

## EFFECT OF TREE SPECIES DIVERSITY ON THE NEUROPTERID COMMUNITY IN A DECIDUOUS FOREST

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**Abstract** - The neuropterid communities of a temperate deciduous forest in Germany were studied using flight-interception traps in the tree crown stratum in the year 2005. In total 884 specimens were captured, representing 23 species of Neuropterida. The communities captured in monospecific beech stands significantly differed from those of more diverse stands. Diversity of Neuropterida was positively correlated with tree species diversity. Abundance of dominant species was either negatively or positively correlated with tree diversity, indicating different levels of host tree association of the particular species.

**KEY WORDS:** Habitat heterogeneity, Neuropterida, canopy fauna, tree species diversity, neuropterid diversity

### **Izveček** – UČINEK RAZNOLIKOSTI DREVESNIH VRST NA MREŽE-KRILSKE ZDRUŽBE V LISTOPADNEM GOZDU

S prestreznimi pastmi za leteče žuželke v drevesnih krošnjah smo leta 2005 raziskovali združbe mrežekrilcev zmernega listopadnega gozda v Nemčiji. Ujeli smo skupno 884 primerkov, pripadajočih 23 vrstam mrežekrilcev. Združbe, ujete v enovrstnih bukovih sestojih so se pomembno razlikovale od tistih iz bolj raznolikih sestojev. Raznovrstnost mrežekrilcev je bila pozitivno odvisna od raznovrstnosti drevesnih vrst. Pogostost prevladujočih vrst je bila negativno ali pozitivno odvisna od drevesne raznovrstnosti, kar kaže na različne stopnje vezanosti na gostiteljska drevesa posameznih vrst.

KLJUČNE BESEDE: Habitatna raznolikost, Neuropterida, favna drevesnih krošenj, raznolikost drevesnih vrst, raznovrstnost mrežekrilcev

## Introduction

Several hypotheses exist to explain the organization of insect communities in time and space (Price, 1984; Spight *et al.*, 2008). In particular, species richness of arthropods has been reported to be positively correlated with plant diversity (Hutchinson, 1959; Southwood, 1978; Gaston, 1992; Siemann *et al.*, 1998; Novotny *et al.*, 2006). Increased habitat heterogeneity, i.e. an increase in plant species with different morphological, physiological and phenological traits causes a more complex environment, thereby offering a greater niche array and hence supporting a larger number of arthropod species (Humphrey *et al.*, 1999; Hansen 2000, Hamer *et al.*, 2003; Lassau and Hochuli 2008). Tests of this hypothesis were up to now mostly restricted to herbivores (Altieri, 1984; Root, 1973; Siemann *et al.*, 1998), but the effect of plant diversity can cascade up to higher trophic levels. Increased plant diversity is hypothesized to directly enrich predator and parasitoid diversity by increasing availability of structural and floral resources, and also indirectly by increasing prey abundance and diversity (Hunter and Price, 1992; Siemann *et al.*, 1998).

Few studies have been published that correlate diversity of neuropterid communities with vegetational diversity. Szentkiralyi (1989) and Bozsik (1992) did not find a relationship between neuropterid diversity and vegetational diversity. Thierry *et al.* (2005) typified European ecosystems using diversity indices of neuropterid (Chrysopidae) communities, but plant diversity was not included in the characterization of the studied ecosystems.

Studies of the neuropterid fauna in tree crowns of European forests have been published since the early 1990s (Saure and Kielhorn, 1993; Czechowska, 1994; Barsig and Simon, 1995; Pantaleoni, 1996; Czechowska, 1997; Schubert and Gruppe, 1999; Gruppe and Schubert, 2001; Czechowska, 2002; Duelli *et al.*, 2002; Gruppe *et al.*, 2004; Gruppe, 2006; Gruppe, 2007; Gruppe and Müller, 2007). Many arboreal species of Neuropterida prefer certain plant species (Monserrat & Marin 1992, 1994, 2001), but the degree of association is weak due to opportunistic resource use (Szentkiralyi, 2001; Gruppe, 2008). The factors determining why adult Neuropterida show a preference for certain plant species are manifold and include microclimatic conditions, shelter options, accessory floral food, resources for arthropod prey and substrate for oviposition. Therefore, this taxon can be expected to respond well to plant diversity.

