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The BIOKLIM Project in the National Park Bavarian Forest: Lessons from a biodiversity survey

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Abstract
Biodiversity is diminishing globally at an unprecedented rate in times of intensive land use and ongoing climate change. Since biodiversity is related to important ecosystem functions and ecosystem services it is nowadays the goal by law to maintain and improve biodiversity. One instrument to achieve this goal is the establishment of protected areas. We carried out a large biodiversity survey (BIOKLIM-Project) within the National Park Bavarian Forest (German part of the Bohemian Forest) to provide a broad range of data to assess the effects of the benign neglect strategy on species and communities across different taxonomic groups. A further aim was to assess and predict the consequences of climate change on the low mountain range. We provided evidence that the benign neglect strategy leading to large scale disturbance by bark beetle increased habitat heterogeneity and consequently overall species diversity in former commercial forest. Our study furthermore showed that species assemblages are currently under re-organization caused by climate change. Our findings supported the National Park management and contributed to the question how biodiversity respond due to the benign neglect strategy. Our results underline the importance of gathering long term biodiversity data in order to answer numerous upcoming questions in times of heavy human-caused environmental change. Such data finally inspired forest managers, conservation biologists, and ecologists. As a bunch of new hypotheses arose during BIOKLIM, we already set up some experiments as a complementary tool to deepen our understanding on specific objects such like dead-wood ecology.

Key words: biodiversity, climate change, conservation, ecology, protected areas

INTRODUCTION

Biodiversity faces growing pressure from human actions, including habitat conversion and degradation, habitat fragmentation, climate change, harvesting, and pollution (TITTENSOR et al. 2014). As a result, global assessments show that the species' extinction risk is increasing on average while population sizes are declining (PIMM et al. 2014). In the past 20 years remarkable progress has been made towards understanding how the loss of biodiversity affects the functioning of ecosystems and thus affects society (CARDINALE 2012). Evidence is mounting that extinctions are altering key processes important to the productivity and sustainability of Earth's ecosystems (ISBELL et al. 2011). As a consequence, a plenty of initiatives has been started on different spatial scales to prevent biodiversity from loss (e.g. global scale: Convention on biological diversity, continental scale: Natura 2000, national scale: German biodiversity strategies, federal state scale: Bavarian biodiversity strategy). One important instrument to maintain biodiversity is the establishment of protected areas. Recent reviews showed, that setting up protected areas as a core conservation strategy is well justified (GELDMANN et al. 2013, BUTCHART et al. 2012).

The National Park Bavarian Forest was set up in 1970 in a former commercial forest. In the 1990s, the National Park (NP) experienced large-scale disturbance in mature spruce stands by bark beetle (mainly *Ips typographus*, >5000 ha, see Lehnert et al. 2013). Due to the benign neglect strategy of the NP, this development led to a considerable enrichment of spruce dead wood along with rather open conditions within a very short-time frame, a situation unique for central Europe (Lehnert et al. 2013, Beudert et al. 2015). However, data from a broad range of taxonomic groups in this area were still missing and evidence on the response of species to this development lacking. Moreover, apart from such kind of structural changes due to a benign neglect strategy, analysis of long term climate data showed that the NP experienced considerable changes in the temperature regime (Bässler 2008). Both, natural disturbance and climate change triggered the need to establish a long term biodiversity monitoring – the BIOKLIM-Project was born (Bässler et al. 2008). In this contribution we summarise the conceptual framework and the most important outcome from the first inventory (for the complete list of publications about the BIOKLIM-project, see Appendix 1). We finally demonstrate why a long term monitoring is necessary and how such a monitoring inspires experimental efforts as a complementary tool to deepen our understanding on underlying processes in order to improve conservation actions.

