Master thesis

Summer term 2011

The effect of native forest dynamics upon the arrangements of species in oak forests-analysis of heterogeneity effects at the example of epigeal arthropods

Die Auswirkungen natürlicher Walddynamiken auf die Artengefüge in Eichenwäldern: Untersuchung von Heterogenitätseffekten am Beispiel epigäischer Raubarthropoden

Study course: Ecology, Evolution and Nature conservation (M.Sc.)
University of Potsdam

presented by

Marco Langer
757463

1. Evaluator: Prof. Dr. Monika Wulf, Institut für Landnutzungssysteme
Leibniz-Zentrum für Agrarlandschaftsforschung e.V.

2. Evaluator: Tim Mark Ziesche, Landeskompetenzzentrum Eberswalde

Published online at the
Institutional Repository of the University of Potsdam:
URL http://opus.kobv.de/ubp/volltexte/2011/5558/
URN urn:nbn:de:kobv:517-opus-55588
http://nbn-resolving.de/urn:nbn:de:kobv:517-opus-55588

Abstract

The heterogeneity in species assemblages of epigeal spiders was studied in a natural forest and in a managed forest. Additionally the effects of small-scale microhabitat heterogeneity of managed and unmanaged forests were determined by analysing the spider assemblages of three different microhabitat structures (i. vegetation, ii. dead wood. iii. litter cover). The spider were collected in a block design by pitfall traps (n=72) in a 4-week interval. To reveal key environmental factors affecting the spider distribution abiotic and biotic habitat parameters (e.g. vegetation parameters, climate parameters, soil moisture) were assessed around each pitfall trap. A *TWINSPAN* analyses separated pitfall traps from the natural forest from traps of the managed forest. A subsequent discriminant analyses revealed that the temperature, the visible sky, the plant diversity and the mean diameter at breast height as key discriminant factors between the microhabitat groupings designated by The *TWINSPAN* analyses. Finally a *Redundant analysis* (RDA) was done revealing similar environmental factors responsible for the spider species distribution, as a good separation of the different forest types as well as the separation of the microhabitat groupings from The *TWINSPAN*.

Overall the study revealed that the spider communities differed between the forest types as well as between the microhabitat structures and thus species distribution changed within a forest stand on a fine spatial scale. It was documented that the structure of managed forests affects the composition of spider assemblages compared to natural forests significantly and even small scale-heterogeneity seems to influence the spider species composition.

Figures:

Tables:

Acknowledgements

I want to mention and thank all people who made this Master thesis possible.

At first I want to thank my adviser Tim Mark Ziesche, who was always helpful either in the field or in the stage analyzing the data. Secondly I have to thank my second evaluator Prof. Dr. Monika Wulf, who was always very helpful with statistical questions and discussions about further possibilities to analyse the data.

Huge thanks to Theo Blick, for rechecking certain unclear spider species and providing a lot of literature for further information.

The use of the laboratory of the *Fachhochschule Eberswalde* in the time of spider determination was very helpful, and I like to thank Prof. Andreas Linde for this issue as well as Ms. Andrea Koj for supporting the analysis of the soil.

I am deeply grateful to my parents and especially to my girlfriend for supporting me all the time. They also patiently tolerated the situation when i was stressed or being in moods.

Last but not least I'd like to thank all my friends. Without you all this wouldn´t be possible, and I promise to be around more often again.

1 Introduction

Virgin forest are the most naturally forest ecosystems. They are described of having natural vegetation, being without any human influence and the natural ecosystem dynamic is not disturbed (FAO, 2005). About 36% of the world's forests can be classified to be virgin forests and they are reduced by six million hectare annually (FAO, 2005). The original forest landscape of central Europe was converted by human activities (e.g. agriculture, settlement) into a cultivated landscape (Wohlgemuth *et al.*, 2002). The only large remnants of virgin forests in Europe can be found in Nordic countries like Finland, the boreal part of Poland and Russia as well as along the Carpathian belt in central Europe (Chumak *et al.*, 2005).

Many of the native fauna and flora species are adapted to typical forest structures or to large-scale forested areas. The loss of forested areas and non-sustainable forestry has lead to a significant loss of species and suitable habitats in Germany (Raths *et al.*, 1995). But this phenomenon could also be observed worldwide (e.g. Brash, 1987; Corlett, 1992; Turner *et al.*, 1994).

Globally rethinking, of the use of natural resources, was initiated at the *Rio Conference* (1992) with adopting the *Rio Declaration*. This persists of 27 fundamentals, intended to guide future sustainable development. Following the *Rio Conference*, meetings in Helsinki (1993) and Lisbon (1998), declared regulations for the dealing with forest ecosystems on a European scale. The sustainable management of forests, as well as the maintenance of the native biodiversity in forest ecosystems are therefore primary objectives to archive.

Forests in Germany are reduced to 30% of the total area, and less disturbed areas are barely existent. Ssymank (1994) estimated that 6 to 10% of the forests in Germany can be referred as close to nature forests and these are mostly found on special habitats. Due to a lack of these forests Europe-wide, the evaluation of nativeness is complicated, and can only be constructed hypothetical (Reif, 1999/2000 as cited in Liepold, 2003). Nevertheless the idea of strict forest reserves (SFR) dates back to the 19th century where individual forests, in central Europe, were excluded from utilization (Welzholz & Johann, 2007). SFR are permanent protected forest areas, which are excluded from human influences, where

the ecosystem processes are the subject of protection (Rüffer, unknown year). First scientific concepts for SFR were suggested by Hesmer (1934) and Hueck (1937) but large-scaled designation and investigation started not before the sixties (East-Germany) and the seventies (West-Germany) of the 21th century (Bauer & Niemann, 1965; Hesmer, 1934; Hueck, 1937; Trautmann, 1976) as cited in (Meyer *et al.*, 2007). Beside research facilities, SFR also supports nature conservation, allowing the undisturbed development of native forests, without human intervention (Meyer *et al.*, 2007). Currently 716 SFR, with an area of 31,176 hectare are designated in Germany. The research of these forests, as a reference for a potential natural biodiversity as well as for the examination of ecological connectivity, is getting increasingly important. Even more the results are meanwhile used within concepts of the forestry, as well as the forest nature protection (Meyer *et al.*, 2007).

In the past biodiversity studies were concentrated on mammals, birds or butterflies, but recent research started to study the requirements of invertebrates and using the results for forest management strategies (Humphrey *et al.*, 1999; Oliver *et al.*, 2000). Arthropods in general are a functionally and taxonomically important component of forest biodiversity (Chumak *et al.*, 2005). Spiders are of special importance, because of their abundance in most terrestrial ecosystems and they are primarily affected by changes in habitat structure (Uetz, 1991). Moreover being generalist predators spiders help to regulate the herbivore populations in forests (Lawrence & Wise, 2000) and thus have an important functional position in terrestrial food webs (Ferris *et al.*, 2000). Therefore spiders are used in studies which determine the effects of habitat disturbance (Downie *et al.*, 1996; Huhta, 2002; Marc *et al.*, 1999).

Oak composite-coppice forests are known as notably species-rich (Treiber, 2003 as cited in Müller-Kroehling, 2007) but especially acid soil oak forests are rather rare presented (3.3%) in Germany when considering the potential natural vegetation. Its percentage within strictly forest reserves is small with 1.1% of all SFR (Meyer *et al.*, 2007). Therefore little is known about the effects of management to the natural biodiversity, in soil acid oak forests.

This forest type was studied, using epigeal arthropods (*Araneae*), to compare the potential natural diversity in SFR with the diversity in managed forest. Many studies concentrated on the comparison of different strictly forest reserves (e.g. Albrecht, 1992; Ammer, 1992; Rau, 1993) but only a few studies are dealing

with the direct comparison of strictly forest reserves and managed forests (e.g. Chumak *et al.*, 2005; Liepold, 2003; Loch, 2002; Otto, 2004; Pawelka, 1997; Schubert, 1998; Schulz, 1996). Thus, more investigations need to be done, to improve the knowledge about how forest management practice impact the natural biodiversity and what kind of biodiversity changes are appearing through management and which throughout natural disturbances. Therefore a strict forest reserve (20.31 ha) and a reference area (26.16 ha) were reviewed, for the direct comparison of spider composition aspects in natural and managed oak forest in the state of Brandenburg.

The answering of the following questions were the main objects of this study:

1. Are there differences between the natural forest and the managed forests in terms of the amount of species, as well as between the different investigated microhabitats?

2. Do specific spider species, or groups, prefer particular habitat characteristics e.g. much dead wood or a specific amount of light?

3. Which influencing variables cause the differences in the composition of species in the different forests respectively the microhabitats?

This study is part of the research project *Biodiversity in managed oak forests in Northeast Germany*. The aim of this project is the development of articles to facilitate the close to nature forestry.

2 Methods

2.1 Description of the study area

The study area *Fünfeichen* of the nature protection area and the reference area are located about 110 km southeast of Berlin and about 3 km southeast of the small town of *Schernsdorf* (Figure 1). Both areas are located in the *Forst Siehdichum* upon the *Lieberoser Hochfläche*.

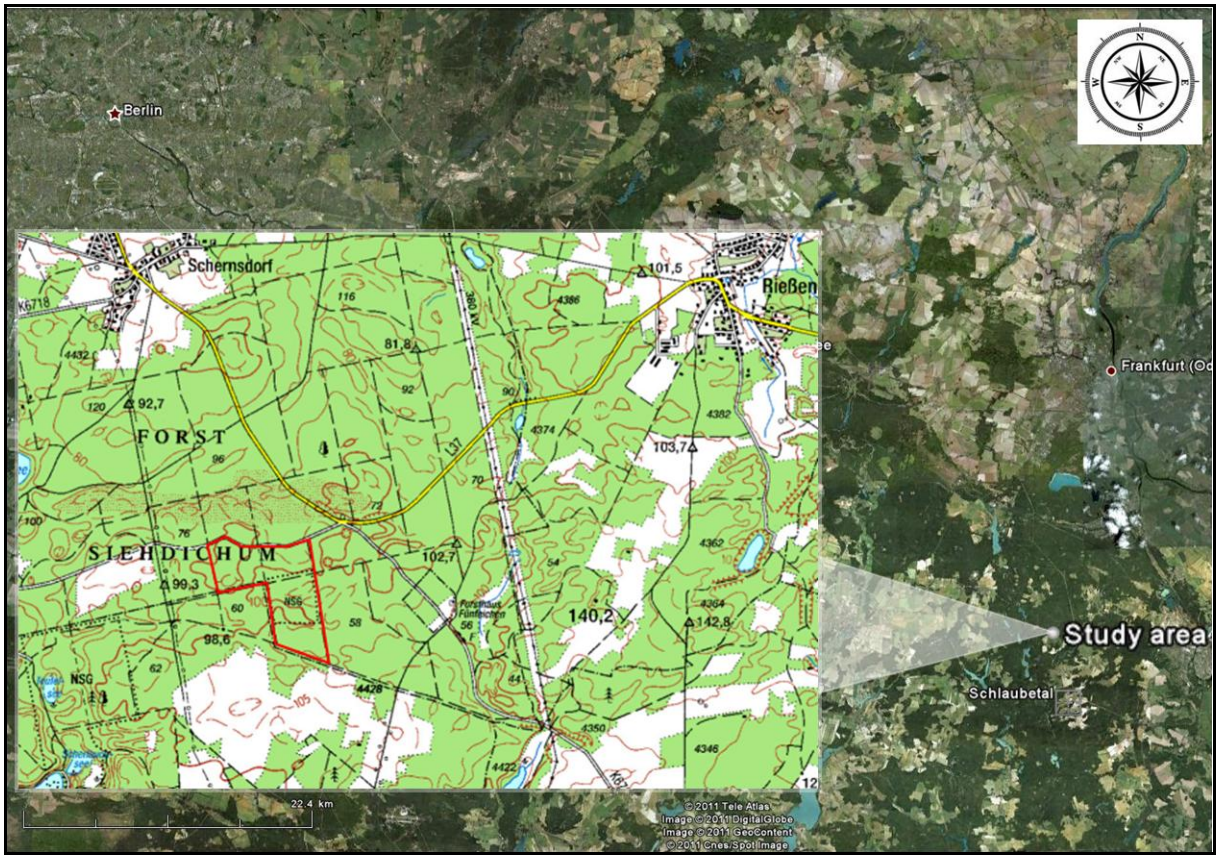


Figure 1: Location of the study area southeast of Berlin, the red frame marks the strict forest reserve and the reference area