Up to now, no study was conducted trying to correlate the diversity of Neuropterida with tree species diversity in forests. Here we present data on Neuropterida dwelling in forest stands of different diversity ranging from pure beech stands to forest plots with up to 10 deciduous tree species. The data were obtained in the Hainich National Park within the overarching research project of the University

of Göttingen “The role of biodiversity for biogeochemical cycles and biotic interactions in temperate deciduous forests” (Mölder *et al.*, 2006).

## Materials and Methods

The research sites were located in the Hainich National Park, Thuringia, Germany, in the year 2005. The national park covers a total area of 16,000 ha with 7,600 ha of semi-natural deciduous forest (Nationalpark Hainich; www.nationalparkhainich.de). Conifers occur only exceptionally throughout the park, and removal is part of the management concept to allow for a late successional stage of purely deciduous forest. The region has a temperate climate, with an average temperature of 7.5 °C and a mean precipitation of 590 mm (1973-2004, Deutscher Wetterdienst). The predominant soil type is stagnic luvisol on loess-limestone as parent material.

Sampling was carried out in deciduous forest stands of different tree diversity and designed *a priori* to test effects of a tree diversity gradient on arthropod diversity (Sobek, 2008). All forest stands shared main characteristics like flat elevation, absence of canopy gaps and had remained undisturbed for more than 40 years since the last logging event. No conifers were present in the surroundings of the sampled forest stands. Plots within the stands were arranged in three diversity levels (DL) with different numbers of dominant tree species. Diversity level 1 (DL-1) was represented by nearly pure beech stands (*Fagus sylvatica* L.), DL-2 by stands with three dominant tree species (*F. sylvatica* L., *Fraxinus excelsior* L., *Tilia cordata* L.) and DL-3 by stands with at least six tree species (*Acer pseudoplatanus* L., *Carpinus betulus* L., *Fagus sylvatica* L., *Fraxinus excelsior* L., *Quercus robur* L., *Sorbus torminalis* L., *Tilia cordata* L./*T. platyphyllos* L.) (Mölder *et al.*, 2006). Tree diversity of the sampled plots (50 x 50 m) was calculated as Shannon index based on stem counts (diameter breast height > 7 cm), which accounts for the relative abundance of individual tree species as well as for richness (Magurran, 2004).

In each plot arthropods were captured using six flight interception traps installed in the centre of individual tree crowns of the dominant tree species. In plots of DL-3 two individual trees of each of six species were sampled resulting in 12 traps. The Collecting jars of the traps were filled with ethylene-glycol (1:1 diluted with water) as a preserving liquid and emptied every month from May to October 2005. All arthropods were sorted to order level.

Adult Neuropterida (Raphidioptera, Neuroptera) were determined to species level according to Aspöck *et al.* (1980, 1991). All species collected on one specific plot are hereafter referred to as the community of that plot. For statistical analyses, the data set of DL-3 was reduced to six traps per plot by random selection of one trap per tree species. Species representing less than 0.32% of all captured specimens are termed transients and were excluded prior to statistical calculations.

Diversity of Neuropterida was calculated as log series with BioDiversity Professional (McAleece, 1997). Differences between diversity levels (ANOVA) and the relationship between tree species diversity and neuropterid diversity or abundance of single neuropterid species was tested with Spearman rank correlations using

SPSS 16.0. To show differences between communities, detrended correspondence analysis (DCA) based on neuropterid abundance data was conducted using PC-ORD 4.1 (McCune and Mefford, 1999)

## Results

In total 884 adult Neuropterida were captured representing 23 species (Tab. 1). *Hemerobius micans* (54.1 %) and *Chrysoperla carnea* (28.1 %) occurred in domi-

**Tab. 1:** List of neuropterid species and their abundance in flight interception traps in forest stands of different diversity levels. Numbers in parentheses indicate values used for statistical analyses, i.e. after random reduction of trap numbers.

