from the extremes of continuous logging activity to process protection) affecting biodiversity are to be examined. The study site consists of extensive areas of forest which have not been used for decades or even for about a hundred years. Relicts of old growth forests and stands, parts of which have been killed by bark beetle attack, allow a broad span of woody debris availability and light conditions to be investigated. The significance of habitat parameters as drivers of biodiversity change revealed by our studies considerably improves the understanding of montane forest ecosystems. Based on this knowledge we can derive implications for management. The main questions are (i) how is terrestrial biodiversity affected by the protection of the natural processes that facilitate massive bark beetle infestations? (ii) What effect do huge amounts of coarse woody debris have on the build up of donor populations of highly endangered relict species of virgin forest, or endangered species in general? (iii) What are the consequences for biodiversity of measures against bark beetles? And finally (iv) Which habitat factors account for the occurrence of typical montane species and endangered species in low mountain range forest ecosystems and what conclusions can be drawn for multifunctional silvicultural treatment of these ecosystems?

After detecting the principal determinants in the system as a whole, it may be possible to answer further questions such as the impacts of climate change on taxonomical or functional groups. The ultimate aim of the study is to establish an empirical-statistical model of how species assemblages of different groups of organisms react to various scenarios of environmental change in low mountain range forests.

The well-documented samples and standardized sampling methods, together with the sensitive groups and species which these reveal (indicators), form a solid foundation for long term monitoring to detect environmental change and its impacts on a broad spectrum of forest inhabitants.

2 Study Area - Model Region

The Bavarian Forest National Park is situated in the German part of the Bohemian Forest, forming a homogenous landscape with the contiguous forests in the Czech Republic. This forest landscape is one of the largest in Central Europe. The highest ridges of the low mountain range form the watershed between the Danube and Elbe catchment areas. The Bavarian part of the Bohemian Massif is called the Inner Bavarian Forest.

The Bavarian Forest National Park (24235 ha) is located in the centre of the Inner Bavarian Forest and is about 98 % covered by forest (Elling et al. 1987).

The region is characterized by montane and high montane areas within a vertical range of approximately 800 m (from 650 m to 1420 m a .s. l.). Slopes in the National Park have mainly a southwestern exposition. Long-term phases of weathering and erosion have led to rounded, elevated landforms. Below 900 m a.s.l., typical geomorphological elements are foothills, between 900 und 1100 m a. s. l. flat hillsides and valleys with steep hillsides dominate and between 1100 und 1400 m a. s. l. flat ridges are overtopped by summits

Geologically, the Bavarian Forest is the south-western part of the Bohemian Massif (Variscian basement) and consists essentially of granite and gneiss. Accordingly, soils are acidic, with dominantly sandy and loamy soils (particularly brown earths and podsols), and are partly covered with rocks. All altitudinal levels, but especially the valleys, are characterized by a persistent or intermittent water-table in both mineral and organic soils.

On a larger scale the Bavarian Forest belongs to the temperate zone and is characterized by atlantic and continental influences. The total annual precipitation is between 1200 und 1800 mm depending on altitude. Annual mean air temperature varies between 5.1°C per year in the valley sites, 5.8°C on hillsides and 3.8°C in the higher montane zones (Noack 1979, Bässler 2004).

At the lowest sites forest is characterized by *Picea abies* (83 %), *Fagus sylvatica* L. (5 %), *Abies alba* Mill. (5 %) and *Sorbus aucuparia* L. (2.4 %). The montane forest zone consists of *Picea abies* L. H.Karst (58 %), *Fagus sylvatica* L. (34 %) and *Abies alba* Mill. (3 %). The high montane zone is characterized by *Picea abies* L. H.Karst (90 %), *Sorbus aucuparia* L. (8 %) and *Fagus sylvatica* L. (2 %).

3 Study Design

We set up a total of 288 plots (Figure 1) along four straight transects (Meyer et al. 2001) following the altitudinal gradient (Figure 2). Five additional plots were installed beside the main transects to compensate for the lack of old growth forest samples at higher altitude. Thus the plots comprise various altitudinal ranges and forest structures. The four transects were selected by using a stratified random scheme. First imperative was to include within the straight transects from valleys to mountain tops the entire vertical gradient of the study area. As a result of the division of the National Park into two main areas of wilding and continuous management, we planned to set up two transects in each category. Finally, we balanced the lines in order to avoid autocorrelation in forest structure. We thus avoided, for example, a continuous or discrete change in the ages of stands along the altitudinal gradient. In general, the sampling design should contain an adequate number of replications (Bernstein and Zalinski 1983), but design is also influenced by criteria of practicability and feasibility (Leyer and Wesche 2006). The use of 293 plots ensures that the dataset contains gradual structural differences, which is not so with case studies. The number of plots investigated was decided upon as a result of the estimation of the expected range of environmental variables. A recommendation exists that use of 10 random samples

Tab. 1: *Number of replications within the altitudinal range (100 m steps) for the entire sample plot design and the pre-stratified subsample plot designs.*

Altitudinal range	293 sample plots	180 subsamples	113 subsamples	36 subsamples
< 700	31	14	7	2
700 – 799	64	31	22	5
800 – 899	60	20	12	5
900 – 999	23	22	14	3
1000 – 1099	27	25	17	6
1100 – 1199	33	23	15	5
1200 – 1299	31	25	13	6
1300 – 1399	24	20	13	4