The natural forest area covers 20.31 ha within the compartment *59* while the reference area covers an area of 26.16 ha and is located in the two subsections *74 a* and *75 a* (Figure 2). Geologically the investigation area is affected through sediments of the *Weichselian glaciations* as well as the elder *Wolstonian stage*. The old moraine, originated through the *Wolstonian stage*, was passed over again by ice, during the last glacial period. Hence the soil is mixed with sediments of both glacial

periods with boulder clay, from the *Wolstonian stage*, lying below the sand. The gravel originated brought in by the last glacial period. Both study areas lie upon a shallow rippled plateau between 89 and 107 meter above sea level. The macroclimatic situation is affected by sub-continental climate (*γ*) with a mean annual precipitation (1951-2003) at the study area of 533 mm. The mean annual temperature (1951-2003) was 8.98°C, with a yearly fluctuation of the monthly mean air temperature of 19.41°C.

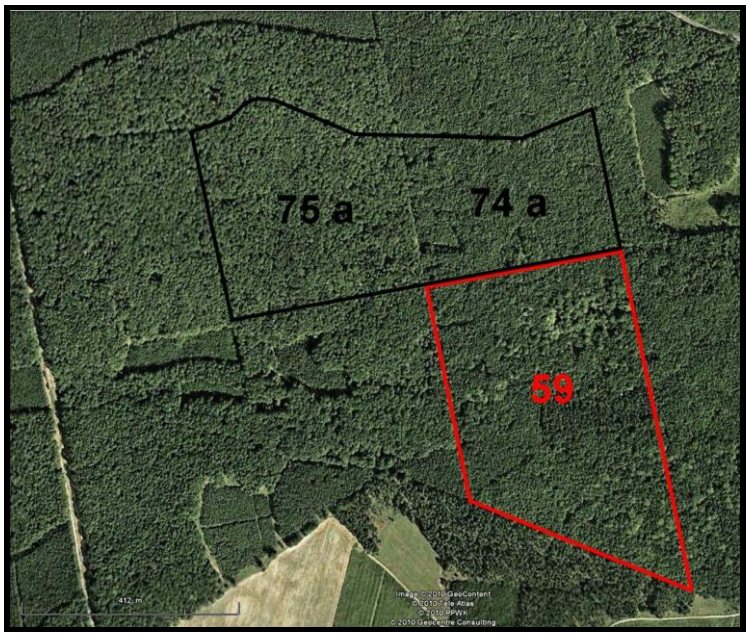


Figure 2: Strict forest reserve (59) and the reference areas (74a &75a)

The oldest description of the today´s forest area *Forst Siehdichum* dates back to the *Neuzeller Atlas* from 1763. This cartography served as a capture of all forested areas as well as acreages belonging to the trust *Stift Neuzelle* in the mid of the 18th century. The state of the forest in the study area, at that time called *Gemarkungen* was measured between 1742 and 1743 and described in the *Neuzeller Atlas* in 1763. Because of the signature in the cartography the study area was identified as a deciduous forest with oak beside of birch and scattered beech trees. Due to the affiliation to the trust *Stift Neuzelle* and mainly because of hunting reasons this forest area was not heavily cleared as well as the use of the wood was low. The forest area was measured again in 1823, belonging now to the *Königlichen Oberförsterei Siehdichum*. In 1849 the area was scaled in quadrates and 1852 a map showing the state of the forest was published. Comparing both maps from 1763 and 1852 an

extensive decline of the deciduous forest area was visible. Only in the south of the forest area, close to the present nature protection area, continuous oak stocks still exist. In the west of the today´s nature protection area (Compartment 59) and in the southwest of the today´s reference area (Compartment 74 a) a 140 respectively 160 year old oak forest, interstratified with numerous same aged pines was growing in 1852. In the second reference area (Compartment 75 a) a nine to 14 year old oak forest originated out of coppicing was existent. Because oak was the main tree species in the past, it was planned to support the regeneration through sowing and planting. By the end of the 1920s first regeneration success in the forest *Fünfeichen* was described. The oaks which were present in the today's nature protection area as well as in the reference area were growing up to a 280 years old light oak stand with a 40 to 60 years old regeneration of oak. For the following years it was planned to continue further regeneration of the old oak stands in the different departments. A subarea in the northeast of the compartment 59 with up to 337 year old oaks and an area of 1.6 ha were declared as a natural monument in 1935. Because of a lack of knowledge, more than half of the solid cubic meter in this area was cut and used in 1946/1947. All in all in the middle of the 19th century, the present nature protection area and the reference area were the small remains of an extensively cultivated deciduous forest complex. Today only a small area of 2 ha is left from the natural virgin forest *Fünfeichen* in the protection area, with several old oaks.

The declaring of an area as a *Natural monument* in 1935, mentioned above, was the beginning of the protection of the oak stands in the forest *Fünfeichen*. Effective from the 30th of March 1961, the rest of the former virgin sessile oak forest stand, was declared as a strict forest reserve. With a size of 10.84 ha it had covered only a subarea of the compartment 59. The whole protection area is excluded from any kind of utilization. In 2000 the protection area was extended to the whole compartment 59 and covers an area of 20.31 ha. According to the responsible forester (Mr. Goethert, verbal) the last thinning activities in the managed forest were in the year 2004. In 2011 the whole forest areas was negotiated to the *Stiftung Stift Neuzelle*.

2.2 Site selection and study design

Twelve blocks were each equipped with six pitfall traps. Eight of the blocks were located within the natural forest site, and four of them within the managed forest (reference area). A certain block was selected when it had three different microhabitat characteristics, to compare even inside the blocks for small scale distribution pattern of ground dwelling arthropods. Thus, each block comprises of two plots showing a high coverage of ground vegetation (*Herb*), two plots with a large amount of dead wood *(Dead wood)* as well as two plots with a high coverage of leaf litter *(Litter)*. Pitfall traps within the same structure had a distance of at least ten meters to each other. The distance between the different microhabitats, within one block, depended on the condition on-site, but the microhabitats were at least 10 m away from each other. The microhabitats are entitled in this work as follows *Herb* = high coverage of ground vegetation, *Dead wood* = high amount of dead wood and *Litter* = high coverage of leaf litter. The used abbreviations *NF* and *MF* are standing for Natural forest (*NF*) and Managed forest (*MF*).

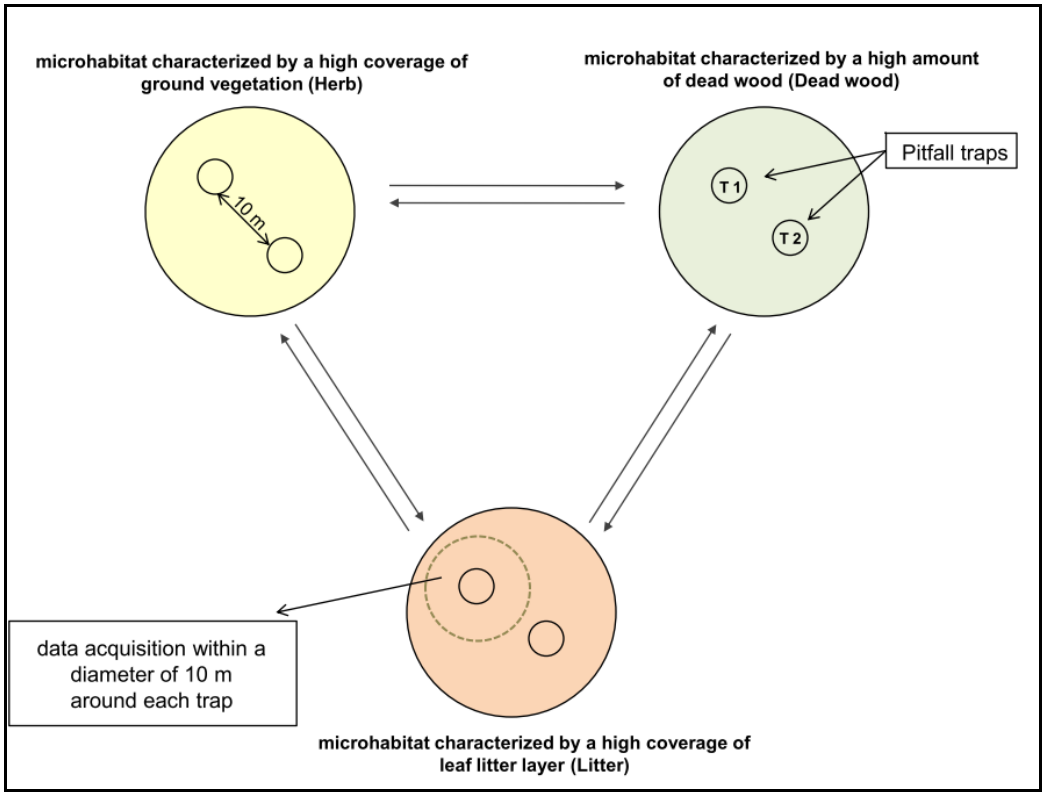


Figure 3: Study design with the microhabitat characteristics of each block

Within the 12 blocks, 72 pitfall traps were placed in the study area. Forty-eight traps were placed within the natural forest and 24 within the managed forest. This was done because of little heterogeneity within the managed forest. The distribution of the 12 blocks and plots can be seen in figure 4 and figure 5. The labelling of the plots (e.g. P1) in the figure 4 and 5 (yellow) refers to the different investigated microhabitats.