Materials and Methods

Brief overview of the study area

The study area is the German part of the Bohemian Forest, located in southeastern Germany (48°54' N, 13°29' E), covering an area of ~5,000 km² at altitudes from 300 to 1450 m a.s.l. The study area belongs to the temperate zone and is characterized by atlantic and continental influences. The total annual precipitation along the gradient is between 900 and 1800 mm. The mean annual temperature varies between 3.5°C at high elevations and 9.0°C at low elevations. The area is characterized by a homogenous geology (Bohemian Massif, granitic and gneissic bedrock) and predominantly acidic soils. Cultivation and management in this area became important only around 1850 and small areas of old-growth forests still exist (Röder et al. 2010). The proportion of spruce at all elevations increased during the last century owing to forest management (Röder et al. 2010). Nowadays European beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) are the main tree species at all elevations, however admixed with *Quercus* sp. at the lowest elevations. Above 1200 m a.s.l., Norway spruce becomes dominant with a lower proportion of beech.

The conceptual framework

In 2006, we set up a total of 288 plots along four straight transects following the altitudinal gradient. Five additional plots were installed beside the main transects to compensate for the lack of old growth forest samples at higher altitude. 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 in the NP Bavarian Forest. As a result of the division of the NP 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. The chosen design using 4 main transects with 100 m between plots ensures that a minimum of 23 replications for each altitudinal range exists, which is sufficient to overcome simultaneous environmental effects. As outlined by Bässler et al. (2008), the plots represent fairly well the main plant communities of the NP. The first analysis revealed the weakness in estimating the consequences of climate change on species distributions (Bässler et al. 2010a), which led to the decision to extend the elevational gradient by its maximum in 2008. We hence set up 38 additional plots at elevations between ca. 300 m a.s.l. (close to the Danube River) to 650 m a.s.l. (the lowest sites within the NP Bavarian Forest) outside the NP. The final number was therefore 331 plots distributed across elevations from 287 m a.s.l. to 1420 m a.s.l (Fig. 1).

On each plot a plethora of environmental variables were measured, recorded, or modelled. They include for example basic topographic information (e.g. altitude, exposition), forest structural variables (e.g. dead wood, tree species composition at different strata), soil chem-