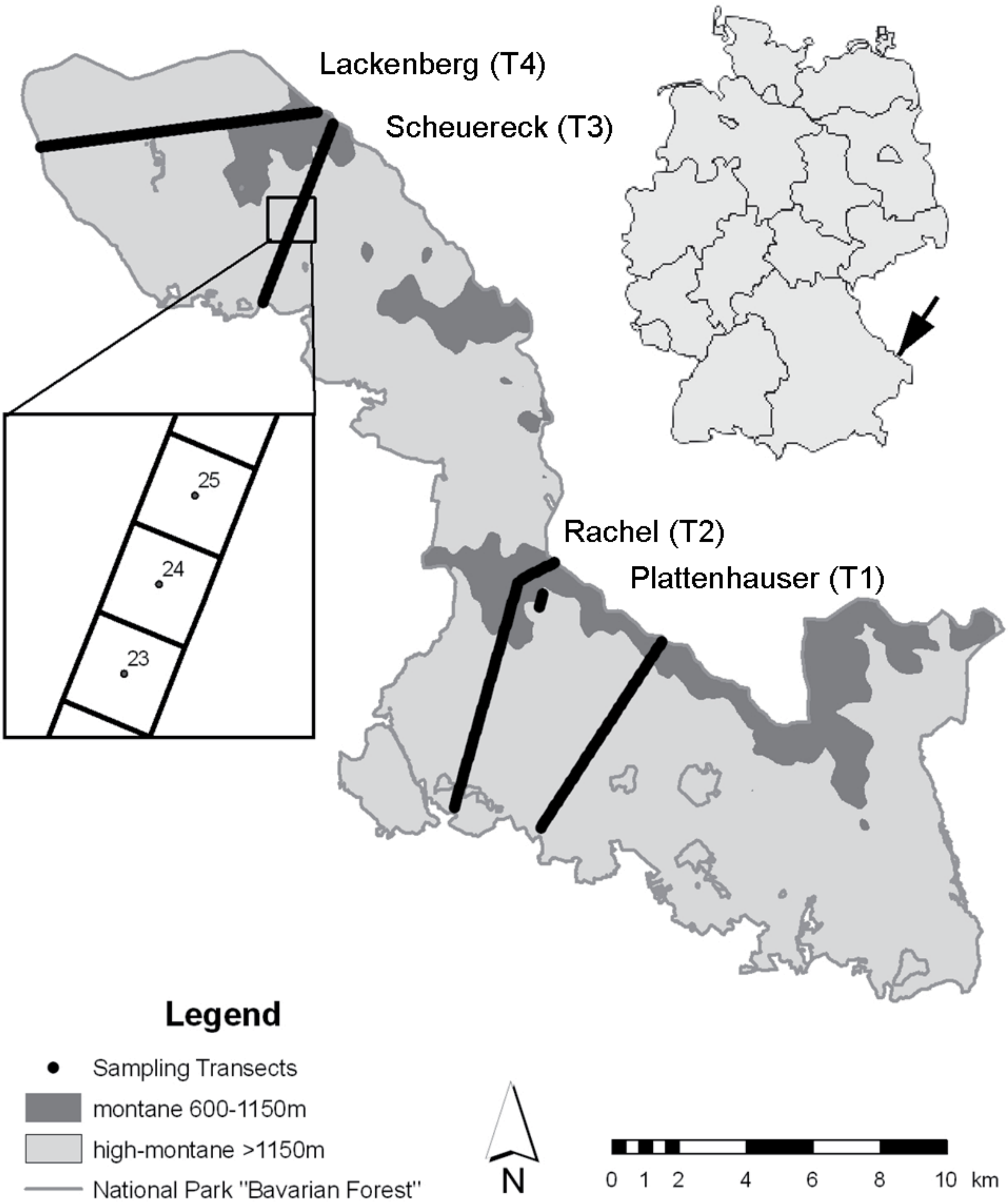

Fig. 1: *Study area and study design of the sampling transects with indication of the boundaries of the montane and high montane zone.*

per environmental explanatory variable is sufficient to ensure a balanced data frame (Steyerberg et al. 2001). This equates the $p/10$ rule of thumb with $p = \min[\Sigma(\text{presences}, \Sigma(\text{absences})]$ (Guisan & Zimmermann 2000). Our use of 293 sample plots and consideration of approximately 30 main explanatory variables (Table 3) satisfies these conditions. Due to difficult accessibility in the wilderness areas and the involvement of many specialists, we decided to set up transects with a simple design which enables effective execution of sampling and mapping. A small path, cleared by chainsaw, connects all plots of a transect, thus reducing the risk of accidents and making fieldwork very effective. The choice of design results also from local research experience and a pilot study carried out in 2005 (one transect

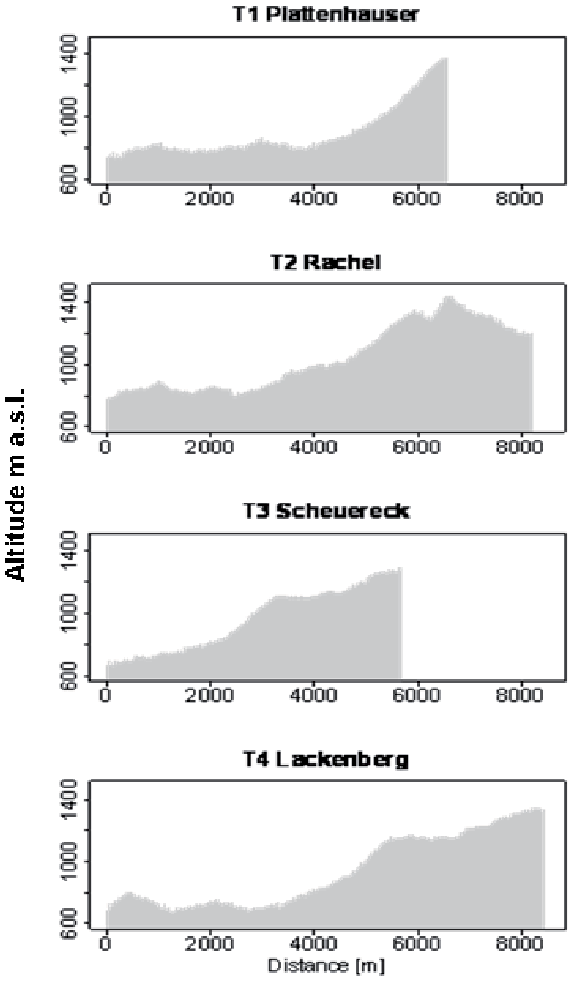

Fig. 2: *Vertical profiles of the four transects, from airborne laser scanner data.*

Tab. 2: *Number of plots, degree of management and core zone affected plots for the transects.*

Transect	Number of plots		
	Wilding	Management	Old growth
Plattenhauser	62	4	0
Rachel	73	8	0
Scheuereck	17	38	2
Lackenberg	22	48	14
Rachelsee	0	0	5
Total	174	98	21

and two taxonomic groups). The chosen design using 4 main transects with 100 m between plots ensures that a minimum of 23 replications for each altitudinal range exists; sufficient to overcome simultaneous environmental effects (Table 1). Orthogonality was also taken into consideration in selecting the pre-stratified sub-samples, balanced over the altitudinal gradient (Table 1). Two transects were set up in areas where the focus is on the protection of natural processes. Most of these plots are in bark beetle infested stands, where management and land-use measures were abandoned several decades ago (Table 2). The other two transects were set up in areas still subject to management. Transects were marked permanently, to reduce the need for repeated measurement and sampling. The distance between the plots is 100 m (Figure 1). The plots represent fairly well the main plant communities of the National Park (Figure 3).

4 Data sampling

The marked plot centre is the basic reference point for any data collection. The scale of data collection depends on the taxonomic group (Table 4). The goal is to obtain data of all types from the same sampling plots from all disciplines, in contrast to the frequently applied approaches concentrating on individual species, which often present problems in interpretation within projects with a greater scope (LEGENDRE & LEGENDRE 1998). Every investigation in the project was therefore conducted essentially on the same plots, to enable proper comparability in studies on the relationships between the different kinds of data (HENLE et al. 2006).

4.1 Abiotic

All environmental variables derived from field measurement, aerial photographs (LIDAR data) and climate stations are listed in Table 3. General information comprises, i. e., geographical coordinates and altitude, both generated using geographic information systems (GIS). Basis of calculation was a digital terrain model (DTM) with a cell size of 50 m.

Climate parameters result from geostatistical modelling using ArcEGMO (BECKER et al. 2002, PFÜTZNER 2002). To obtain reliable climate data we set up 30 data loggers with temperature and humidity registration and 10 rain gauges arranged on geomorphologically representative plots on the transects. Additionally, data are included from five main meteorological stations with extended climatological programs in the study area.

Variables on stand structure were recorded by measuring and estimation at each plot supplemented by interpretation of aerial photographs using the stereo analyst tool (MC GRATH et al. 2004). This was applied at different spatial scales (0.02 ha, 0.1 ha, 1 ha and 50 ha). In addition to the terrestrial measurement of stand structures, we used airborne laser scanning to get more detailed information on terrain and the canopy and its variation. Ages of stands are based on forest inventory (2002) using core samples. This information is also available in GIS.