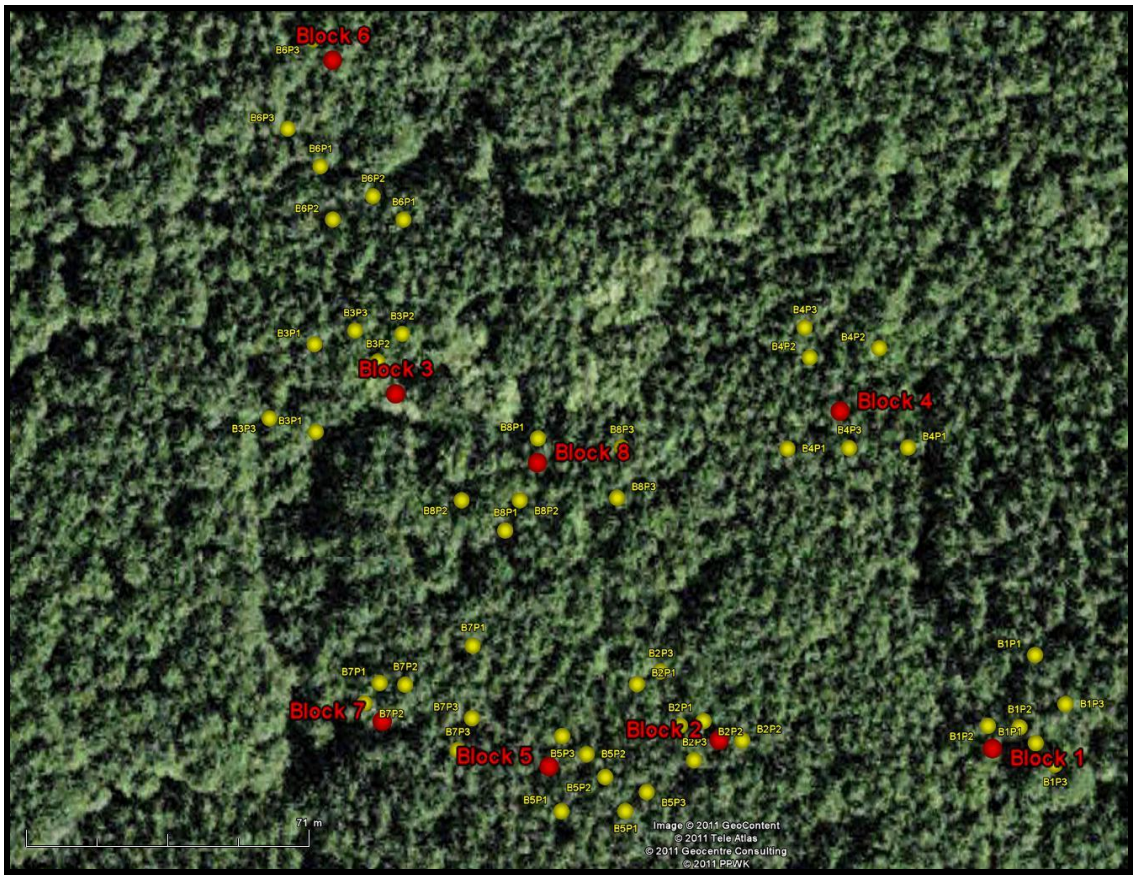


Figure 4: GPS points of the blocks in the natural forest together with the microhabitats

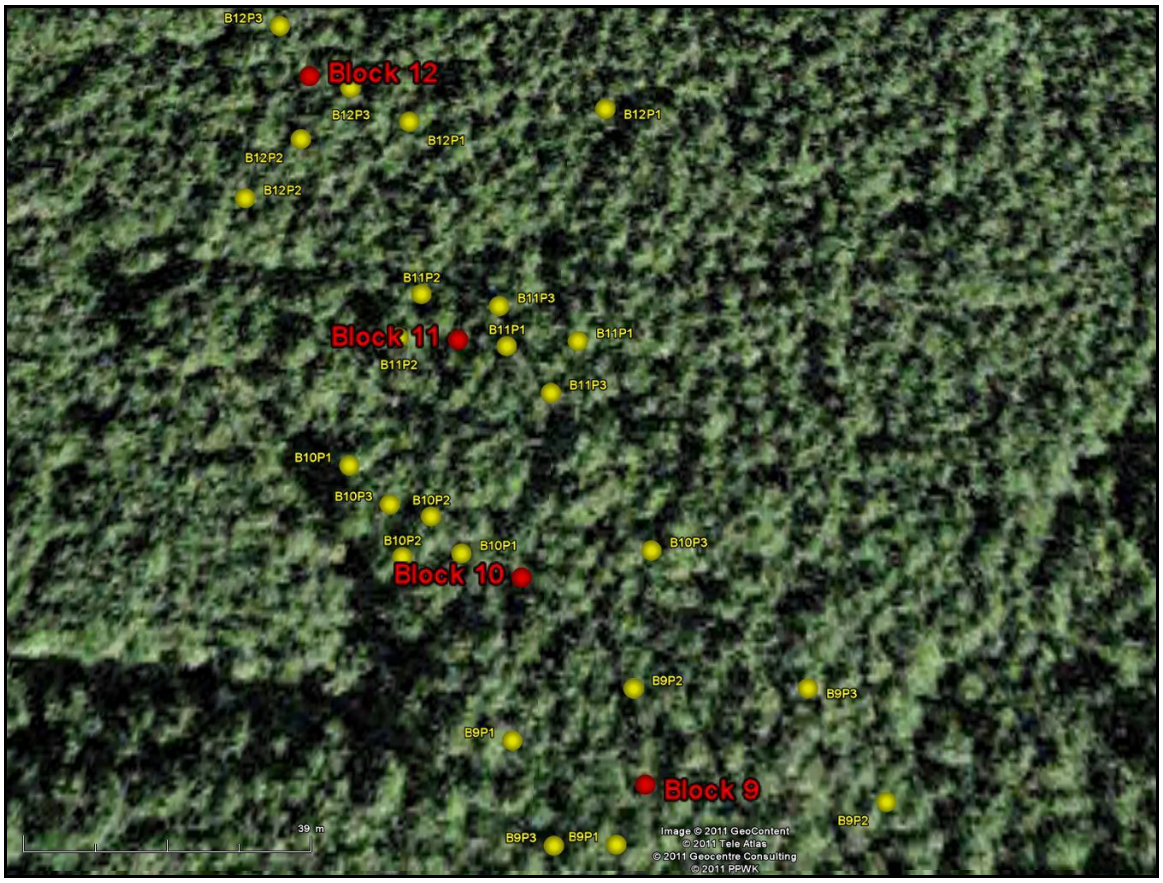


Figure 5: GPS points of the blocks in the managed forest together with the microhabitats

2.3 Data acquisition

2.3.1 Invertebrate sampling

Pitfall traps by Barber (1931) were used for the recording of the epigeous fauna. This principle of catching with traps was first published 1931.Since then, this method is often modified and used very often, especially when studying epigeal arthropod diversity. Thus, this method is established and can be seen as a standard method for the research of epigeous fauna (Lohse, 1981; Mühlenberg, 1993). With pitfall trapping, the activity of animals walking on the ground is measured. This so called activity density is marking *the number of individuals crossing a borderline of a specific length*. In this case, the borderline is the edge of the pitfall trap (Heydemann, 1960). Pitfall trapping was conducted for a total of eight weeks from 25th of May till 20th of July 2010. Honey classes (Ø 7.5 cm, volume of 360 ml) containing saturated benzoic acid and detergent were used as traps. Clear plastic plates were placed above them to protect the traps from rain (Figure 6). The traps

were installed in each of the 72 plots as described above and emptied twice every four weeks. In the course of controlling the vegetation the traps were controlled as well, because of disturbance by, for example, wild pigs. At the 20th of July the traps were finally collected for the evaluation. The samples were washed and stored in small plastic bins containing 75% ethanol till determination.

Figure 6: Pitfall traps containing a rain shield at the study area

2.3.2 Microhabitat measurements

At the 72 plots certain environmental parameter were recorded, to describe the characteristics of every microhabitat. All measurements took place during the time period from May 2010 to October 2010, in a diameter of 10 m around each pitfall trap. Vegetation was firstly assessed from 25th till 28th of May 2010 with the methodology of Braun-Blanquet (1964). To examine the vegetation, within the 10 m around the trap, two laces (each 10 m long) were placed across the pitfall trap, one running north-south and the other east-west (Figure 7). Each plant species within this area was determined and the coverage rate was estimated using a *Braun-Blanquet scale*.

Figure 7: Assessing the vegetation around the pitfall traps using two 10 meter long laces

Changes in the vegetation, as well as the coverage of the vegetation were controlled every two weeks. The total degree of vegetation coverage was determined with the percentage of the total herbal layer together with the mosses and lichens. The remaining percentage was either dedicated to litter layer and/ or visible open mineral soil and altogether was summering up to 100%. The depth of the litter was measured at four points around the pitfall trap. The canopy cover under each trap and the diameter at breast height of the trees, within 10 m around the trap, were measured.

The amount of course woody debris (>2cm) was measured with a slide caliper and a tape at three random plots in the natural forest as well as in the managed forest. With the help of the diameter in cm, the course woody debris was arranged in classes (Table 1).

Table 1: Diameter classes in cm used in this study

Class	Diameter in cm
1	≥ 2 and < 7
2	≥ 7 and < 20
3	≥ 20 and < 35
4	≥ 35 and < 50
5	≥ 50

Furthermore the course woody debris was scaled in four different decomposition stages from fresh dead wood to strongly moldered and continuous soft dead wood. The arrangements of the decomposition stages are adopted from Albrecht (1990) and are displayed in Table 2. The decomposition stage is abbreviated with *ds* within this thesis.

Table 2: Decomposition stages of the dead wood (*Albrecht, 1990*)

Decomposition stage (ds)	Dead wood condition
1	fresh dead wood, 1-2 years
2	beginning decomposition, loose bark, wood still hard, heart rot <1/3 diameter
3	advanced decomposition, soft splint, core only in parts hard, heart rot >1/3 diameter
4	highly moldered, constantly soft wood, drained contour

Additionally to the decomposition stage and the diameter class, the position of dead wood was also considered. Finally it was considered when the dead wood was covered with mosses and lichens. The amount of dead wood was calculated per hectare.

Microclimatic conditions, namely the humidity and the temperature were automatically recorded hourly with data loggers (*Tinytags Ultra TG 1500*) for the time of invertebrate sampling. In each forest type nine data logger (three blocks and in each case within the three microhabitats) were attached 70 cm above the ground on a tree close to a pitfall trap. The three blocks in each forest type

were randomly chosen, but the different microhabitats (*Herb, Dead wood* and *Litter*) were considered in equal numbers in both forest types for comparability. Together 19 data logger recorded microclimatic conditions from 25th of May till 20th of July 2010.
At each of the 72 plots a soil sample, without litter, was taken with a cylinder (5.3 cm x 5.0 cm, volume = 100 cm³) to examine the soil moisture and the pH-value (Figure 8). Soil samples were stored in air-tight plastic bags, to prevent the loss of moisture till examination. In a laboratory the soil moisture as well as the pH-value was determined.

Figure 8: Sampling of the soil with a cylinder, close to the pitfall trap

Hemispherical photography, with a fisheye objective, was done to estimate solar radiation over the year. Therefore a picture of the canopy cover was taken above each pitfall trap and different parameters were recorded (visible sky, direct site factor (DSF), indirect site factor (ISF), global site factor (GSF), leaf area index and the ground cover).

2.4 Data Evaluation

2.4.1 Pitfall traps

After emptying the traps, the content was washed with the help of a close meshed sieve. After this the catch was preserved in 70% ethanol in honey classes. The spiders were separated from the rest of the catch and stored in small plastic bins within 70% ethanol. Using a stereo microscope, the adult spiders were determinate to the species level. The identification of spider species followed the identification keys of Roberts (1985) and Heimer & Nentwig (1991) the ecological characterization followed Platen *et al.,* (1999) and the nomenclature of spiders followed (Platnick, 2011). During the complete sample period one pitfall trap, in the first clearance period, could not be found again. Probably wild pigs displaced the trap. This trap could not be analyzed and is not part of the results. Each new species was attached to a collection of specimen's copies. Two species were sent to an expert for rechecking. The females of the two species *Pardosa alacris* and *Pardosa lugubris* could not be clearly identified, therefore these species are always named *Pardosa lugubris-group* in the following.