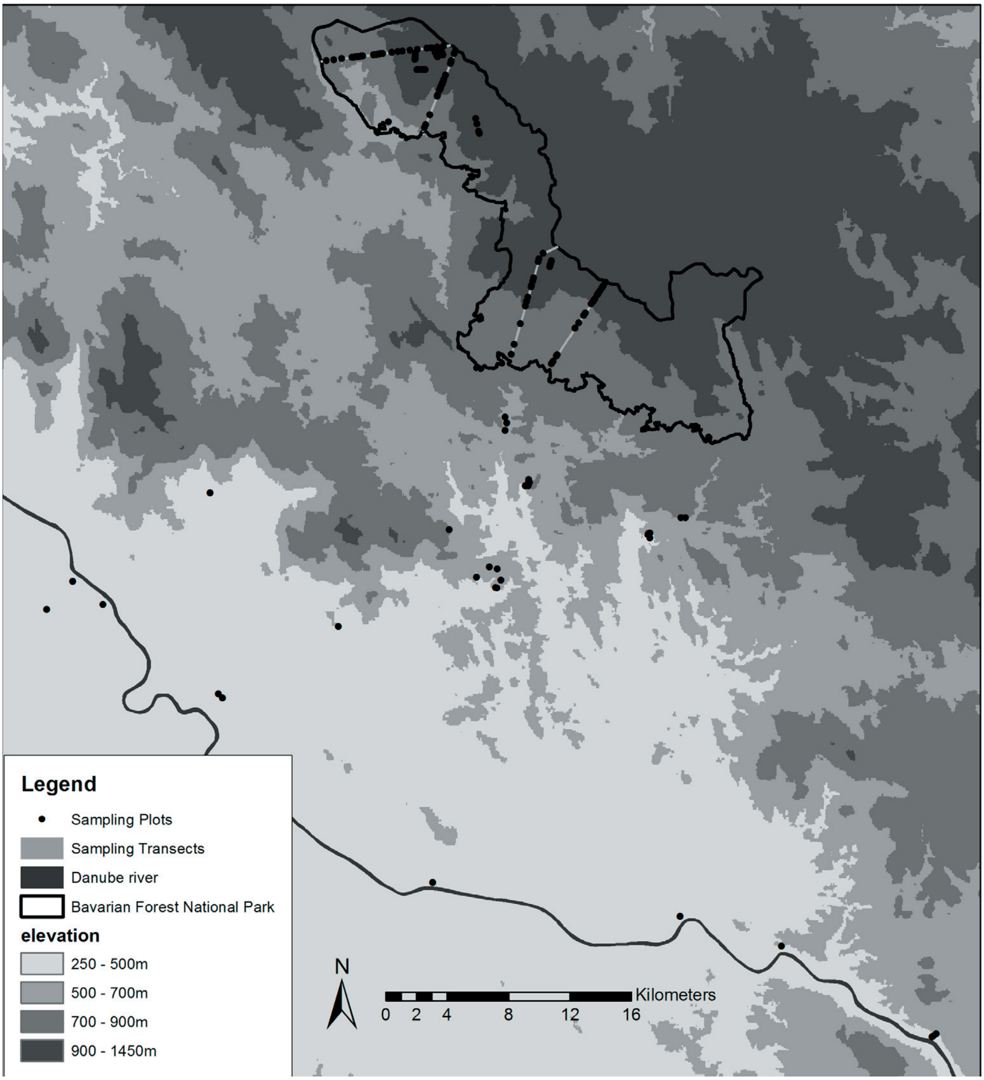

Fig. 1. An overview map of the 331 sampling plots across the altitudinal gradient. Main sampling transects (grey lines) are located within the Bavarian Forest National Park. Additional lowland plots (<650m) outside the NP extended the elevational gradient down to the Danube River representing the gradient from 287–1420 m a.s.l.. For repetition in 2016, an optimized set of 147 sampling plots (black circles) was selected. Some sampling points are not visible (overlayed) due to scaling.

ical-physical and chemical properties, and a set of biologically meaningful climate variables (see Bässler et al. 2008 and references therein). All taxonomic groups, methods and number of sampled plots (replications) are presented in Bässler et al. (2008). Altogether we collected data on 25 higher taxa. The number of plots to be sampled depended on the nature of the scientific enquiry and on the target group. For this reason, we stratified 331 sample plots, selecting pre-stratified sub-samples with respect to the two main gradients (altitude and forest structure) for some groups (Bässler et al. 2008).

Lessons from the first BIOKLIM inventory

Response of species and communities to large scale disturbance

The analysis based on the forest structural inventories demonstrated convincingly that disturbance by bark beetle increased the habitat variability considerably (Lehnert et al. 2013, Moning & Müller 2008). This supported the general view that disturbances caused, e.g., by bark beetle, fire, or windthrow increase habitat heterogeneity in the early serial stage (Swanson et al. 2011). The most obvious and ecologically meaningful habitat feature changed after disturbance was the rapid enrichment of dead wood along with the openness of the canopy (Moning & Müller 2008). Allowing the natural disturbance in a former commercial forest led therefore to an enrichment of dead wood known from natural forests (Müller & Bütler 2010, Müller et al. 2010). The availability of resources subsequently led to the restoration of species communities, which has been shown for saproxylic beetles (Müller et al. 2010), wood-inhabiting fungi (Bässler et al. 2010b), bryophytes (Raabe et al. 2010), lichens (Moning et al. 2009), and birds (Moning & Müller 2008). Rare and red-listed specialist species strongly related to spruce were favored by the openness of the canopy and dead-wood as it was the case for spruce regeneration (Lehnert et al. 2013, Beudert et al. 2015, Moning & Müller 2008, Müller et al. 2010, Jarzabek-Müller & Müller 2008, Bässler & Müller 2010, Bässler et al. 2012, Müller & Simonis 2010). A red-listed polypore (*Antrodiella citrinella*) for example, was enabled to leave the boundaries of two old-growth reserves and re-colonized large areas of the disturbed sites. This species especially profited by the huge number of spruce dead-wood colonized by its predecessor *Fomitopsis pinicola* (Bässler & Müller 2010). We recently summarised the overall positive effect of the bark beetle disturbance on species diversity across taxonomic groups thereby demonstrating that an increase in biodiversity did not affect other ecosystem services such as drinking water (Beudert et al. 2015). However, we still miss important species in the disturbed area, which are either extinct or still only confined to old-growth forest relicts (Bässler et al. 2012, Rieger et al. 2010). Recently, we focused not only on the response of species diversity to the disturbance but also on the response of the functional and phylogenetic diversity as well as the functional composition of species assemblages. Such kind of studies provides, on the one hand, a deeper mechanistic understanding on the species assembly after the disturbance and, on the other hand, a better understanding on the functional response as an important measure for ecosystem processes and functions (Mouillot et al. 2012). For example, we recently demonstrated that the disturbance did not act as a habitat filter on wood-inhabiting fungal and lichen communities but it restored the functional composition of the assemblages (Bässler et al. 2015). A NP can act as an important place to learn; improving our understanding on the species–environmental relationship, hence, should contribute to improve conservation activity in commercial forests. In that respect, we provided guidelines and concrete recommendations to improve biodiversity needs in mountain mixed commercial forests (Moning & Müller 2008, Moning et al. 2010, Moning & Müller 2009).