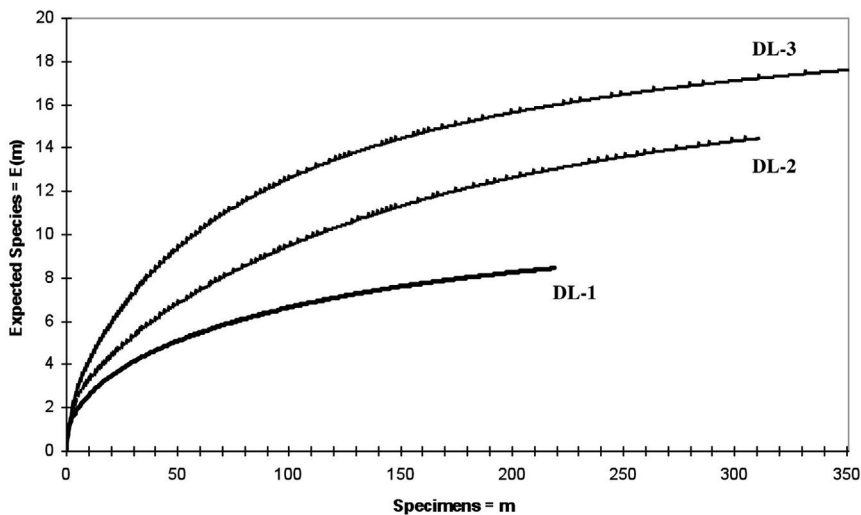
|  | DL-1 | DL-2 | DL-3      | Total |
|--|------|------|-----------|-------|
| <b>Raphidioptera: Raphidiidae</b>                  |      |      |           |       |
| <i>Phaeostigma notata</i> Fabricius, 1781          |      |      | 3 (1)     | 3     |
| <b>Neuroptera: Chrysopidae</b>                     |      |      |           |       |
| <i>Notochrysa fulviceps</i> (Stephens, 1836)       |      | 2    | 5 (3)     | 7     |
| <i>Hypochrysa elegans</i> (Burmeister, 1839)       |      | 3    | 2 (2)     | 5     |
| <i>Nineta flava</i> (Scopoli, 1763)                |      | 2    | 6 (6)     | 8     |
| <i>Chrysotropia ciliata</i> (Wesmael, 1841)        |      |      | 3 (2)     | 3     |
| <i>Dichochrysa abdominalis</i> Brauer, 1856        |      | 1    |           | 1     |
| <i>Cunctochrysa albolineata</i> (Killington, 1935) |      |      | 2 (1)     | 2     |
| <i>Peyerimhoffina gracilis</i> Schneider, 1851     |      |      | 1 (0)     | 1     |
| <i>Chrysoperla carnea</i> (Stephens, 1836)         | 25   | 104  | 119 (69)  | 248   |
| <i>Chrysoperla pallida</i> Henry et al., 2002      |      | 2    |           | 2     |
| <b>Neuroptera: Hemerobiidae</b>                    |      |      |           |       |
| <i>Hemerobius contumax</i> Tjeder, 1932            |      | 1    |           | 1     |
| <i>Hemerobius humulinus</i> Linnaeus, 1758         | 3    | 2    | 11 (4)    | 16    |
| <i>Hemerobius marginatus</i> Stephens, 1836        | 1    |      |           | 1     |
| <i>Hemerobius micans</i> Olivier, 1792             | 173  | 161  | 144 (76)  | 478   |
| <i>Hemerobius pini</i> Stephens, 1836              | 2    | 2    | 2 (1)     | 6     |
| <i>Hemerobius stigma</i> Stephens, 1836            |      |      | 1 (0)     | 1     |
| <i>Symphorobius elegans</i> (Stephens, 1836)       |      | 1    | 1 (1)     | 2     |
| <i>Symphorobius pellucidus</i> (Walker, 1853)      | 9    | 2    | 7 (3)     | 18    |
| <i>Drepanopteryx phalaenoides</i> Linnaeus, 1758   |      | 3    | 1 (0)     | 4     |
| <b>Neuroptera: Coniopterygidae</b>                 |      |      |           |       |
| <i>Coniopteryx borealis</i> Tjeder, 1930           | 2    |      | 8 (2)     | 6     |
| <i>Coniopteryx tineiformis</i> Curtis, 1834        |      | 8    | 12 (7)    | 9     |
| <i>Parasemidalis fuscipennis</i> (Reuter, 1894)    | 2    |      |           | 2     |
| <i>Conwentzia psociformis</i> (Reuter, 1894)       |      |      | 1 (1)     | 1     |
| <b>Specimens</b>                                   | 219  | 311  | 354 (197) | 884   |
| <b>Species</b>                                     | 8    | 14   | 18 (15)   | 23    |