Four soil samples from each plot were mixed together to provide two samples separated as humus layer and mineral soil up to 30 cm depth. Before chemical analysis the samples were dried at 65°C for 5 days and sieved through a 2 mm sieve. An aliquot of the mixed sample was milled. Soil pH was measured in 1 M KCl, using a Hamilton glass electrode (BUNDESMINISTERIUM FÜR ERNÄHRUNG 1990). C and N were analysed according to the Dumas method with the CHN analyser LECO CHN-1000 after complete oxidative combustion. Total elemental content of cations was measured following HNO_3 digestion (BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN 1990) with an ICP-IES (Perkin Elmer Optima 3000). The cations of all substrates were extracted with 1 M NH_4Cl for 2 hours on a rotation shaker (BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN 1990, LUEHR & BÖHMER 2000). Finally, cation exchange capacity, base saturation and C/N ratio were calculated.

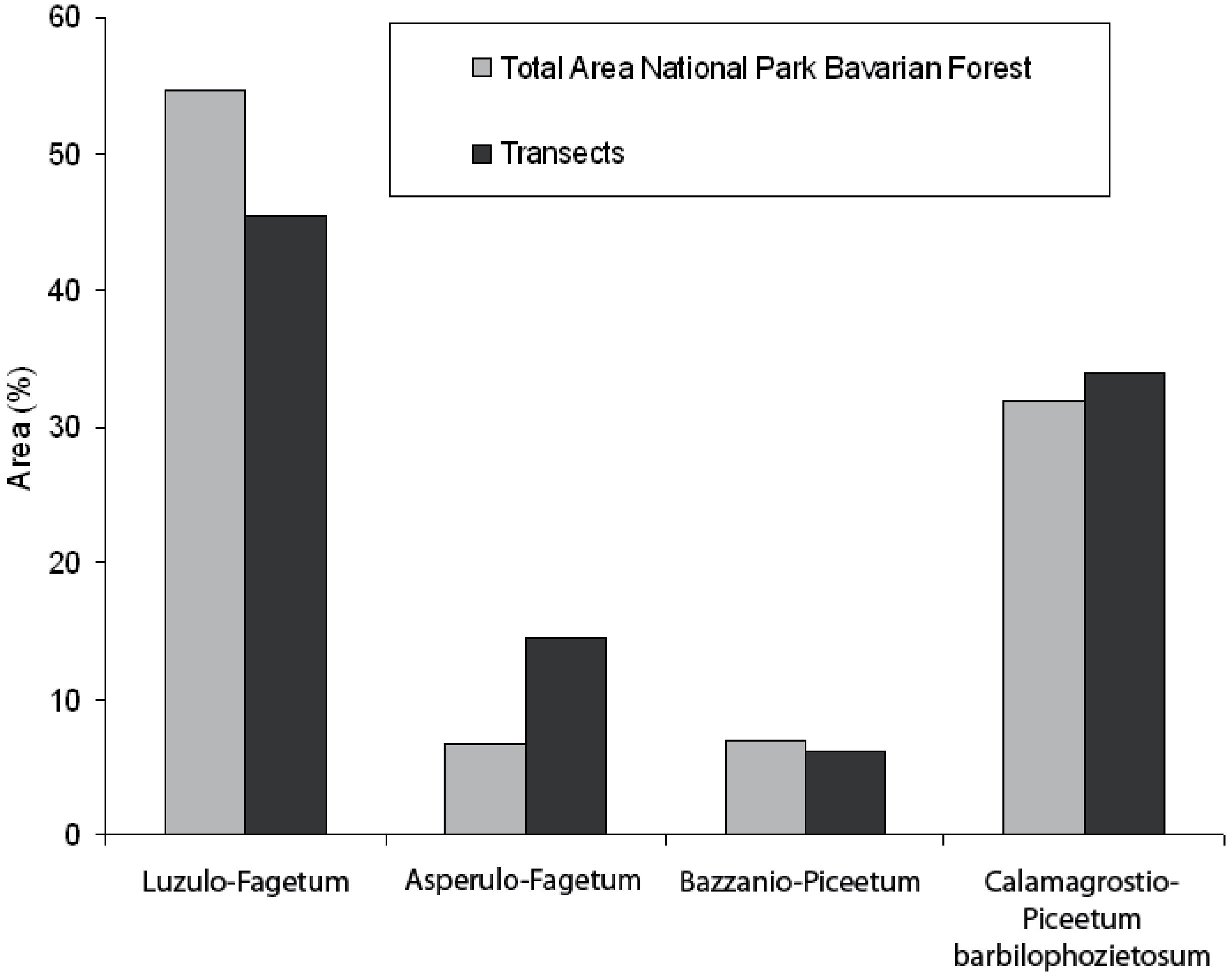

Fig. 3: *Vegetation type represented by our study plots and their frequency throughout the whole area of the National Park.*

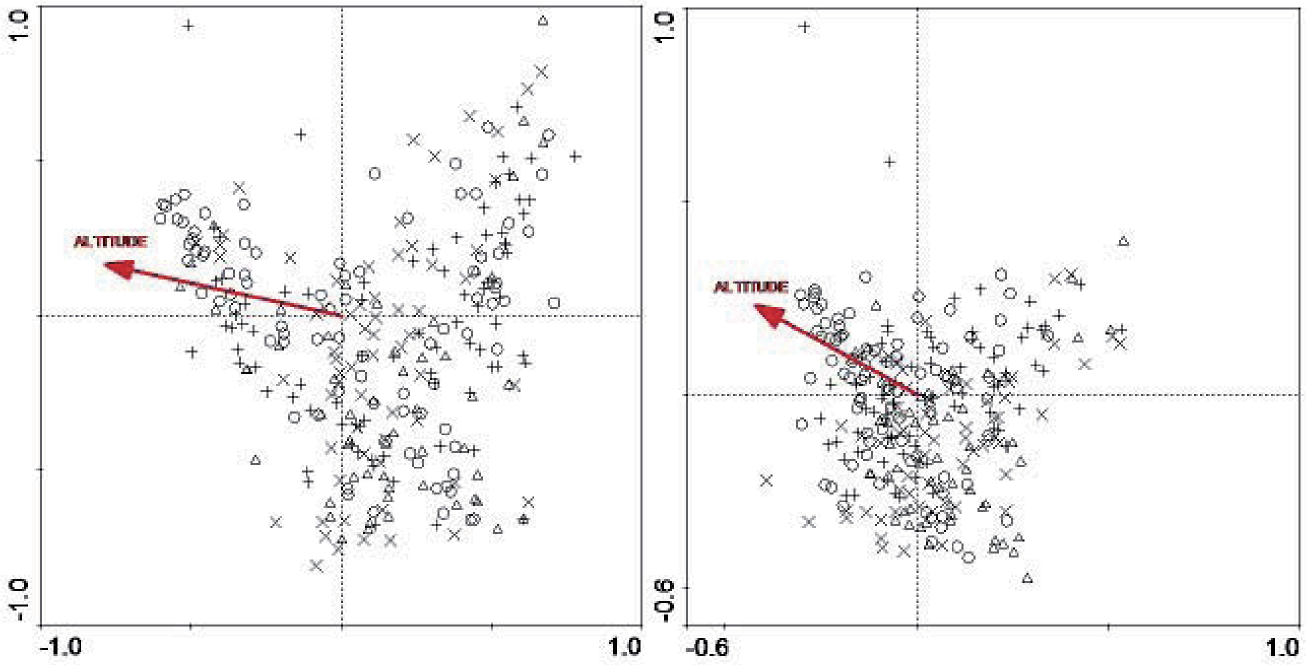

Fig. 4: *Joint Plot based on the 1st and 2nd axes of a Correspondence Analysis (CA) of vascular plant composition on the transect plot with (right) and without (left) consideration of geographical coordinates as co-variables. Same symbols represent plots from the same transect.*

Tab. 3: Environmental factors (general information, climate parameters, forest stand structure variables and soil variables): definitions, spatial distribution and measurement.