Impacts of climate change

By law, the NP administration has the obligation to maintain the natural occurring specific natural species communities of the landscape. In times of climate change this is somehow challenging. Knowledge on the consequences of climate change on the distribution of species and how species communities will be affected are important for the NP management. Moreover, the importance of climate change effects on species might be modified by the existence of specific habitat features provided by a benign neglect strategy. The first studies therefore focused on the relative importance of macroclimate versus local forest structural variables (Bässler et al. 2010a, Bässler et al. 2010b, Raabe et al. 2010, Moning et al. 2009). For the species groups using dead-wood as a habitat it has been shown that, at the scale of the NP, resource and habitat availability seems more important than macroclimate (Bässler et al. 2010b, Raabe et al. 2010, Moning et al. 2009). This suggests that availability of deadwood might buffer the effects by climate change at least to a certain extend. On the other hand, we have evidence that the species communities within the NP are under re-organization due to climate change (Bässler et al. 2013). In one study comparing the upper distributional limits of species from around 1900 (Thiem 1906) with the more recent BIOKLIM records, we found for example that ectothermic insects even overshot the expected shift caused by climate change (Bässler et al. 2013). A shift due to climate change was not consistent across taxonomic groups (e.g. plants showed no response), which suggests a considerable re-organization of species communities across taxonomic groups. Climate change effects in a low mountain range might be more pronounced, e.g., compared to the Alps, simply because of the limited elevational range. Hence, the assumption that high montane species should be most vulnerable seems justified (Thuiller 2007). This view is supported by a statistical exercise, where we modelled the probability of occurrence of typical high montane species by future climate scenarios. These studies showed that even a moderate increase of temperature (1.8 K, IPCC 2007) decrease the probability of the occurrence above ~1100 m a.s.l. considerably (Müller et al. 2008, Bässler et al. 2010c). Furthermore the habitat area available at the high montane zone is generally limited (less than 10% of the area of the NP, Bässler et al. 2010c). At the same time, we recently recorded new thermophile species entering the NP (Bässler & Leibl 2012). A very prominent example is the immigrant *Oxythyrea funesta,* a pontic-mediterranean species spreading out from the donor site close to the Danube River towards and into the NP since a few years (Bussler 2007). The first approaches were carried out focusing on the effects of climate change on the genetic structure of populations (Oberprieler et al. 2015, Schade 2010). One study underlines that the genetic variability within high montane species populations (*Semilimax kotulae*) is rather low (gene drift is larger than gene flow) indicating a high level of susceptibility to climate change (Schade 2010). Another study suggested that hybridisation caused by a shift of species due to climate change led to genetic swamping of a rare species (*Senecio hercynicus*) by its more common congener (*S. ovatus*) (Oberprieler et al. 2015). Finally, a recent study focusing on within-species variability of rodent species along the climate gradient clearly suggested that we should pay more attention to the potential significance of genetic and/or phenotypic plasticity of life history traits to environmental heterogeneity such as climate (Müller et al. 2014).