2.4.2 Soil samples

Soil samples were analyzed in the laboratory. For the determination of the soil moisture, 20 g of each fresh sample was filled in weighted glasses, weighted again, and stored in a muffle furnace (105°C) till they reached constant weight (completely dry) The difference of the weight was the percentage of the soil moisture. For analyzing the pH-value a mixture of 50 ml distilled water filled with 20 g soil (current acidity). The combination was agitated and stands overnight. Than the pH-value was measured using a *WTW inolab pH/Cond 720* (Figure 9).

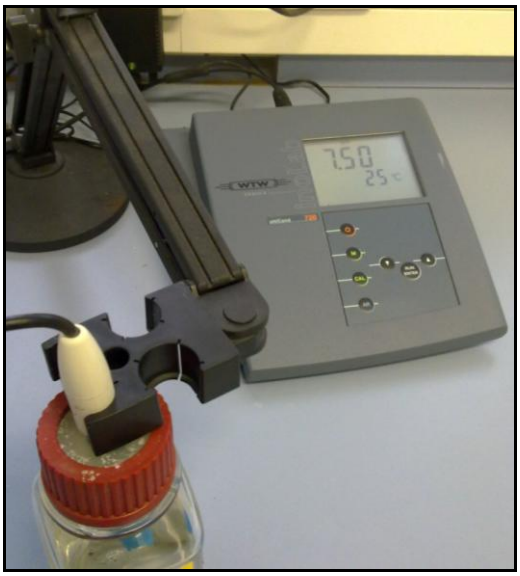


Figure 9: WTW inolab pH/Cond 720 for determining the pH-value

2.4.3 Additional evaluation

Evaluation of the data logger was done with the software *Tinytag Explorer* and mean values of the recorded parameters were calculated. The examination of the hemispherical photography was done with the software *Hemiview 2.1* and mean values were calculated.

Figure 10: Hemispherical photography within the nature forest

2.5 Statistical analysis

Within the time of data acquisition eight blocks were examined in the natural forest and four in the managed forest. Anyway, the same numbers of blocks are needed for comparability. Therefore four blocks, out of the eight blocs within the natural forest, were randomly chosen for the statistical analyses. These blocks are classified as the block one, four, five and eight in the natural forest. When comparing between the natural forest and the managed forest these four blocks are used, to have the same sample size with each forest type. The same procedure was applied when comparing the different microhabitat structures. The statistical analyses of the environmental parameters were done for the different forest types, and between the three different microhabitats. In contrast to the faunistic analysis, the microhabitats were also distinguished within the forest types. This was done to see if there are also differences within the same microhabitat (e.g. *Herb*) between the two forest types, in terms of spider assemblages.

2.5.1 Species accumulation

Accumulation curves were generated after 100 randomizations with the nonparametric estimators *Chao 1* and *Jacknife 2*, for total found individuals, using the software *Estimate 8.2.0* (Colwell, 2009). *Chao 1* gives an estimate of the absolute number of species in an assemblage based on the number of rare species (singletons and doubletons) in a sample. To estimate the inventory completeness value (ratio between observed and estimated richness) *Chao 1* species richness estimator is recommended by certain authors (Sørensen *et al.*, 2002; Scharff *et al.*, 2003). *Jacknife 2* estimator works quite well in extrapolation of species richness with greater precision, less bias and less dependence on sample size than other estimators (Palmer, 1990; Baltanás, 1992).

Chao 1: $$S_{Chao1} = S_{obs} + \frac{F_1(F_1 - 1)}{2(F_2 + 1)}$$

$S_{Chao\ 1}$: Estimated species richness (Chao 1)

S_{obs}: Total number of species observed in all samples pooled

F_1: Frequency of singletons

F_2: Frequency of doubletons

Jacknife 2: $$S_{Jacknife2} = S_{obs} + \left[\frac{Q_1(2m-3)}{m} - \frac{Q_2(m-2)^2}{m(m-1)} \right]$$

$S_{Jacknife\ 2}$: Estimated species richness (Jacknife 2)

S_{obs}: Total number of species observed in all samples pooled

Q_1: Frequency of unique species

Q_2: Frequency of duplicates

m: Total number of samples

2.5.2 Dominance

The dominance (D) describes the relative frequency of one species in comparison to the remaining species and moreover characterizes the biocoenosis (Mühlenberg, 1993). Through pitfall traps obtained dominance values are called activity dominance (Heydemann, 1953). The following formula is used to calculate the dominance:

Dominance: $$D_i = \frac{A_i * 100}{G}$$

A_i: Number of individuals of one species

G: Total number of individuals in the species community

The dominance represents a percentage of which a certain species is found within all individuals. In this thesis only the main species (>3.2%) are presented in logarithmic classes by (Engelmann, 1978).

Main species:

Eudominant:	32.0% - 100%
Dominant:	10.0% - 31.9%
Sub-dominant:	9.9% - 3.2%

All other species (<3.2%) are classified as secondary species. According to (Engelmann, 1978) 85% of the individuals are normally belonging to the main species.

2.5.3 Jaccard and Sørensen coefficient of the community

The *coefficient of the community* is the percentage of the total species that two communities have in common. The community coefficient of Jaccard is calculated with the following formula:

Jaccard (J_A):

$$J_A = \frac{100 * b}{c + d - b}$$

b: Number of species found in both communities

c: Number of species found in first community

d: Number of species found in the second community

The similarity coefficient by Sørensen is calculated by the following formula:

Sørensen (S_A):

$$S_A = \frac{2 * b}{c + d} * 100$$

To compare both coefficients between more than two communities the calculated values are presented in a trellis diagram.

2.5.4 Dominance identity

The Renkonen coefficient (R_e) is an index for the correlation of the dominance ratio of two species communities (Mühlenberg, 1993). It is calculated with the following two formulas:

Renkonen (R_e): $$R_e(\%) = \sum_{i=1}^{G} \min D_{A,B}$$

$$D = \frac{n_A}{N_A} \text{ bzw. } \frac{n_B}{N_B}$$

Min $D_{A,B}$ = sum of the respectively smallest dominance values (D) of the species found in both communities (in this case A and B)

i: Species i

G: Number of shared species in both communities

$n_{A,B:}$ Number of individuals of the species i in area A respectively B

$N_{A,B}$: Total number of individuals in the area A respectively B

The Wainstein coefficient (C_W) considers the shared species in two communities as well as the relative frequency of them. The formula is as follows:

Wainstein (C_W): $C_W = R_e * J_A$

R_e: Renkonen coefficient

J_A: Jaccard coefficient

Values of the Wainstein coefficient can be between 0 and 100.Higher values document larger similarities between communities.

2.5.5 Multidimensional scaling

The multidimensional scaling was developed by Torgerson (1958) and enhanced to the *Non-metric multidimensional Scaling* (Nmds) by Shepard (1962) and Kruskal (1964). The aim is, similar to the principal component analysis and factor analysis, to reveal pattern in a multidimensional data set as well as the graphical illustration (Lozán & Kausch, 2007). The illustration is based on a distance matrix of the original data set. Objects which are close to each other in the two or three-dimensional illustration shall be also similar in reality (Hamerle & Pape, 1984 as cited in Lozán & Kausch, 2007). The advantage compared to e.g. the principal component analysis, is that this method can deal better with raw data comprising zeros. It is therefore used for comparison of habitats concerning the species abundance of found organism (Lozán & Kausch, 2007).
For reducing the weight of common species, the original data set was fourth-root transformed before analysis. Secondary a *Bray-Curtis dissimilarity matrix* was produced (Clarke, 1993). Nmds-plots were constructed, based upon similarity values of species composition, across the forest sites and the microhabitats with the software *R* (R Development Core Team, 2011) using the package *ecodist* (Goslee & Urban, 2007). Comparison of the different sites for significant differences between the spider assemblages was done with the function *adonis* (*multivariate anova based on dissimilarities*) using *R* and the package *vegan* (Oksanen *et al.*, 2011). It divides dissimilarities for the sources of variation, and uses permutation tests to inspect the significance of those separations. The generated R-value is a measure of differences between groups, whereas R-values close to zero indicate that the spider composition is barely separable (Clarke, 1993). Differences were assumed to be significant when the p-value (*probability of error*) was <0.05.

2.5.6 Guild composition

The guild composition was compared between the forest sites as well as between the different structures to see how community structure varies between microhabitats and stages of disturbances. Different foraging modes can be found in spiders and

each guild has a different need for vegetation structure and microhabitat characteristics. The spiders were classified to the following guilds, according to their mode of foraging (Gertsch, 1979; Table 3). For each forest site and the different structures, the abundance of each guild was calculated and X^2 tests of homogeneity were done between each pair.

Table 3: Guild composition of the spider families according to *Gertsch* (1979)

Family	Guild	Family	Guild
Agelenidae	Web-Sheet	**Lycosidae**	Wandering-Active
Anyphaenidae	Wandering-Active	**Philodromidae**	Wandering-Active
Araneidae	Web-Orb	**Pisauridae**	Wandering-Active
Atypidae	Wand-Ambush	**Salticidae**	Wandering-Active
Clubionidae	Wandering-Active	**Segestriidae**	Web-Sheet
Corinnidae	Wandering-Active	**Tetragnathidae**	Web-Sheet
Dysderidae	Wandering-Active	**Theridiidae**	Web-Matrix
Gnaphosidae	Wandering-Active	**Thomisidae**	Wand-Ambush
Linyphiidae	Web-Sheet	**Zodariidae**	Wandering-Active
Liocranidae	Wandering-Active	**Zoridae**	Wand-Ambush

2.5.7 Ecological type

Each species prefers a certain range of environmental factors like temperature, humidity, light availability, as well as vegetation. If abiotic and biotic conditions are optimal reproduction is possible in this habitat. Habitat preferences of spiders were investigated in many studies, and classification of Platen (1999) was used in this study. There are many different habitat preference classes, but only those which were used in this study are listed below.

Species of woodless areas:

H: Hygrophilous species (fens, wet meadows)

Eu: Eurytopic species (woodless areas independent from moisture ratio)

X: Xerophilous species (woodless dry habitats)

Species of forested and woodless areas:

(h)(w) Species living in areas with average moisture values

(x)(w) Species living in dry areas

Species of forested areas:

w: Eurytopic forest species (independent of the moisture ratio)

(w): Species predominantly in forests

(h)w: Species living in precious deciduous forests

(x)w: Species living in dry deciduous and conifer forests

Arb: Arboreal species (trees and shrubs)

Like for the guild composition, the abundance of each ecological type was calculated and X^2 tests of homogeneity were done between each pair.

2.5.8 Diversity

The diversity describes the multiplicity of a biocoenosis and is an essential, but mostly difficult and incomplete discoverable, characteristic (Schubert, 1986). It describes a structure characteristic of an ecosystem and indicates the arrangement of the individuals upon the species (Pospischil, 1982). But only in combination with other characteristics of an ecosystem the diversity gets signification.

2.5.8.1 Shannon-Wiener-Index

One possibility of calculating the diversity is the *Shannon-Wiener-Index* (in the following referred as Shannon-Index). This index gives the probability to meet a certain species, when sample randomly in a community (Mühlenberg, 1993). The *Shannon-Index* is calculated with the following formula:

Shannon-Wiener-Index:

$$H_s = -\sum_{i=1}^{S} p_i * \ln p_i \qquad p_i = \frac{n_i}{N} \qquad \sum_{i=1}^{S} p_i = 1$$

H_s: Diversity obtained to a certain species

S: Total number of species

p_i: Probability of the appearance of species i, relative frequency of species i

N: Total number of individuals

n_i: Number of individuals of species i

The diversity value H_s rises with an increasing number of species, as well as increasing equal distribution of species (Mühlenberg, 1993). Therefore the diversity value H_s is zero if all individuals are belonging to one species. The maximum value will be reached when all individuals are distributed equally between the species. Because this is not normally the case in nature, the maximum values reaches 4.5, but generally biocoenosis reaching values between 1.5 and 3.5 (Mühlenberg, 1993). Statistical comparison of the species richness by means of a randomization test was done using the software *R* (R Development Core Team, 2011) and the package *rich* (Rossi, 2011).