nant proportions and represented more than 80% of all specimens. Ten species were transients, each accounting for less than 0.32% of the total. The latter group also included species which are known to develop as larva on conifers (*Dichochrysa abdominalis* Brauer, 1856, *Peyerimhoffina gracilis* Schneider, 1851, *Hemerobius contumax* Tjeder, 1932, *H. stigma* Stephens, 1836).

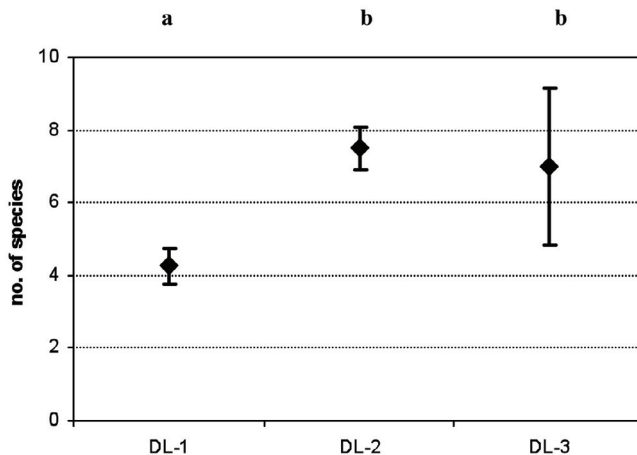
Absolute number of species increased from DL-1 (8 species) to DL-2 (14 species) and DL-3 (18 species) (Tab. 1). This increase was also supported by Hurlbert rarefaction curves for normalized number of individuals (Fig. 1). However, statistical analysis with standardized numbers of traps indicated significantly lower average species numbers for DL-1 compared to DL-2 and DL-3 only, but no differences between the latter two treatments (Anova,  $p < 0.05$ ) (Fig. 2).

The communities of Neuropterida of different diversity levels were separated by a DCA based on abundance data (Fig. 3). The first axis explains about 40% of the total variation (39.4% of inertia), separating communities in pure beech stands from the rest. DL-2 and DL-3 overlap on axis 1 but are separated by axis 2 (6.6% of inertia).

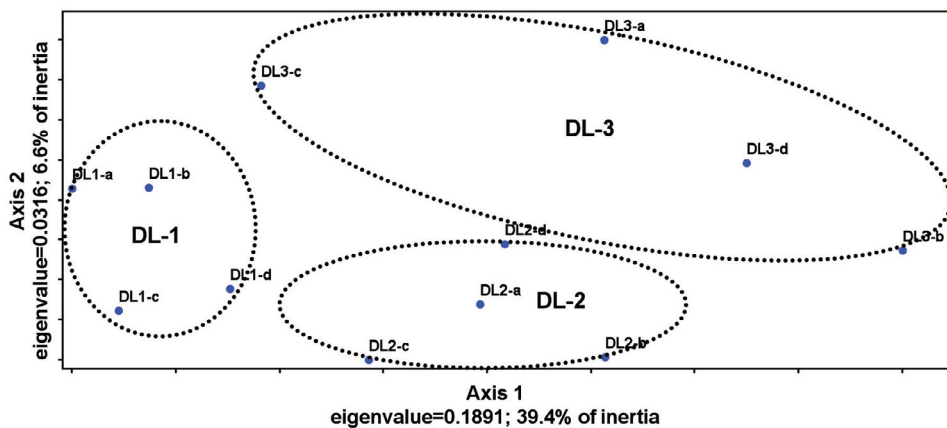
Diversity (log series  $\alpha$ ) of Neuropterida was positively correlated with diversity of tree species (Shannon diversity) (Spearman rank correlation:  $\rho = 0.711$ ,  $p < 0.005$ ) (Fig. 4). Regarding abundance of dominant neuropterid species, the generalist *Chrysoperla carnea* was also positively correlated with tree species diversity (Spearman rank correlation:  $\rho = 0.564$ ,  $p < 0.028$ ) (Fig. 5), whereas for *Hemerobius micans* significant but negatively correlated values were calculated (Spearman rank correlation:  $\rho = -0.863$ ,  $p < 0.0001$ ; Fig. 6).