Predicting biodiversity from the air

Extensive biodiversity data across different taxonomic groups including important environmental gradients provide the opportunity to test the predictability of biodiversity measures by novel rapid inventory techniques such like LiDAR laserscanning. The underlying idea is to test for the possibility getting information about biodiversity measures in remote areas, or where taxonomic knowledge is limited. Moreover, due to a precise reflection of the three dimensional structure of the forest canopy by LiDAR data, such measures provide new opportunities to improve our understanding on species occurrence and habitat use (MÜLLER et al. 2009). Based on the BIOKLIM data, we carried out several studies and showed that species diversity is well predictable from airborne laserscanning. Such data act fairly well as a suitable surrogate reflecting the variability of the forest canopy with a high resolution (MÜLLER & BRANDL 2009, VIERLING et al. 2011). With NATURA 2000, the EU implemented a large scale conservation program. Success of this conservation effort depends strongly on the ability to detect relevant changes in terms of the conservational aim of the NATURA 2000 habitat types via a monitoring program. Such a monitoring program is even challenging at the spatial scale of a NP. We demonstrated, however, that LiDAR data are a suitable instrument to predict adequately NATURA 2000 habitat types (BÄSSLER et al. 2011).

Optimizing the BIOKLIM design for repetition

The above mentioned studies all followed the first survey. However, the value of such data doubles more than two-fold when carrying out a temporal repetition. We hence plan to repeat the BIOKLIM survey in 2016. The preliminary studies but also a recent analysis of the

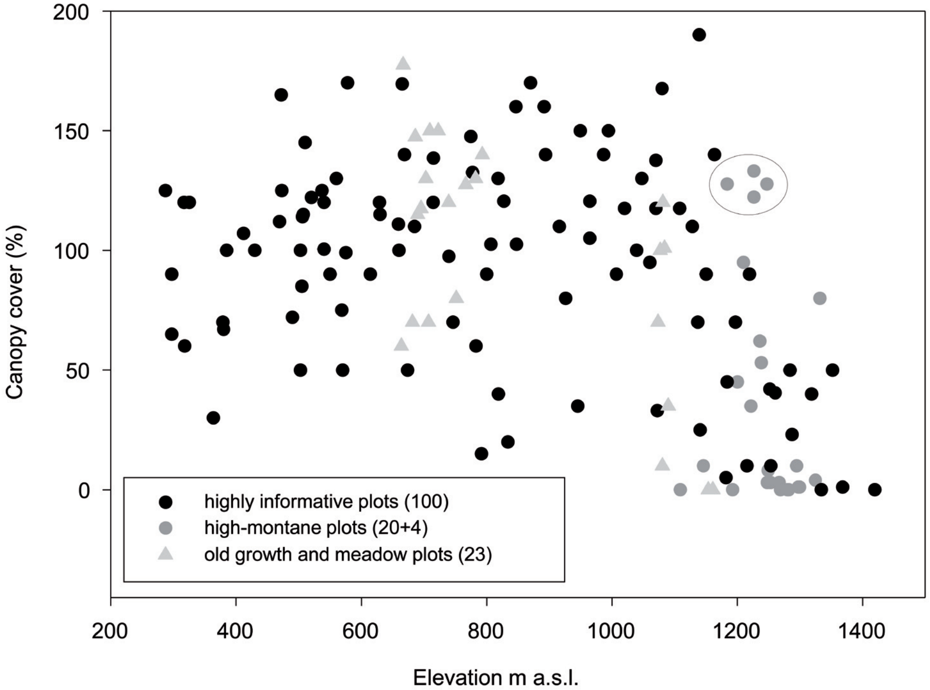

Fig. 2. Set of 147 sampling plots for repetition in 2016. A total of 100 out of the most informative plots were selected, including 62 plots within the National Park and 38 lowland plots (<650 m). This selection was completed by 23 old growth and meadow plots and 24 high-montane plots (>1000 m). Please note, 4 high-montane plots "*Picea* stand" (framed) are new established, still lacking for exact information about canopy, but it was estimated by aerial photos with more than 100% canopy cover. Canopy values with more than 100% results from adding canopy cover (%) by different strata (shrub layer: 1–5 m, tree layer 2: >5–15 m, and tree layer 1: >15 m).