Variables	Definition	Plot point	0.02 ha	0.1 ha	1.0 ha	50 ha	Measurement
Generell informations							
Geographical co-ordinates	Co-ordinates according Gauss Krüger	x					GIS Model (DTM 25)
Altitude	Elevation in metres above sea level	x					
Exposition	Degree	x					
Slope	Degree	x					
Radiation	Potential sum of radiation in the growing season (kwh/m2)	x					
Climate Parameters							
Temperature	Year mean (1980 – 2006) in °C	x					GIS Model (ArcEgmo)
Precipitation	Year mean (1980 – 2006) in °C	x					
Global Radiation	Year mean (1980 – 2007) in kwh/m^2	x					
Stand structure							
Canopy Cover	Sample area shaded by horizontal projection of tree layer (upper L., middle L., under L.) seperated for occured tree species (leaves, branches, trunks) in %		x		x	x	Visual estimation, Areal photography, LIDAR
Bedrock cover	Sample area covered by horizontal projection		x		x	x	
Waterbody cover	Sample area covered by horizontal projection		x		x	x	
Gaps	Sample area covered by horizontal projection		x		x	x	
Maximum of breast height diamter	DBH in 1.3 m height				x		Measurement
Stand age	Mean age (years) of stands (forest inventory data)			x			Core sample
Understorey cover	Mean vegetation height < 1 m in %		x				Visual estimation
Canopy maximum height	Digital surface-, terrain- and canopy model (DSM, DTM, DCM)		x	x	x	x	Airborne Laserscanner
Canopy mean height			x	x	x	x	
Canopy standard deviation			x	x	x	x	
Woody debris (CWD)	CWD-Fractions, decay level, length and diameter			x			Measurement, visuel estimation
Soil variables							
Soil water balance	Index calculated according to Ewald (2000)		x				Calculation
pH value-litter	4 soil samples per plot (Bundesministerium für Ernährung 1990)		x				1 M KCl, Hamilton glass electrode
pH value-topsoil			x				1 M KCl, Hamilton glass electrode
Humus forms	4 humus layer samples, classification according AK Standortskartierung (1996)		x				Visual estimation
Podsol grade	4 samples up to 30 cm, 4 categories according AK Standortskartierung (1996)		x				Visual estimation
Exchangable nutrient elements	seperated into litter and topsoil (µeq/g); H, Al, Ca, Fe, K, Mg, Mn, Na		x				ICP-IES (Perkin Elmer Optima 3000), CHN-analyser LECO CHN-1000
Base saturation	seperated for litter and topsoil (µeq/g and %)		x				
Cation exchange capacity (CEC)	CEC seperated for litter and topsoil (µeq/g)		x				
C/N ratio	Carbon (%) / Nitrogen (%) ratio		x				

Tab. 4: Number of samples and sampling methods for the taxonomical groups considered in the BIOKLIM Project.

Taxonomical groups	1 ha grid	0.1 ha plot	0.02 ha plot	0.1 ha grid	Methods
Spermatophyta			x		mapping (293 plots)
Pteridophyta			x		
Bryophyta			x		
Lichenes			x		
Eumycophyta		x			
Aves	x				grid mapping (293 plots)
Chiroptera				x	sound mapping (293 plots)
Soricidae		x			180 pitfall trap, 36 snap trap
Rodentia		x			
Mollusca		x			180 pitfall trap, 113 hand sampling
Lepidoptera		x			36 light trap
Coleoptera		x			180 flight interception traps, 36 malaise traps, 180 pitfall traps, 113 hand sampling
Heteroptera		x			180 flight interception traps, 36 malaise traps, 180 pitfall traps
Neuroptera		x			
Syrphidae		x			
Symphyta		x			
Aculeata		x			
Fomicidae		x			180 pitfall traps
Araneae		x			
Opiliones		x			
Chilopoda		x			
Diplopoda		x			
Collembola		x			
Isopoda		x			
Mecoptera		x			36 malaise traps

Chemical analysis provides data on pH value, cations, anions, base saturation and cation exchange capacities. Additionally, we assessed visual soil parameters (e.g. soil texture) for the humus layer and the mineral soil up to 30 cm depth. Based on these data a soil water balance index was calculated for each plot following Ewald et al. (2000).

4.2 Biotic

All taxonomic groups, methods and number of sampled plots (replications) are presented in Table 4. Altogether we collected data on 25 higher taxa. The number of plots to be sampled depends on the nature of the scientific enquiry and on the target group. For this reason we stratified 293 sample plots, selecting pre-stratified sub-samples with respect to the two main gradients (altitude and forest structure) for some groups. Plants, ferns, wood inhabiting fungi and birds were mapped on all 293 plots. 180 of these plots were chosen for flight interception traps. Out of these 180 plots we selected 113 for sampling molluscs and mosses, and mapping of lichens. Moths and hoverflies were caught using light traps and Malaise traps with the smallest sample size of 36 plots.

5 Data processing

The large volume of data gathered in the BIOKLIM project necessitates a collective data management system for all the scientists involved, of all disciplines. All data is attributable to the same set of geo-referenced plots. MS Access was used for data management, because it is widespread and reasonably easy to use. We constructed a general database, in which all baseline data are included. Besides general information (e. g. geographical coordinates, altitude, slope, exposition, climate and soil variables, data from analysed aerial photographs etc.), it also includes aggregated data as explanatory variables for various higher taxa, such as abundance data on understorey vegetation, which is important to phytophagous insects, or number of fungal fruit bodies, etc. In a second main database we subsumed all data on stand structure at various levels (canopy cover, tree layer data, woody debris etc.). In addition to the two general databases we constructed a separate database for each taxonomic group, designed to satisfy the differing requirements of each group. No single database for all groups was created, which has permitted more flexibility in analyses of data. All databases are administered and managed by the project leader (National Park Administration), ensuring that they remain consistently accurate and original.

5.1 Spatial Correlation

One of the key assumptions, the independence of the observations (Hurlbert 1984, Dormann et al. 2007), is difficult to prove or possibly not valid for data collected along a transect with adjacent sampling points. Dealing with spatial autocorrelation has become a serious issue over the past decade (Legendre 1993). Especially in ecology, spatial autocorrelation may become a problem when its presence alters the parameter estimates and error probabilities of linear models (Diniz-Filho et al. 2003, Haining 2003, Kühn et al. 2006, Kühn 2007). The arrangement of plots along transects as used in the BIOKLIM Project, obliges us to consider possible effects of spatial autocorrelation (Hurlbert 1984). There are two ways of evaluating spatial autocorrelation where plots are strung together in straight lines. Correspondence analysis may be applied to evaluate spatial dependencies of the plots of a transect at every level of ordination. Here we also considered the role of geographical coordinates as co-variables in the ordination by comparing the general pattern with and without their implementation. This is illustrated using vascular plant data in Figure 4. According to this analysis, the importance of altitude as main driver is not obscured by spatial dependency.