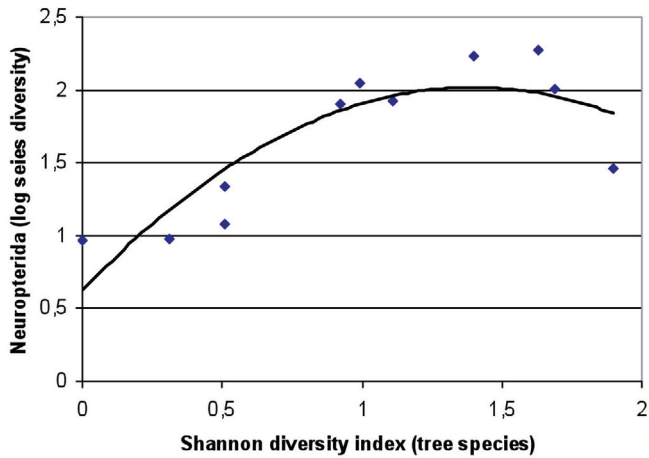
**Fig. 1:** Hurlbert rarefaction curves of Neuropterida captured in plots of different tree species diversity (DL-3 all specimens).



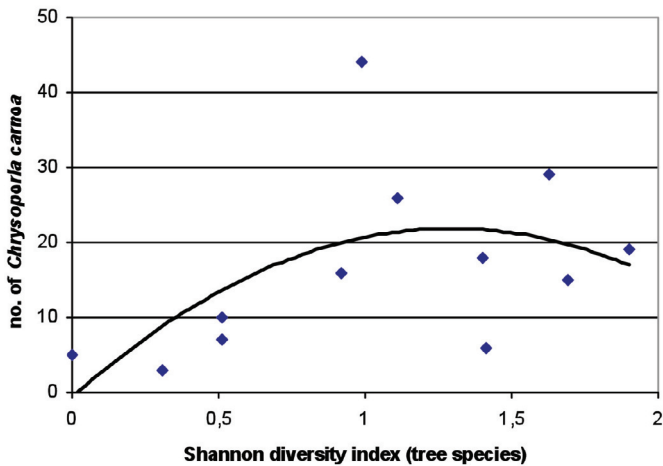
**Fig. 2:** Average number of neuropterid species captured on plots of different tree diversity levels [Means  $\pm$  standard deviation. Different letters indicate significant differences (Anova, LSD-test:  $p < 0,05$ )]



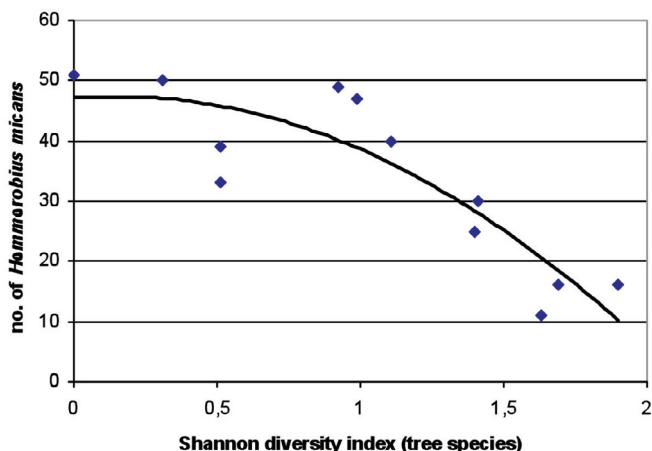
**Fig. 3:** DCA ordination of neuropterid communities in forest stands of different diversity levels.