2.5.8.2 Evenness

A further element for describing diversity is the *Evenness*, which shows the ratio of actual species diversity and maximum potential diversity (Schubert, 1991). It quantifies how equal a certain community is numerically. When different species are found in equal frequency, the evenness index is equal to 1, and decreases with inequality of the frequency of different species. The variables are based on the *Shannon-Index* and the formula is as follows:

Evenness:

$$E_S = \frac{H_S}{H_{max}} = \frac{H_s}{\ln s}$$

2.5.9 Rarefaction

2.5.9.1 Hurlbert curve and estimation of α-diversity

The method of *Rarefaction* was developed by Sanders (1968) and allows the calculation of the species richness for a given number of sampled individuals and allows the construction of so called rarefaction curves. This curve is a plot of the number of species as a function of the number of individuals sampled. The original formula was changed later on by Hurlbert (1971) as cited in Achtziger *et al.*, (1992) to get an unbiased estimation. Assumptions to use the method of *Rarefaction* are that all catches are done with the same method, as well as the comparison of the same taxon. The software *EcoSim 7.0* was used to calculate the rarefaction curves for the forest types as well as for the microhabitat structures (Gotelli & Entsminger, 2011).

Formula:

$$S(n) = \sum_{i=1}^{S} \left[1 - \frac{\binom{N - N_i}{n}}{\binom{N}{n}} \right]$$

The expressions within the brackets are combinations, and are defined as follows:

$$\binom{N - N_i}{n} = \frac{(N - N_i)!}{n!((N - N_i) - n)!} \quad \text{and} \quad \binom{N}{n} = \frac{N!}{n!(N - n)!}$$

Hence, this results in the following formula:

$$S(n) = \sum_{i=1}^{S} \left[1 - \left(\frac{(N - N_i)! * (N - n)!}{((N - N_i) - n)! * N!} \right) \right]$$

S(n): Expected number of species for a specific number of individuals

N: Standardized sample size (1...N)

N: Total number of individuals

N_i: Number of individuals of species i in a sample before rarefaction (detected species abundance)

S: Total number of detected species

2.5.10 Spearman´s rank correlation coefficient

The Spearman´s rank correlation coefficient is a non-parametric measure of statistical dependence of two ranked variables. The coefficient describes how well a relationship between two variables can be described. The correlation coefficient r_S did not only show the power, but also the direction, of the relationship and can be between -1 and +1 (Lozán & Kausch, 2007). Assuming that certain species show negative or positive correlations to one or more environmental parameters, the species were related with parameters assessed in the surrounding of each pitfall trap. Significant species correlation was assumed when the p-value<0.05 (Spearman rank, SPSS 19).

2.5.11 Habitat preference and Indicator analysis

Habitat preferences can be assessed when analyzing the distribution of a certain spider among different sites (Draney, 1997). Preferences for a certain habitat were reviewed for the most common species (>10 individuals) using the nonparametric *Mann-Whitney U-test* between both forest types. For the multiple comparisons of the microhabitats, the *Kruskal-Wallis one-way analysis of variance* was used. The Bonferroni correction was applied to determine if the post-hoc tests are significant. Analysis was done using the program *XLSTAT 2011.* The species data was log-transformed before the analysis. Additionally to the Habitat preferences an *Indicator species* analysis was done (Dufrêne & Legendre P., 1997). This analysis identifies species which were strongly associated with either one the forest types or one of the microhabitats. This method takes into account the concentration of species

abundance in a certain area as well as the steadiness of species abundance in a particular stand type. Linking both information´s the *Indicator analysis* produces an indicator value, which was considered to be significant with p-values <0.05. The *Indicator analysis* was done with the statistic program *R* (R Development Core Team, 2011) using the package *indicspecies* (De Caceres & Jansen, 2010) and the function *multipatt* (multi-level pattern analysis).

2.5.12 Twinspan analysis

TWINSPAN (two way indicator species analysis) analysis (Hill, 1979) were carried out to identify consistent and deviating pattern in the composition of spider assemblages of the microhabitats (pitfall traps; n = 36). At present *TWINSPAN* is possibly the most frequently used procedure for the classification of community data sets (McCune *et al.*, 2002; Mesdaghi, 2001). It is a hierarchical ordination method whose results are comparable with a phytosociologic table work and the algorithms is based on the correspondent's analyses (Leyer & Wesche, 2007). The *TWINSPAN* analysis divides the samples into categories, so called *Microhabitat groupings* (MG), based on the species assemblages (e.g., species spectrum). Furthermore the species are then divided, on the basis of the sample classification, into categories which are called *Species groupings* (*SG*). Even more character species are identified for each microhabitat in which the abundance for a certain species is higher than in the other microhabitats. An essential element of the *TWINSPAN* is the concept of pseudo species and the corresponding cut levels, because analysis works with qualitative data only. This concept was introduced to avoid the loss of information, as well as the quantity of species. According to the quantity in the sample, every species can be present as several pseudo species. The pseudo species is present, when the quantity of the species exceeds the corresponding cut level (Kooch *et al.*, 2008). Therefore the selection of unique and increasing cut levels is very important, to reflect typical values of abundance (present, a little, a lot etc.) of the community data (see Hill, 1979 for details). Species abundance data were transformed to relative abundance data (dominance in %) to eliminate possible differences in catch results of the traps through different activity levels between the 36 microhabitats.

2.5.13 Discriminant analysis

Following the *TWINSPAN* analysis, the discriminant analysis was used to reveal significant environmental factors which are contributing to the explanation of the spider assemblage classification within the *TWINSPAN* analysis. The aim of this analysis is the maximal separation of two or more groups of multidimensional data (Lozán & Kausch, 2007) by finding the environmental factors the discriminate best between the microhabitat groupings found by the TWINSPAN analysis. A stepwise forward analysis was executed and parameters were assumed to be significant with p-values <0.05 (SPSS 19).

2.5.14 Redundancy analysis (RDA)

The graphical ordination of the environmental key factors, explaining the distribution of the spider assemblages, was done using *Redundancy Analysis* (RDA). The *RDA* is an extension of a multiple regression, as well as of the principal component analysis. It should be used when variables having a linear relation among each other and when correlating dependent variables (species abundance) with independent variables, like environmental data (Dormann & Kühn, 2009). Preliminary a *Principal Component Analysis* (PCA) was done, to determine the main environmental parameters responsible for the distribution pattern of the spider species. Furthermore these parameters were tested on multicollinearity, using the *Variance Inflation Factor* (VIF) as an index. A *Detrended Correspondence Analysis* (DCA), with the help of the gradient length, can be used to see the response of the species to environmental parameters, which can be either linear or unimodal (Dormann & Kühn, 2009). The *DCA* show a strong linear response, and thus, *PCA* and subsequent *RDA* were used for graphical ordination. The *PCA* and *DCA* were done with the add-on *XLSTAT 2011* for *Microsoft Excel* and the *RDA* (stepwise forward selection, $p<0.05$, unrestricted Monte Carlo permutations; $n = 9999$) was done with *CANOCO 4.5.* The activity density data of the 36 microhabitats was log-transformed to reduce the overestimation of the most active species. Only species with more than one individual were included in the analysis. The length of a certain environmental gradient within the graphical illustration of the RDA presents the power of this variable.

3 Results

3.1 Environmental parameters

Environmental parameters were determined within a block design, consisting of 72 plots sampled by pitfall trapping and summing up to 12 blocks. Forty-eight of them (eight blocks) were located within the natural forest area and 24 (four blocks) within the managed forest. Most of the environmental data were recorded for the entire 72 plots except the recording of the dead wood and the recording of climate parameters. They were measured at nine plots each in the natural forest and in the managed forest. Comparing ecological values between natural forest and managed forest 24 plots at each forest type were randomly chosen a priori. Selections of the most important influencing variables are presented here and the total list of all collected environmental parameters can be found in the appendix.

3.1.1 Vegetation

The composition of the vegetation was quite similar comparable between the natural forest and the managed forest. All together 21 herbaceous plants were found within both study sites, of which four plant species were unique in the natural forest and two in the managed forest. The most dominating plant species within the study areas was *Calamagrostis arundinacea* which was found at most of the plots with mainly high coverage rates. Other main species were *Vaccinium myrtillus* and *Convallaria majalis* which were observed quit often. *Anemone nemorosa* was found sporadic in the managed forest but the species *Veronica chamaedrys* was only found once in the natural forest. The natural regeneration consisted mainly of *Quercus petraea* and *Sorbus aucuparia* and was always less then eighty centimetres high. Moreover the natural regeneration was denser at the managed forest. More plant species were found in the natural forest, but differences were not significantly different. Nevertheless the number was different between the microhabitats. Fewest species were found at the *Litter* plots and most species at the *Herb* plots in both forest types

(Table 4). The differences between these two microhabitats in terms of the number of plant species are significant for the natural forest ($p < 0.05$) as well as for the managed forest ($p < 0.01$).

Table 4: Comparison of the number of plant species between the microhabitats as well as between the forest type (NF=Natural forest, MF=Managed forest)

		N	Minimum	Maximum	Mean	
Area		Statistic	Statistic	Statistic	Statistic	Std. Error
Herb (NF)	Plant species [N]	8	6	14	9.63	1.06
Dead wood (NF)	Plant species [N]	8	4	13	9.38	1.17
Litter (NF)	Plant species [N]	8	6	8	6.88	0.29
Herb (MF)	Plant species [N]	8	4	12	8.75	0.81
Dead wood (MF)	Plant species [N]	8	4	8	6.50	0.59
Litter (MF)	Plant species [N]	8	5	7	6.13	0.29

The total vegetation coverage of all microhabitats is higher in the managed forest with a mean value of 37.57% vegetation coverage, while in the natural forest a mean value of 27.25% vegetation coverage was reached (Table 5). Nevertheless differences are not significant different ($p = 0.055$).

Table 5: Comparison of the percentage of the vegetation cover between the forest types

		N	Minimum	Maximum	Mean	
Area		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	Vegetation cover [%]	24	5.5	83.0	27.250	4.1521
Managed forest	Vegetation cover [%]	24	17.0	67.0	37.573	3.1977

Comparing the different microhabitats in the naturals forest the *Herb* plots had a significantly higher mean coverage of vegetation compared with the *Dead wood* microhabitat ($p < 0.05$) and the *Litter* microhabitat ($p < 0.01$). The same was observed for the managed forest where the *Herb* plots were characterized through a higher mean ground vegetation than the *Dead wood* plots ($p < 0.001$) as well as the *Litter* microhabitats ($p < 0.001$). The microhabitat *Dead wood* had a significantly higher coverage of ground vegetation in the managed forest than the same microhabitat in the natural forest ($p < 0.01$), alike the microhabitat *Litter* ($p < 0.01$). A graphical comparison of the six microhabitats can be seen in Figure 11.