A further approach to evaluation of autocorrelation is the use of semiparametric spatial generalised linear models. In this method, spatial autocorrelation is alleviated by including a spatial surface in the regression model. Assuming asymptotic normality of the estimated regression coefficients, confidence bands and p-values can be computed from the standard deviations obtained from the Fisher information matrix as implemented in the package “BayesX” , described in more detail in Fahrmeir et al. (2004), Kneib & Fahrmeir (2006).

6 Altitude as the main driver for communities

We expected altitude to be the main driver of distribution patterns for the taxonomic groups considered. Amongst abiotic variables, the altitudinal gradient within the study area is strongly characterised by temperature decrease with increasing altitude (Elling et al. 1987, Bässler 2004). It can therefore be concluded, that conditions for studying the impacts of global warming are appropriate within the study area.

Preliminary unconstrained ordination (CA) of data for the first six taxonomic groups (carabids, breeding birds, wood inhabiting fungi, molluscs, plants and spiders) reveal the altitudinal gradient as the main driver for communities: this follows the first axis (Figure 5). For this analysis we used CANOCO (Ter Braak & Smilauer 2002). The basis of the analysis was the data as specified in Table 4. Where appropriate, the data were preliminary prepared such as e.g. square root transformation of the vascular plant species data. These ordination patterns are intended only to illustrate the strong influence of altitude on the selected assemblages and are not intended as a sustitute for further analysis where other explanatory variables are relevant. Distribution of taxonomic assemblages is limited by altitude, as an expression of climate parameters or limitation of resources (Grabherr et al. 1994, Theurillat & Gui san 2001). Altitude is therefore a surrogate gradient representing many climate factors affecting species directly and is thus correlated with resources and regulators of species development (Austin 1980). The many components of climate, including for example temperature, precipitation and seasonality, vary in a non-random fashion along most elevation gradients (Lomolino 2001). A further component of the proxy altitude is the change in forest structures along the gradient. Alterations in tree species composition correlated with altitude are obvious in forests both of high and low mountain ranges (Doležal & Šrůtek 2002, Walentowski et al. 2004, Lee et al. 2005). A great challenge to the project is to establish the importance of the directly operating physiological factors hidden within the proxy altitude and to deal with confounding environmental effects. To this end, different multivariate approaches such as partial variance (Økland 2003), hierarchical partitioning (Chevan & Sutherland 1991), the application of generalized linear models (McCullough & Nelder 1989) or maximally selected rank statistics (Hothorn & Lausen 2003) could for example be adopted.

A comparable approach to studying biodiversity along an altitudinal gradient is taking place in Queensland, Australia. The IBISCA Queensland Project is a major international collaborative effort to survey different taxonomic groups in south-east Queensland’s Lamington National Park (Epa 2007, Ibisca 2007). The vertical gradient spans 800 m (300 – 1100 m. a. s. l.) within undisturbed, continuous subtropical rainforest, featuring a gradual transition from the highly diverse mixed broadleaved forests at the lower elevations to the almost pure southern beech forests at the highest levels. As for BIOKLIM, the purpose of IBISCA is to identify the species or groups that respond with greatest sensitivity to climatic change (Ibisca 2007). Field work began simultaneously to that of BIOKLIM in 2006, with establishment of permanent research plots. Following the vertical gradient, IBISCA set up five study sites at different altitudes with a total of 20 permanent plots arranged in a nested design. Plants, ferns and mosses were mapped on all 20 plots. Insects were sampled with pitfall traps in an array of nine traps per plot (180 traps on 20 plots). Two light traps (total 40 traps) and 3 yellow pans (total 60 pans) per plot were installed. Furthermore, one Malaise trap and one flight interception trap is operated on each plot (total 20 traps of each type) and litter sampling is also carried out. This methodology will be augmented by bark spraying, canopy knockdown and hand collection. Despite similar project aims, the chosen designs represent different approaches (for review of sampling design techniques see Green 1979). IBISCA works with a single transect laid out quite differently to the chains of sample plots used in the BIOKLIM project, but also oriented on the altitudinal gradient. Replications in different altitudinal ranges result from parallel sampling on the nested plots. The BIOKLIM design and the relatively high number of plots should ensure adequate representation of the variability in environmental and structural conditions within the sampling plots, with a minimum risk of spatial autocorrelation (see 5.1) and avoiding pseudo-replication (Hurlbert 1984).

A second study with a similar approach was set up in Tasmania, Australia. The program aims at monitoring distributional changes in vegetation and invertebrate assemblages along an altitudinal gradient (1230 m) in response to climate change and other environmental events (Doran et al. 2003). During the first two years baseline data were collected, as in BIOKLIM, to obtain long term comparative information. The research concept is based on four transects with a total of 24 plots and 240 subplots (nested design as described for the IBISCA project). Plots were set up in 100 m altitudinal ranges between 70 and 1300 m a. s. l. Focus of this study is on vegetation and invertebrate taxa. Vegetation was mapped on