environmental data enabled us to optimise the design. We categorised all plots in respect to their available taxonomical information. Out of the most informative sampling plots we selected those that best cover the structural gradient (canopy cover) across the elevational gradient (for final selection, see Fig. 2). For representation of the elevational gradient, we created a set of 100 plots out of the original 331 plots, including 62 highly informative plots and all 38 lowland plots (<650m). As special additions, we added the 23 old growth and meadow plots due to their great importance for the area. Further, we completed this selection by 24 high-montane plots: *Picea* stand (8), windthrow area left (8) and cleared (8). The final set of 147 plots for repetition in 2016 is represented as an unconstrained ordination analysis (Fig. 3, for locations see Fig. 1).

CONCLUSIONS

1. Based on our studies we can show that regional data from a large biodiversity survey can be used in various ways: (i) supported decisions of the NP management, (ii) improved our knowledge on how species and communities respond to a benign neglect strategy in a former commercial forest within a highly cultivated landscape in central Europe, (iii) allowed us to make concrete recommendations in order to improve biodiversity needs in commercial forests, (iv) Provided evidence on the impacts of climate change on species distribution and allowed us to make predictions on the extinction risk of species, and (v) contributed to the further development of a rapid assessment of biodiversity using novel inventory techniques.

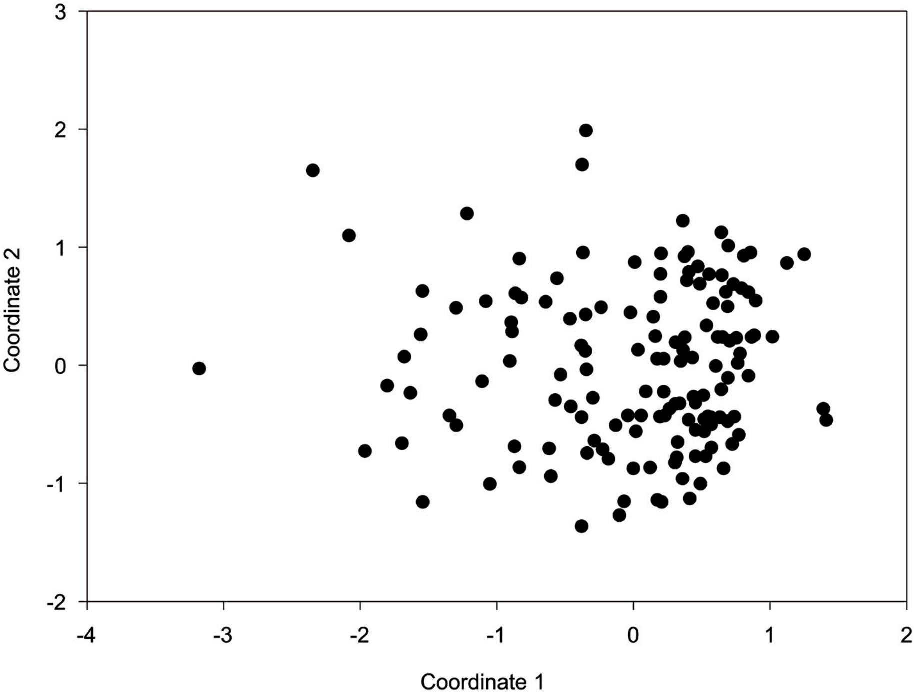

Fig. 3. Unconstrained ordination analysis (NMDS) of the selected 143 sampling plots for repetition in 2016. For analysis, vegetation data were used (tree layer 1 and 2, shrub, herb and grass layer), circles represent vegetation assemblages. For the 4 new established high-montane plots no vegetation data was available.

2. We are aware that survey data have their limitations in providing causal evidence of the observed species-environmental relationships. During the studies within the BIOKLIM project, a plethora of new hypothesis arose by the many scientists involved. As a consequence, we set up several experiments to test specific hypothesis. As an example we started recently a large dead-wood experiment to answer the question on the relative importance of resource availability (dead-wood amount) versus niche availability (dead-wood diversity) on saproxylic diversity (Seibold et al. 2014, Seibold et al. 2015).

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Appendix 1. The complete list of publications out of the BIOKLIM project.

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