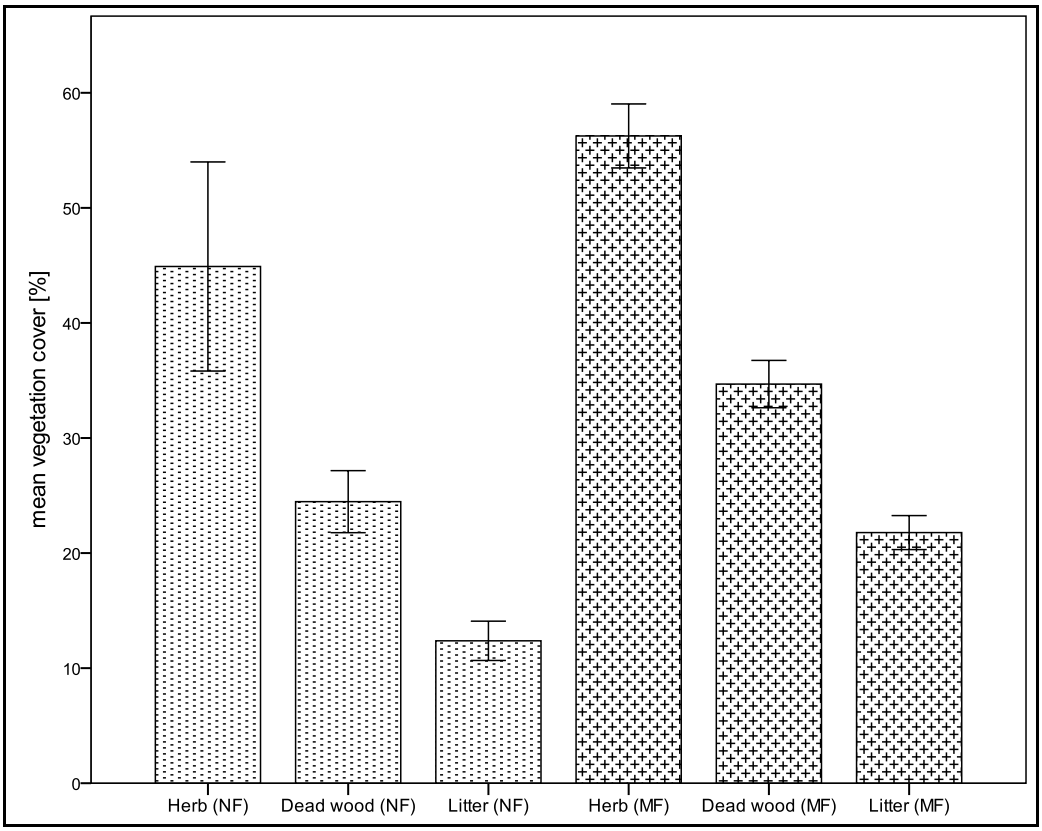


Figure 11: Mean vegetation cover (± 1 SE) of the six microhabitats (NF=Natural forest, MF=Managed forest)

There is a range of the depth of the litter over all study sites from 1 cm to a maximum of 3.5 cm. The differences are significant neither between the natural forest site and the managed forest nor between the structures. Nevertheless the mean average of the depth of the litter is higher in the natural forest (Table 6).

Table 6: Comparison of the depth of the litter between both forest sites

		N	Minimum	Maximum	Mean	
Area		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	Litter depth [cm]	24	1.00	3.50	2.08	0.13
Managed forest	Litter depth [cm]	24	1.50	2.50	1.85	0.06

To have similar site conditions the diameter at breast height is an important criterion for comparability. Both sample areas were selected to have a similar mean diameter at breast height (DBH). However, the DBH was significantly higher ($p < 0.01$) in the natural forest area with a mean diameter at breast height of 22.98 cm (± 1.71 cm). The values are displayed in Table 7.

Table 7: Comparison of the DBH between both forest sites

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	DBH [cm]	24	10.33	46.33	22.97	1.71
Managed forest	DBH [cm]	24	10.92	25.83	17.59	0.77

The canopy cover was calculated by the percentage of the visible sky under each pitfall trap. Additionally hemispherical photography was done to estimate solar radiation. Influenced through a smaller diameter and regular forest activities the canopy cover is considerably lower ($p < 0.001$) in the managed forest (Table 8).

Table 8: Comparison of the Canopy cover between both forest sites

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	Canopy cover [%]	24	50.0	80.0	62.92	1.70
Managed forest	Canopy cover [%]	24	15.0	60.0	37.92	2.33

This was supported by the analyses of the hemispherical photography for the value *visible sky* which was also significantly different ($p < 0.01$). Other parameters, like the leaf area index as well as the ground cover were different between both forest types, but not notably.

Table 9: Comparison of the visible sky between both forest sites

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	visible sky [%]	24	0.13	0.18	0.15	0.00
Managed forest	visible sky [%]	24	0.15	0.19	0.17	0.00

3.1.2 Dead wood distribution

The amount of dead wood was recorded at six blocks, of which three blocks were situated in the managed and three in the natural forest site. In each block the different microhabitats were reviewed to reveal differences in the quantity of dead wood. Values are always given in cubic meter solid per hectare (m^3/ha). Almost the same amount of course woody debris (>1 cm diameter) was found at both

investigated forest sites. In the natural forest a mean of 15.22 m³ (± 4.18 m³) per hectare and in the managed forest a mean of 16.27 m³ (± 3.40 m³) per hectare were found. The most amount of dead wood was found in block four in the natural forest and in block ten in the managed forest. Figure 12 displays the mean values for the amount of course woody debris (m³) at the different blocks.

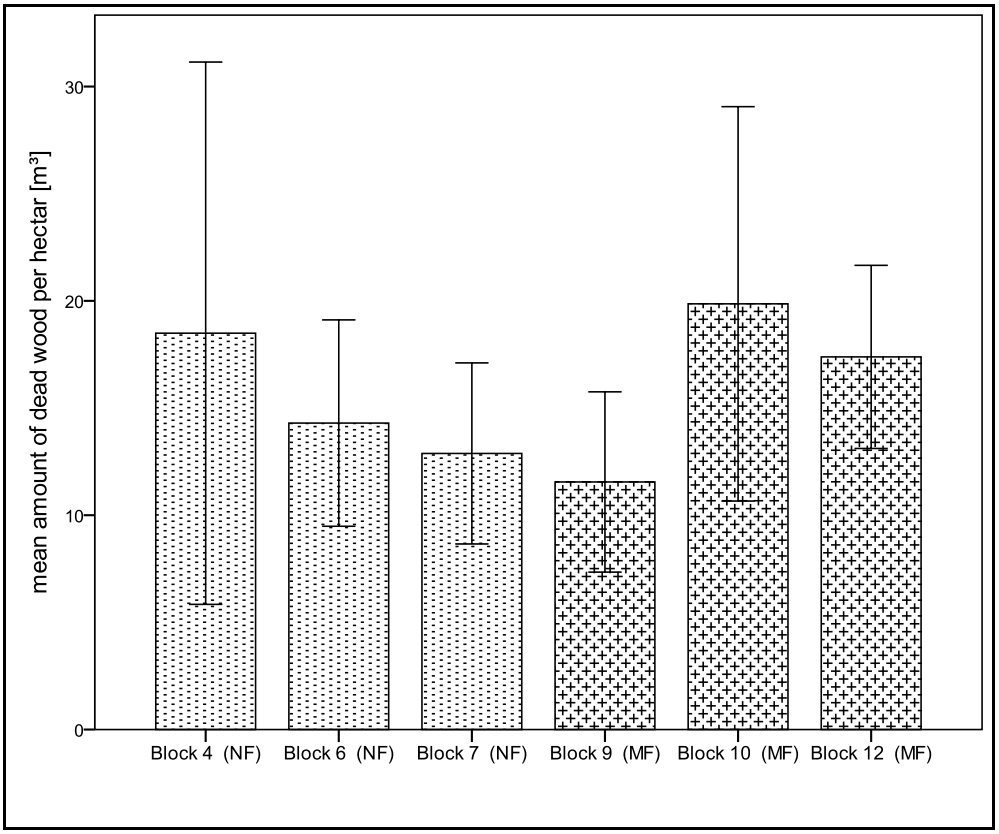


Figure 12: Amount of dead wood (m³) per hectare (±1 SE) at the investigated blocks (NF=Natural forest, MF=Managed forest)

Comparing the different microhabitats in the natural forest the *Dead wood* plots had a significantly higher amount of dead wood compared with the microhabitat *Herb* ($p < 0.05$) but not compared with the microhabitat *Litter*. Similar results were observed in the managed forest where the *Dead wood* plots were characterized through a higher amount of dead wood (mean) compared to the *Herb* plots ($p < 0.05$) as well compared to the *Litter* plots ($p < 0.05$). No statistical differences were observed when comparing the same microhabitats between the forest types. A comparison of the six microhabitats can be seen in Table 10 and Figure 13.

Table 10: Comparison of the amount of dead wood in the different microhabitats (NF=Natural forest, MF=Managed forest)

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Herb (NF)	Dead wood [m³]	3	4.57	8.18	5.97	1.11
Dead wood (NF)	Dead wood [m³]	3	18.36	43.78	28.64	7.72
Litter (NF)	Dead wood [m³]	3	6.52	15.70	11.04	2.65
Herb (MF)	Dead wood [m³]	3	7.35	14.21	10.24	2.05
Dead wood (MF)	Dead wood [m³]	3	19.96	38.17	27.99	5.36
Litter (MF)	Dead wood [m³]	3	7.33	12.23	10.55	1.60

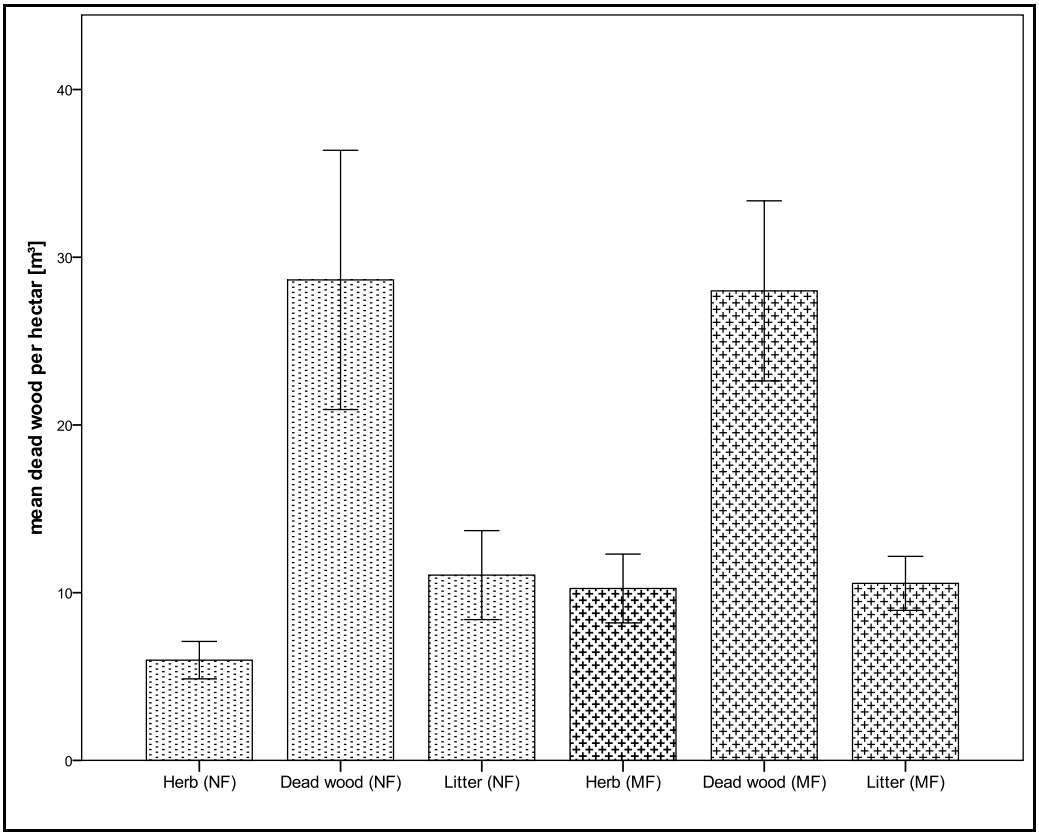


Figure 13: Mean amount of dead wood (m³) per hectare (±1 SE) in the different microhabitats (NF=Natural forest, MF=Managed forest)

Looking at the decomposition stage, only the stages two (ds 2) to four (ds 4) were found at the study area. Fresh dead wood (ds 1), was not present at one of the blocks. No significant differences were observed for one of the decomposition stages between the two forest types ($p > 0.05$). In both forest types the decomposition classes three and four are dominating. Mentionable is that in block seven more than 75% of the dead wood belongs to decomposition stage four and only a small amount to the stage two (Figure 14).