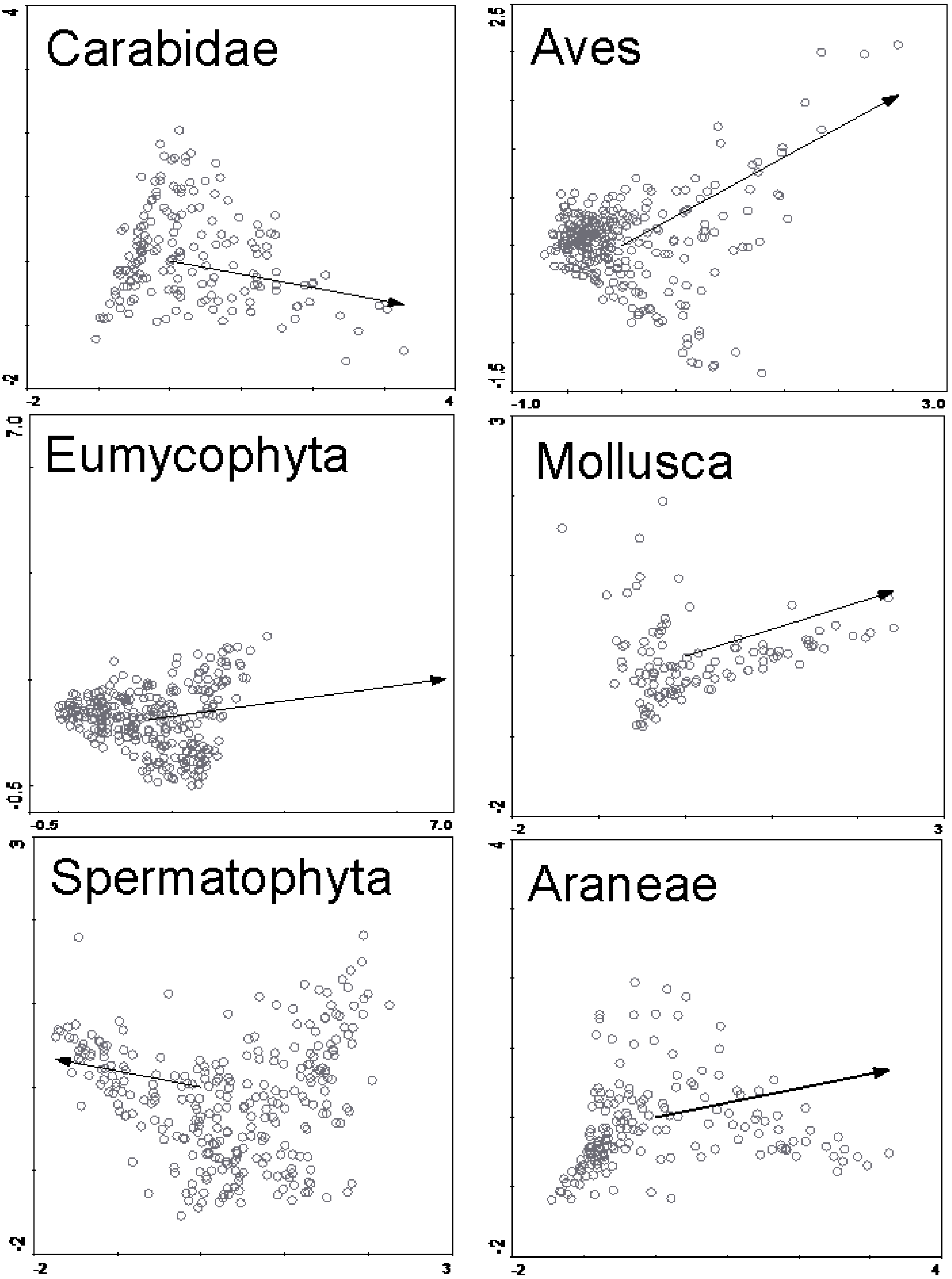

Fig. 5: *Wood inhabiting fungi, vascular plant, bird, mollusc, spider and carabid communities and their dependence on the altitudinal gradient. Joint Plots based on an unconstrained correspondence analysis (CA). The circles represent the assemblages, the vector (arrow) represents the factor altitude.*

all 240 subplots. Altogether 84 pitfall traps were set up on 14 plots. One Malaise trap was set up on each of six plots.

With a special focus on plants, particularly endemic species, the Global Observation Initiative in Alpine Environments (GLORIA) was set up in the 1990's. GLORIA aims at the establishment of an internationally coordinated network focussed on monitoring global warming at a global scale (Grabherr et al. 2000). In this project, alpine environments refer to areas from the timberline to the top of high mountains. Thus there is no consideration of the complete altitudinal gradient from valley floor upwards. Although it can not be doubted that alpine summits are very sensitive to climate change (Grabherr et al. 1994, Kazakis et al. 2007, Pauli et al. 2007), important changes are expected on a wider vertical scale, and there is also a definite need to consider a wider range of taxonomic groups.

Some existing studies deal with responses of selected biological groups to climate change along altitudinal gradients, but most of these consider only a few taxonomic groups. For example Wilson et al. (2007) studied altitudinally restricted communities of Schizophoran flies (Diptera) using Malaise traps, to assess the impacts of further warming. Other studies focus on species richness patterns along altitudinal gradients without considering aspects of climate change. Such studies have been presented for vascular plants (Grytnes 2003), bryophytes and lichens (Grytnes et al. 2006) and ferns (Bhattarai et al. 2004).

Aims and sampling methodology of our research project are essentially similar to those of other projects, using an integrative approach to answering questions about the relationships between biodiversity change and climate change. Despite differences in design and structure of the projects, there is great fundamental similarity in the approach to studying biodiversity along an altitudinal gradient. The sampling methods used (e. g. use of permanent plots, types of traps used, methods of mapping) and the type of taxonomic groups selected for study are also similar. However, with respect to the number of groups considered and number of sampling replications, our project belongs to those few which are based on a large volume of original data.

Conclusions

As a first preliminary result, altitude was revealed as the main factor driving occurrence of the selected taxonomic groups. Due to the strong dependency of temperature on altitude we expect a strong dependency of the taxonomic groups on temperature. This would qualify the project as suitable for studying the impacts of global warming. A special attribute of the BIOKLIM Project is the concentration of studies by specialists on various taxa within the same study design and time frame. This secures availability of complete and reliable baseline information on biota and abiotic factors. A further valuable attribute is the innovative way in which data on environmental and structural variables were obtained. Use of high resolution airborne laser-scanning data for each plot has not previously been applied in investigating the relationships between environmental and structural variables and local distribution of taxonomic groups. Neither has a previous project considered as many as 293 plots, with the resultant high level of replication.

Studies of changes along gradients of altitude and structure are of both high scientific and practical interest. The strong structural gradient caused by varying amounts of woody debris is unique in Central Europe. This allowed modelling of different management intensities to be based on a stock of data sufficient to obtain adequate decision support. It is thus possible to derive thresholds and key criteria for montane forests managed to integrate the requirements of nature conservation with the imperatives resulting from climate change. We hope to obtain long term comparative information from the project by setting up a monitoring program with a continuous record of sampling and mapping results.

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References

Ahas, R. (1999): Long-term phyto-, ornitho-and ichthyophenological time -series analyses in Estonia. Int. J. Biometeorol. **42**: 119-123.

Austin, M.P. (1980): Searching for a model for vegetation analysis. Vegetatio. **43**: 11-21.

Bakkenes, M., Alkemade, J.R.M., Ihle, F., Leemans, R., Latour, J.B. (2002): Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. Glob. Chang. Biol. **8**: 390-407.

Bässler, C. (2004): Das Klima im Nationalpark Bayerischer Wald - Darstellung, Entwicklung und Auswirkung. Nationalparkverwaltung Bayerischer Wald. 133 S.

Becker, A., Klöcking, B., Lahmer, W., Pfützner, B. (2002): The Hydrological Modeling System ArcEGMO. In: Mathematical Models of Large Watershed Hydrology (Eds.:Singh, V.P. and Frevert, D.K.). Water Resources Publikations, Littleton/Colorado.

Beebee, T.J.C. (1995): Amphibian Breeding and Climate. Nature **374**: 219-220.

Bernstein, B.B., Zalinski, J. (1983): Optimum sampling design and power tests for environmental biologists. J.Environ. Manage. **16**: 35-43.

Berry, P.M., Dawson, T.P., Harrison, P.A., Pearson, R.G. (2002): Modelling potential impacts of climate change on the bioclimatic envelop of species in Britain and Ireland. Glob. Ecol. Biogeogr. **11**: 453-462.

Bhattarai, K.R., Vetaas, O.R., Grytnes, A. (2004): Fern species richness along a central Himalayan elevation gradient, Nepal. J. Biogeogr. **31**: 386-400.

Bundesministerium für Ernährung Landwirtschaft und Forsten (1990): Bundesweite Bodenzustandserfassung im Wald – Arbeitsanleitung, BMLF, Bonn.

Chevan, A., Sutherland, M. (1991): Hierarchical Partitioning. Amer. Statistician **45**: 90-96.

Cipra (2007): Appell für eine zukunftsfähige Entwicklung der Bergwälder. Commission Internationale pour la Protection des Alpes, http://www.cipra.org.

Crick, H.Q.P., Dudley, C., Glue, D.E., Thomas, D.L. (1997): UK birds are laying eggs earlier. Nature **388**: 526.

Crick, H.Q.P., Sparks, T.H. (1999) Climate change related to egg-laying trends. Nature **399**: 423-424.

Diniz-Filho ,J.A.F., Bini, L.M., Hawkins, B.A. (2003): Spatial autocorrelation and red herrings in geographical ecology. Glob. Ecol. Biogeogr. **12**: 53-64.

Doležal, J., Šrůtek, M. (2002): Altitudinal changes in composition and structure of mountain-temperate vegetation: a case study from the Western Carpathians. Plant Ecol. **158**: 201-221.