**Fig. 4:** Correlation of tree species diversity and neuropterid diversity  
 $y = -0.7134x^2 + 1.9936x + 0.6256$  Spearman rank correlation:  $\rho = 0.711$ ;  
 $p = 0.005$ .



**Fig. 5:** Correlation of tree species diversity and abundance of *Chrysoperla carnea*  
 $(y = -13.427x^2 + 34.784x - 0.6474)$  Spearman rank correlation:  $\rho = 0.564$ ;  
 $p = 0.028$ ).



**Fig. 6:** Correlation of tree species diversity and abundance of *Hemerobius micans* ( $y=-12.086x^2+3.5386x+47.132$ ; Spearman rank correlation:  $\rho=-0.863$ ;  $p<0.001$ ).

## Discussion

The number of neuropterid species increased across the experimentally designed tree diversity gradient. The lowest number of species was captured in the pure beech stands (total 8 neuropterid species/ average 4.1 tree species), but there was no difference in neuropterid species richness in the more diverse stands DL-2 (14 species/7.5 species) and DL-3 and (15 species/7.0 species). A similar pattern was also observed on the DCA. Along the first axis, only DL-1 was separated from the other diversity levels which overlap completely. In terms of habitat heterogeneity, this might indicate the uniform crown architecture within the monospecific beech stands compared to the more complex mixed forests. In some publications, higher numbers of neuropterid species were found in more complex forest stands, but the data cannot be directly compared to our results, because no values for tree species diversity were given (Ammer and Schubert, 1999; Czechowska, 2002; Gruppe *et al.*, 2004). Lassau *et al.* (2005) described similar patterns of beetle communities captured with pitfall-traps in sites of different habitat complexity, but could not show the same with flight-interception-traps.

Alpha-diversity of Neuropterida in all stands was positively correlated with the tree species diversity, supporting the habitat-heterogeneity hypothesis (Price, 1984). The crown architecture of different deciduous trees in more diverse stands seems to offer a greater niche array and might thereby support a larger number of neuropterid species, which has also been shown for other arthropod taxa (Lawton, 1983; Humphrey *et al.*, 1999; Hansen, 2000; Hamer *et al.*, 2003; Lassau and Hochuli,



2008). It can further be assumed that diverse stands offer more niches for neuropterid larvae, which highly depend on the availability of arthropod prey.

The two dominant species, *Hemerobius micans* and *Chrysoperla carnea* s. str. differed in their reaction to plant diversity. The abundance of *H. micans* was negatively correlated with tree diversity. This was due to the decrease of the abundance of beech (*Fagus sylvatica*) on plots of the higher diversity levels. Even though this neuropterid species is euryoecous and imagines and larvae have previously been found on many tree species (Aspöck *et al.*, 1980; Gruppe, 2008), beech trees are preferred compared to other deciduous trees. In contrast, the abundance of *C. carnea* showed a positive correlation to tree diversity, but again, best fit of the regression curve was calculated for a quadratic term. As an ubiquitous species, *C. carnea* is able to use a great variety of niches, requisites and resources and is favoured by an increase of structural diversity.

We conclude that for neuropterid communities in forest stands of different tree diversity, the habitat-heterogeneity hypothesis is effective. Even though the specific structures determining the observed community patterns are unknown, (e.g. microclimate, availability of prey/accessory food, shelter options), tree diversity seems to be an overarching keystone factor influencing community composition and species richness of neuropterids.

Neuropterida have rarely been considered as a focal arthropod group for ecological studies or for testing ecological hypotheses (New, 1998; Gruppe, 2008). This study demonstrates that even a species poor, but nevertheless important predatory taxon like the Neuropterida can yield valuable results, and should hence be included in faunal assessments. For getting a broader insight in ecosystem functioning, more attention should be paid to previously neglected taxa like Neuropterida.

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