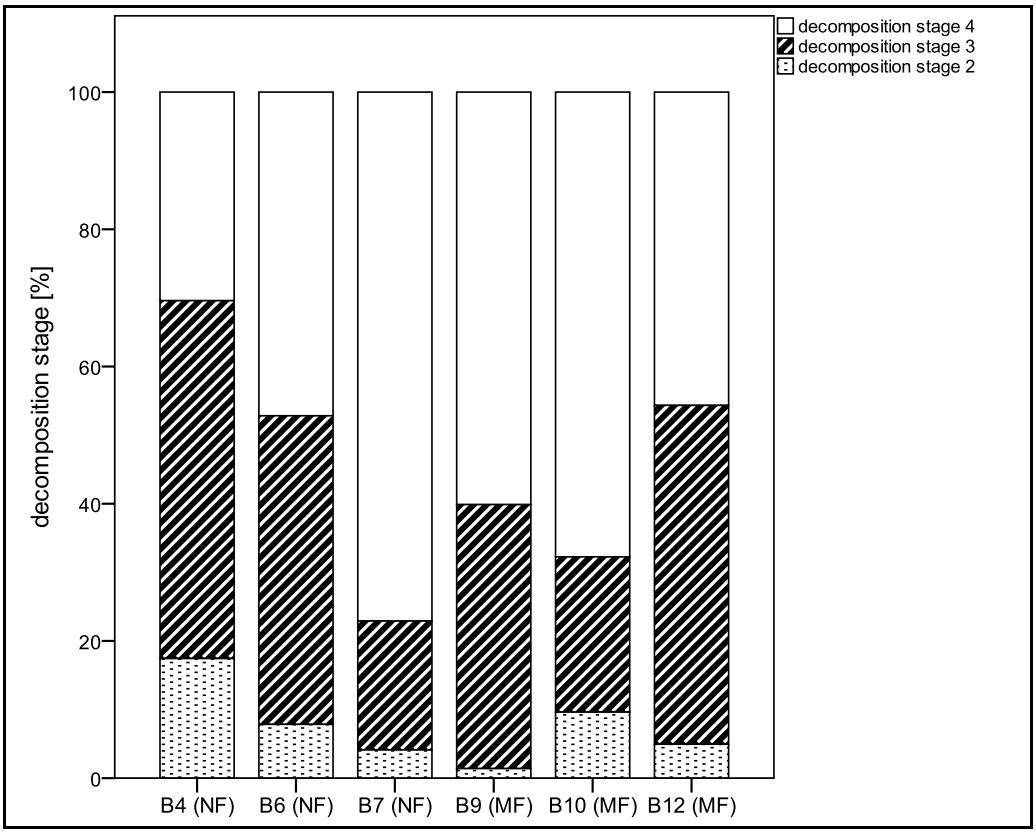


Figure 14: Decomposition stages at the investigated blocks (NF=Natural forest, MF=Managed forest)

Beside the decomposition stages, the coarse woody debris was scaled in diameter size ranges, to detect further differences between the forest types in terms of dead wood. Five classes (from >2 cm diameter) were selected to be suitable for the study. Generally the smaller diameter classes (up to 20 cm diameter) are similar distributed between the natural forest and the managed forest. Significant differences between both forest sites were observed between classes three and five.

Whereas dead wood in the diameter class three was significantly more present at the managed forest ($p < 0.05$), the maximum diameter class five was more existent at the natural forest, but not statistical significant ($p = 0.09$). In the managed forest the diameter class five was only found at the block ten with a small percentage. Thus, big sized dead wood is more present in the natural forest (Figure 15).

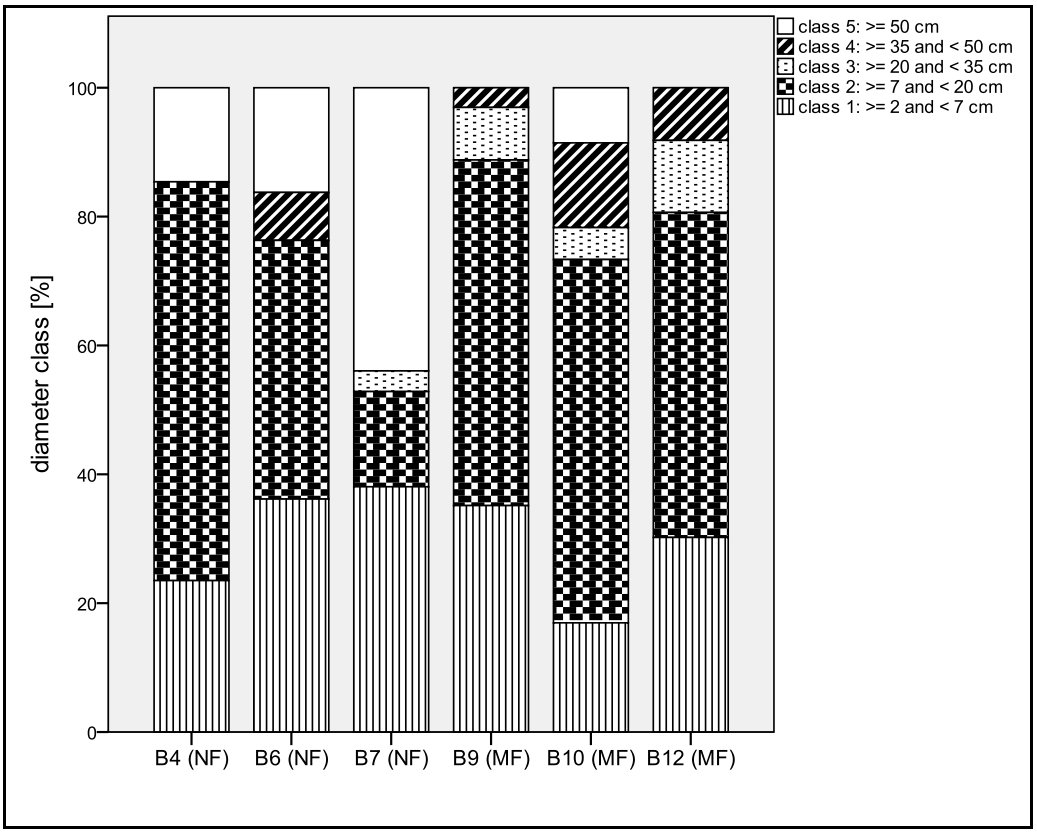


Figure 15: Diameter classes at the different blocks (NF=Natural forest, MF=Managed forest)

3.1.3 Climate of the local population

Equally to the recording of the dead wood, climate parameter were recorded at six blocks, whereas three blocks belonged to the natural forest and three blocks to the managed forest. Eighteen data logger recorded the temperature and the humidity in the different plot structures and between the forest types. During the time of observation, the mean temperature was slightly higher in the managed forest. The values of the daily mean temperatures between natural forest and managed forest are compared in Table 11.

Table 11: Comparison of the daily mean temperature recorded hourly by the data logger

		N	Minimum	Maximum	Mean	
Area		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	mean temperature [°C]	448	9.41	28.82	18.23	0.23
Managed forest	mean temperature [°C]	448	9.59	29.58	18.71	0.23

Compared to the blocks of the natural forests the maximum temperature was higher at each block of the managed forest. The highest temperature of 38.94°C was measured at the 12th of July 2010 at block 11. This block in the managed forest was characterized through the highest temperatures for the complete observation period (Table 16).

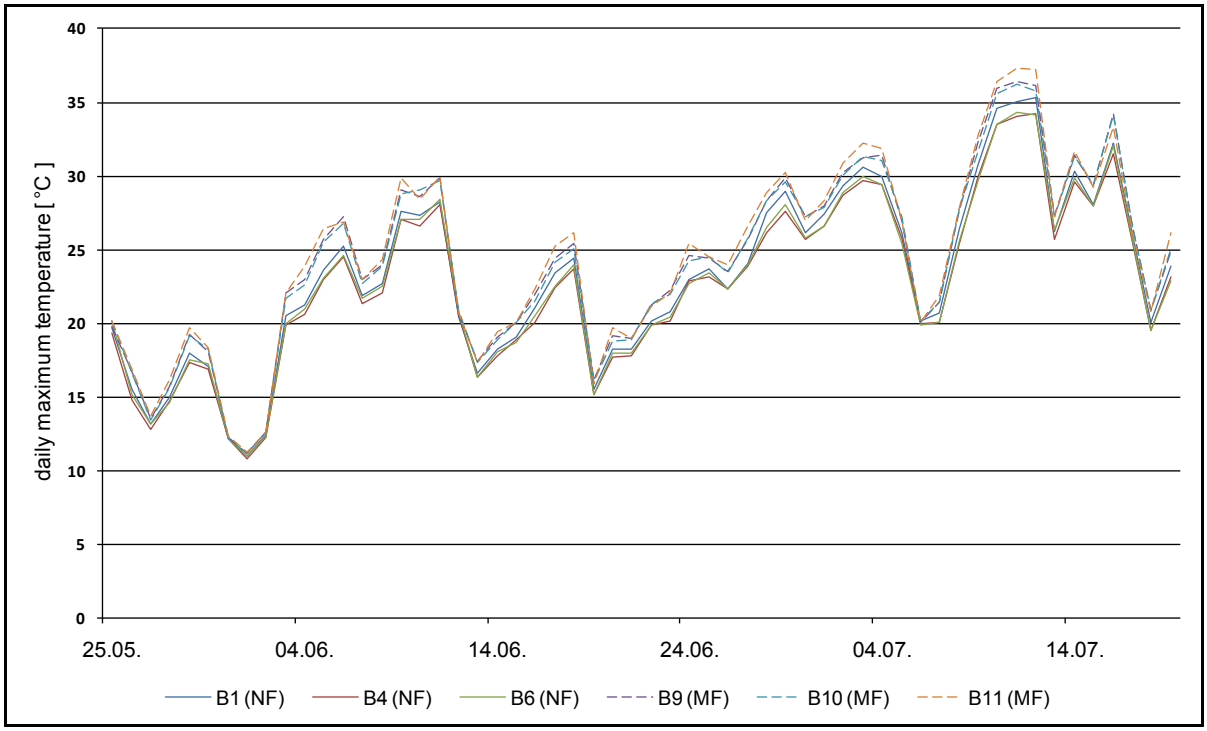


Figure 16: Development of the daily maximum temperature at the different investigated blocks (NF=Natural forest, MF=Managed forest)

Looking at the humidity values were differerent bettween the natural forest and the managed forest. The mean humidity is significantly higher at the natural forest area ($p < 0.01$), and values are displayed in Table 12 and Figure 17. Anyhow block six had constantly higer humidity values than all other blocks in the whole study period.