Doran, N.E., Balmer, J., Driessen, M., Bashford, R., Grove, S., Richardson, A.M., Griggs, J., Ziegeler, D. (2003): Moving with the times: baseline data to gauge future shifts in vegetation and invertebrate altitudinal assemblages due to environmental change. Org. Divers. Evol. **3**: 127-149.

Dormann, C.F., Mcpherson, J.M., Araújo, M.B., Bivand, R., Bolliger, J., Carl, G., Davis, R.G., Hirzel, A., Jetz, W., Kissling, W.D., Kühn, I., Ohlemüller, R., Peres-Neto, P.R., Reineking, B., Schröder, B., Schurr, F.M., Wilson, R. (2007): Methods to account for spatial autocorrelation in the analysis of species distributional data: A review. Ecography **30**: 609-628.

Elling, W., Bauer, E., Klemm, G., Koch, H. (1987): Klima und Böden. Nationalparkverwaltung Bayerischer Wald. 255 pp.

Epa (2007): Lamington National Park, Queensland Government, Environmental Protection Agency, http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=97

Ewald, J., Reuther, M., Nechwatal, J., Lang, K. (2000): Monitoring von Schäden in Waldökosystemen des bayerischen Alpenraumes. Umwelt und Entwicklung Bayern, Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen, Materialien **155**: 3-243.

Fahrmeir, L., Kneib, T., Lang S. (2004): Penalized structured additive regression: A Bayesian perspective. Statist. Sinica. **14**: 731-761.

Frahm, J.P., Klaus, D. (2000): Moose als Indikatoren von rezenten und früheren Klimafluktuationen in Mitteleuropa. NNA Berichte **13**: 69-75.

Grabherr, G., Gottfried, M., Pauli, H. (1994): Climate effects on mountain plants. Nature **369**: 448-448.

Grabherr, G., Gottfried, M. & Pauli, H. (2000): GLORIA: A Global Observation Research Initiative in Alpine Environments. Mt. Res. Dev. **20**: 190-192.

Green, R.H. (1979): Sampling Design and statistical Methods for Environmental Biologists. John Witey and Sons, New York, 272 pp.

Grytnes, J.A. (2003): Species-richness patterns of vascular plants along seven altitudinal transects in Norway. Ecography **26**: 291-300.

Grytnes, J.A., Heegaard, E., Ihlen, P.G. (2006): Species richness of vascular plants, bryophytes and lichens along an altitudinal gradient in western Norway Acta Oecol. **29**: 241-246.

Guisan, A., Zimmermann, N. (2000): Predictive habitat distribution models in ecology. Ecol. Model. **135**: 147-186.

Haining, R.P. (2003): Spatial data analysis:theory and practise, Cambridge, UK: Cambridge University Press.

Harrington, R., Woiwod, I., Sparks, T. (1999): Climate Change and trophic interactions. Trends in Ecol. Evol. **14**: 146-150.

Henle, K., Dziock, F., Foeckler, F., Follner, K., Hüsing, V., Hettrich, A., Rink, M., Stab, S., Scholz, M. (2006): Study Design for Assessing Species Environment Relationships and Developing Indicator Systems for Ecological Changes in Floodplanes - The Approach of the RIVA Project. Internat. Rev. Hydrobiol. **91**: 292-313.

Hill, J.K., Thomas, C.D., Fox, R., Telfer, M.G., Willis, S.G., Asher, J., Huntley, B. (2002): Responses of butterflies to twentieth century climate warming: implications for future ranges. Proc. R. Soc. B. **269**: 2163-2171.

Hooper, D.U., Chapin, F.S., Ewel ,J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vandermeer, J., Wardle, D.A. (2005): Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge. Ecol. Monogr. **75**: 3-35.

Hothorn T., Lausen B. (2003): On the exact distribution of maximally selected rank statistics. Comput. Stat. Data Anal. **43**: 121-137.

Hurlbert, S.H. (1984): Pseudoreplication and the Design of Ecological Field Experiments. Ecol. Monogr. **54**: 187-211.

Ibisca (2007): First Annual Report July 2007, Centre of Innovative Conservation Strategies, Griffith University, Australia, http://www.griffith.edu/ibisca

Ipcc (2001): Climate Change. The Third Assessment Report. Cambridge University Press, Cambridge, New York.

Ipcc (2007a): Climate Change 2007 - Impacts, Adaption and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, New York.

Ipcc (2007b): Climate Change 2007 – The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, New York.

Kazakis, G., Ghosn, D., Vogiatzakis, I.N., Papanastasis, V.P. (2007): Vascular plant diversity and climate change in the alpine zone of Lefka Ori, Crete. Biodivers. Conserv. **16**: 1603-1615.

Kneib, T., Fahrmeir, L. (2006): Structured additive regression for categorical space-time data: A mixed model approach. Biometrics **62**: 109-118.

Kühn, I. (2007): Incorporating spatial autocorrelation may invert observed patterns. Diversity Distrib. **13**: 66-69.

Kühn, I., Biermann, S.M., Durka, W., Klotz, S. (2006): Relating geographical variation in pollination types to environmental and spatial factors using novel statistical methods. New Phytol. **172**: 127-139.

Lawler, J.J., White, D., Neilson, R.P., Blaustein A.R. (2006): Predicting climate-induced range shifts: model differences and model reliability. Glob. Chang. Biol. **12**: 1568-1584.

Lee, T.D., Barret, J.P., Hartman, B. (2005): Elevation, substrate, and the potential for climate-induced tree migration in the White Mountains, New Hampshire, USA. For. Ecol. and Manage. **212**: 75-91.

Legendre, P. (1993): Spatial autocorrelation - Trouble or new paradigm. Ecology **74**: 1659-1673.

Legendre, P., Legendre, L. (1998): Numerical Ecology. Elsevier, Amsterdam.

Leuschner, C., Schipka, F. (2004): Vorstudie Klimawandel und Naturschutz in Deutschland. Bundesamt für Naturschutz: 35 pp.

Leyer, I., Wesche, K. (2006): Multivariate Statistik in der Ökologie, Marburg: 1-221.

Lomolino, M.V. (2001): Elevation gradients of species-density: historical and prospective views. Glob. Ecol. Biogeogr. **10**: 3-13.

Loreau, M., Naeem, S., Inchausti, P., Bengtsson, J., Grime, J.P., Hector, A., Hooper, D.U., Huston, M.A., Raffaelli, D., Schmid, B., Tilman, D., Wardle, D.A. (2001): Ecology - Biodiversity and ecosystem functioning: Current knowledge and future challenges. Science **294**: 804-808.

Luehr, B., Böhmer, A. (2000): Comparison between percolation and extraction with 1 M NH4Cl solution to determine the effective cation exchange capacity (CECeff) of soils. J. Plant Nutr. Soil Sci. **163**: 555-557.

McCullough, P., Nelder, J.A. (1989): Generalized linear models. Chapman & Hall, London, 2nd edition.

Mc Grath, D.A., Evans, J.P., Smith, C.K., Haskell, D.G., Pelkey, N.W., Gottfried, R.R., Brockett, C.D., Lane, M.D., Williams, E.D. (2004): Mapping Land-Use Change and Monitoring the Impacts of Hardwood-to-Pine Conversion on the Southern Cumberland Plateau in Tennessee. AMS **8**: 1-24.

Menzel, A. (2003): Anzeichen des Klimawandels in der Tier- und Pflanzenwelt. LWF aktuell **37**: 14-18.

Menzel, A., Fabian, P. (1999): Growing season extended in Europe. Nature **397**: 659.

Menzel ,A., Sparks, T., Estrella, N., Koch, E., Aasa, A., Ahas, R., Alm-Kübler, K., Bissolik, P., Braslavska, O., Briede, A., Chmielewski, F.M., Crepinsek, Z., Curnell, Y., Dahl, A., Defila, C., Donnel,y A., Filella, Y., Jatcak, K., Mage, F., Mestre, A., Nordli, O.P.J., Pirinen, P., Remisova, V., Scheifinger, H., Striz, M., Susnik, A., Van Vliet, A.J.H., Wielgolaski, F.E., Zach, S., Zust, A. (2006): European phenological response to climate change matches the warming pattern. Glob. Chan. Biol. **12**: 1969-1976.

Meyer, P., Ackermann, J., Balcar, P., Boddenberg, J., Detsch, R., Förster, B., Fuchs, H., Hoffmann, B., Keitel, W., Kölbel, M., Köthke, C., Koss, H., Unkrig, W., Weber, J., Willig, J. (2001): Untersuchung der Waldstruktur und ihrer Dynamik in Naturwaldreservaten, Methodische Empfehlung. Arbeitskreis Naturwälder in der Bund-Länder-Arbeitsgemeinschaft Forsteinrichtung.

Muradin, R. (2001): Ecological thresholds: a survey. Ecol. Econo. **38**: 7-24.

Noack, E.M. (1979): Witterung und Klima im Bayerischen Wald. Nationalparkverwaltung Bayerischer Wald: 132 pp.

Økland, R.H. (2003): Partitioning the variation in a plot-by-species data matrix that is related to *n* sets of explanatory variables. J. Veg. Sci. **14**: 693-700.

Parmesan, C. (2003): A globally coherent fingerprint of climate change impacts across natural systems. Nature **42**: 37-42.

Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas C.D., Descimon H., Huntley B., Kaila L., Kullberg J., Tammaru, T., Tennent, W.J., Thomas, J.A., Warren, M. (1999): Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature **399**: 579-583.

Pauli, H., Gottfried, M., Reiter, K., Klettner, C., Grabherr, G. (2007): Signals of range expansion and contractions of vascular plants in the high Alps: observations (1994-2004) at the GLORIA master site Schrankvogel, Tyrol, Austria. Glob. Chan. Biol. **13**: 147-156.

Pfützner, B. (2002): Description of ArcEGMO. Official homepage of the modelling system ArcEGMO. http://www.arcegmo.de.

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

Schröter, D., Acosta-Michlik, L., Arnell, A.W., Araújo, M.B., Bedeck, F., Bakker, M., Bondeau, A., Bugmann, H., Carter, T., de la Vega-Leinert, A.C., Erhard, M., Espiñeira, G.Z., Ewert, F., Fritsch, U., Friedlingstein, P., Glendining, M., Gracia, C.A., Hickler, T., House, J., Hulme, M., Kankaanpää, S., Klein, R.J.T., Krukenberg, B., Lavorel, S., Leemans, R., Lindner, M., Liski, J., Metzger, M.J., Meyer, J., Mitchell, T., Mohren, F., Morales, P., Moreno, J.M., Reginster, I., Reidsma, P., Rounsevell, M., Pla, E., Pluimers, J., Prentice, I.C., Pussinen, A., Sánchez, A., Sabaté, S., Sitch, S., Smith, B., Smith, P., Sykes, M.T., Thonicke, K., Thuiller, W., Tuck, G., van der Werf, G., Vayreda ,J., Wattenbach, M., Wilson, D.W., Woodward, F.I., Zaehle, S., Zierl, B., Zudin, S., Cramer, W. (2004): ATEAM Final Report 2004. Potsdam Institute for Climate Impact Research (PIK): 139 pp.

Sparks, T.H. (1999): Phenology and the changing pattern of bird migration in Britain. Int. J. of Biometeorol. **42**: 134-138.

Spekat, A., Enke, W., Kreienkamp, F. (2007): Neuentwicklung von regional hoch aufgelösten Wetterlagen für Deutschland und Bereitstellung regionaler Klimaszenarios auf der Basis von globalen Klimasimulationen mit dem Regionalisierungsmodell WETTREG auf der Basis von globalen Klimasimulationen mit ECHAM5/MPI-OM T63L31 2010 bis 2100 für die SRES-Szenarios B1, A1B und A2. Publikationen des Umweltbundesamtes: 1-149.

Steyerberg, E.W., Harrell, F.E., Borsboom G.J.J.M., Eijkemans, M.J.C. , Vergouwe, Y., Habbema, J.D.F. (2001): Internal validation of predictive models - efficiency of some procedures for logistic regression analysis. J. Clin. Epidemiol. **54**: 774-781.

Sutherland, W.J. (2006): Predicting the ecological consequences of environmental change: a review of the methods. J. Appl. Ecol. **43**: 599-616.

Sutherland, W.J., Armstrong-Brown, S., Armstrong, P.R., Brereton, T., Brickland, J., Campell, C., D., Chamberlain, D.E., Cooke, A.I., Dulvy, N., K, Dusic, N.R., Fitton, M., Freckleton, R.P., Godfray, H.C.J., Grout, N., Harvey, H.J., Hedley, C., Hopkins, J., J., Kift, N., B., Kirby, K.J., Kunin, W.E., MacDonald, D.W., Marker, B., Naura, M., Neale, A.R., Oliver, T., Osborn, D., Pullin, A.S., Shardlow, M.E.A., Showler, D.A., Smith, P.L., Smithers, R.J., Solandt, J.-L., Spencer, J., Spray, C.J., Thomas, C.D., Thompson, J., Webb, S.E., Yalden, D.W., Watkinson, A.R. (2006): The identification of 100 ecological questions of high policy relevance in the UK. J. Appl. Ecol. **43**: 617-627.

Ter Braak, C.J.F., Smilauer, P. (2002): CANOCO Reference Manual and CanoDraw for Windows User`s Guide: Software for Canonical Community Ordination version 4.5 Microcomputer Power, Ithaca.

Theurillat, J.P., Guisan, A. (2001): Potential impact of climate change on vegetation in the European Alps: A Review. Clim. Chang. **50**: 77-109.

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

Travis, J.M.J. (2002): Climate change and habitat destruction: a deadly anthropogenic cocktail. Proc. R. Soc. B. **270**: 467-473.

Walentowski, H., J. Ewald, A. Fischer, C. Kölling, Türk W. 2004. Handbuch der natürlichen Waldgesellschaften in Bayern. Geobotanica, Freising: 441 pp.

Walther, G.R., Berger, S., Sykes, M.T. (2005): An ecological “footprint” of climate change. Proc. R. Soc. B **272**: 1427-1432.

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O., Bairlein, F. (2002): Ecological response to recent climate change. Nature **416**: 389-395.

Willdenow, K.L. (1805): The principles of botany, and vegetable physiology. Blackwood, Cadell and Davies, London.

Wilson, E.O. (1992): The diversity of life. Belknap Press, Cambridge.

Wilson, R.D., Trueman, J.W.H., Williams, S.E., Yeates, D.K. (2007): Altitudinally restricted comunities of Schizophoran flies in Queensland´s Wet Tropics: vulnerabilty to climate change. Biodivers. Conserv. **16**: 3163-3177.

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