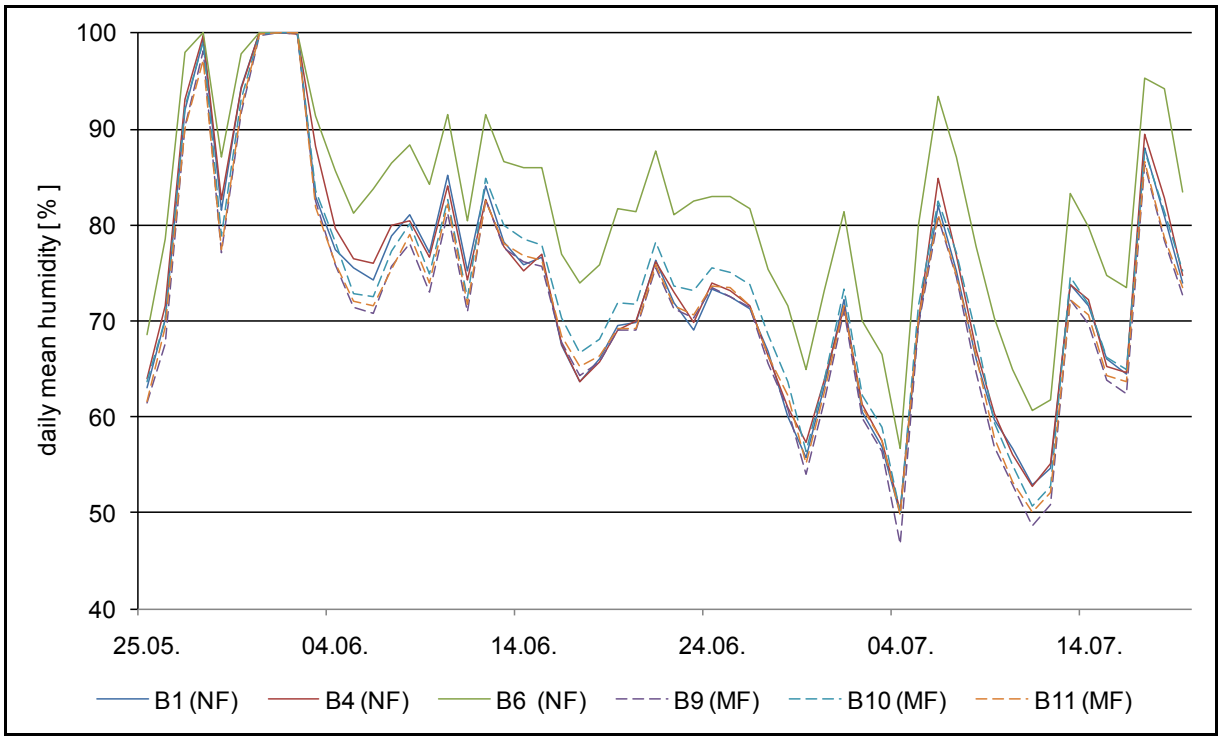


Figure 17: Development of the daily mean humidity at the different investigated blocks over the whole time period (NF=Natural forest, MF=Managed forest)

Table 12: Comparison of the humidity values between both forest types

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	mean humidity [%]	448	48.49	100.00	75.83	0.57
Managed forest	mean humidity [%]	448	45.87	100.00	72.94	0.56

3.1.4 Soil parameters

The pH- value and the water content of the soil was recorded at each of the plots in the two forest types. The pH-value was not different between both study sites and pH-values of the soil indicate acid soil conditions over the whole study area (Table 13).

Table 13: Comparison of the pH-value between both forest types

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	pH-value	24	3.01	4.96	3.56	0.08
Managed forest	pH-value	24	3.23	4.16	3.55	0.04

Like the ph-values the soil moisture was not different between the natural forest and the managed forest site (Table 14).

Table 14: Comparison of the soil moisture between both forest types

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	soil moisture [%]	24	15.37	62.13	30.62	2.68
Managed forest	soil moisture [%]	24	14.13	52.76	29.36	2.25

Although soil moisture was almost similar between the forest types, differences were observed between the microhabitats, but not statistical significant. In the *Dead wood* microhabitat as well as in the *Litter* microhabitat, the soil contained more water than the *Herb* microhabitat in both forest types (Figure 18).

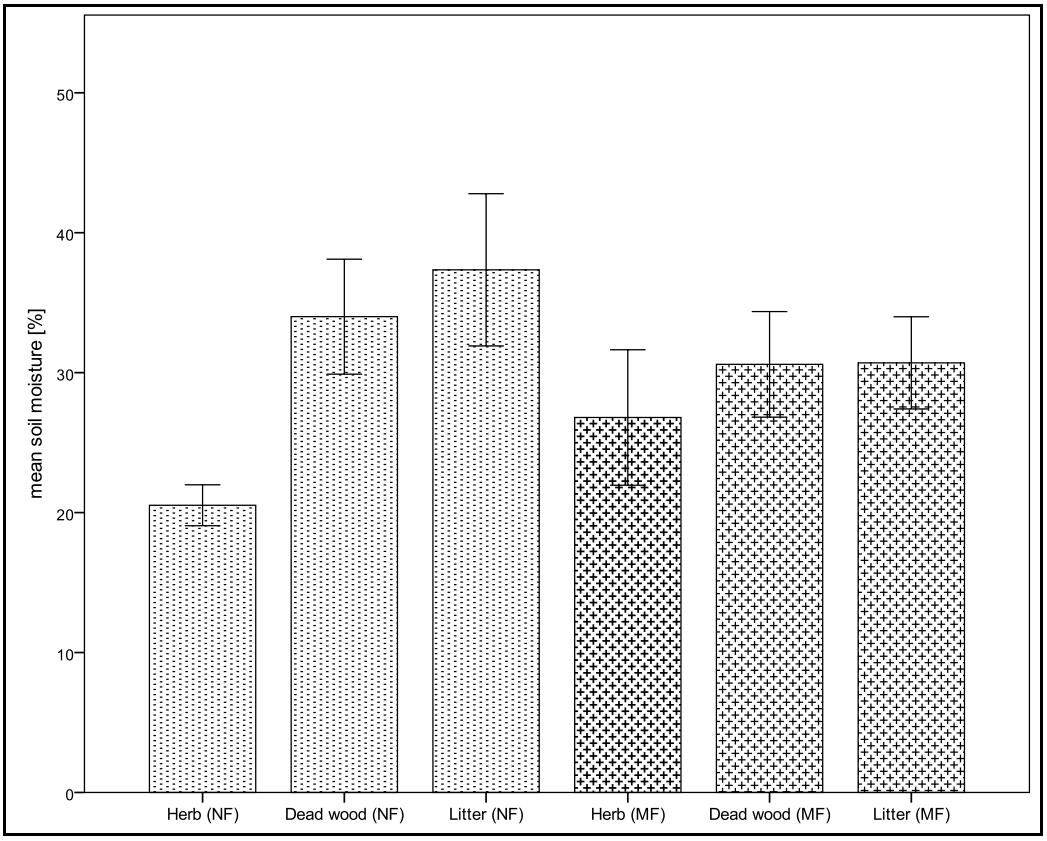


Figure 18: Comparison of the mean soil moisture (±1SE) of the different microhabitats (NF=Natural forest, MF=Managed forest)

Table 15: Summary of important environmental variables (mean), NF=Natural forest, MF=Managed forest

	Vegetation %	*Moss/Lichen* %	*Plant species* N	*Leaf litter* %	*Mineral soil* %	*Depth Litter* cm	*Canopy closure* %
Herb (NF)	40.16	4.75	9.63	52.34	2.75	1.88	65.63
Dead (NF)	14.22	10.25	9.38	72.28	3.25	2.19	57.50
Litter (NF)	9.06	3.31	6.88	83.13	4.50	2.19	65.63
Herb (MF)	52.00	4.25	8.75	40.00	3.75	1.94	38.75
Dead (MF)	22.56	12.13	6.50	59.06	6.25	1.88	35.00
Litter (MF)	17.78	4.00	6.13	74.09	4.13	1.75	40.00

	Mean DBH cm	*Soil moisture* %	*pH*	*Temperature* $_{max}$ T°C	*Temperature* $_{mean}$ T°C	*Humidity* $_{mean}$ %	*Dead wood* m^3/ha
Herb (NF)	23.82	20.52	3.80	31.40	18.21	75.23	5.97
Dead (NF)	21.34	34.00	3.51	31.12	18.17	77.47	28.64
Litter (NF)	23.76	37.35	3.40	31.59	18.14	75.63	11.04
Herb (MF)	18.81	26.80	3.58	33.72	18.70	73.86	10.24
Dead (MF)	15.96	30.59	3.64	33.11	18.66	72.95	27.99
Litter (MF)	18.02	30.70	3.45	33.57	18.75	73.15	10.55

3.2 Faunistic

Seventy-two pitfall traps were installed in the study area for a period of 56 days, of which 48 traps were placed in the natural forest and 24 in the managed forest. These traps were placed in the microhabitat structures (*Herb*, *Dead wood*, Litter) with 24 traps at each structure. The traps were emptied twice every 28 days. In the first clearance period one trap could not be recovered, leaving 71 traps over all. In the second clearance period, all traps could be evaluated. When comparing both study areas 24 traps of each study site are determined. In the natural forest the blocks one, four, five and eight were randomly chosen to compare them with four blocks in the managed forest.

3.2.1 Spectrum of species

In total 4,620 individuals were cached in seventy-two pitfall traps. In the second clearance period the activity density was almost twice as high as in the first clearance period (Table 16).

Table 16: Number of individuals and adults collected at each block, B=Block

	first clearance of traps (25th of May till 22nd of June 2010)												
	B 1	**B 2**	**B 3**	**B 4**	**B 5**	**B 6**	**B 7**	**B 8**	**B 9**	**B 10**	**B 11**	**B 12**	**Σ**
individuals	98	69	51	41	66	46	100	72	335	345	230	148	**1,601**
adults	85	58	47	33	63	43	88	60	298	323	206	134	**1,438**
	second clearance of traps (23rd of June till 20th of July 2010)												
	B 1	**B 2**	**B 3**	**B 4**	**B 5**	**B 6**	**B 7**	**B 8**	**B 9**	**B 10**	**B 11**	**B 12**	**Σ**
individuals	367	199	128	81	92	69	225	93	621	478	426	240	**3,019**
adults	134	114	104	73	60	51	77	65	208	144	173	150	**1,353**

In both clearance periods, most individuals were captured in the managed forest. Also the mean amount of individuals found in the managed forest was significantly higher ($p < 0.01$) than in the natural forest (Table 17).

Table 17: Comparison of the number of individuals between the forest types

		N	Minimum	Maximum	Total	Mean	
Area		Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	Individuals [N]	24	8	149	910	37.92	6.19
Managed forest	Individuals [N]	24	50	243	2,823	117.63	12.27

About 60% (n = 2,791) of the individuals were adults, and could therefore be identified to species. In total 68 species, from 22 families, were identified in the study area. While 57 species were identified in the natural forest, 44 species were found in the managed forest. Twenty-four species were only found in the natural forest and 11 species were unique in the management forest (Table 20). A summary of the mean number of species, mean number of individuals and the total number of species in each block is displayed in Figure 19. Most species were found in block nine in the managed forest, and the mean number of individuals was also highest in this block. Fewest species were observed in the block three in the natural forest.

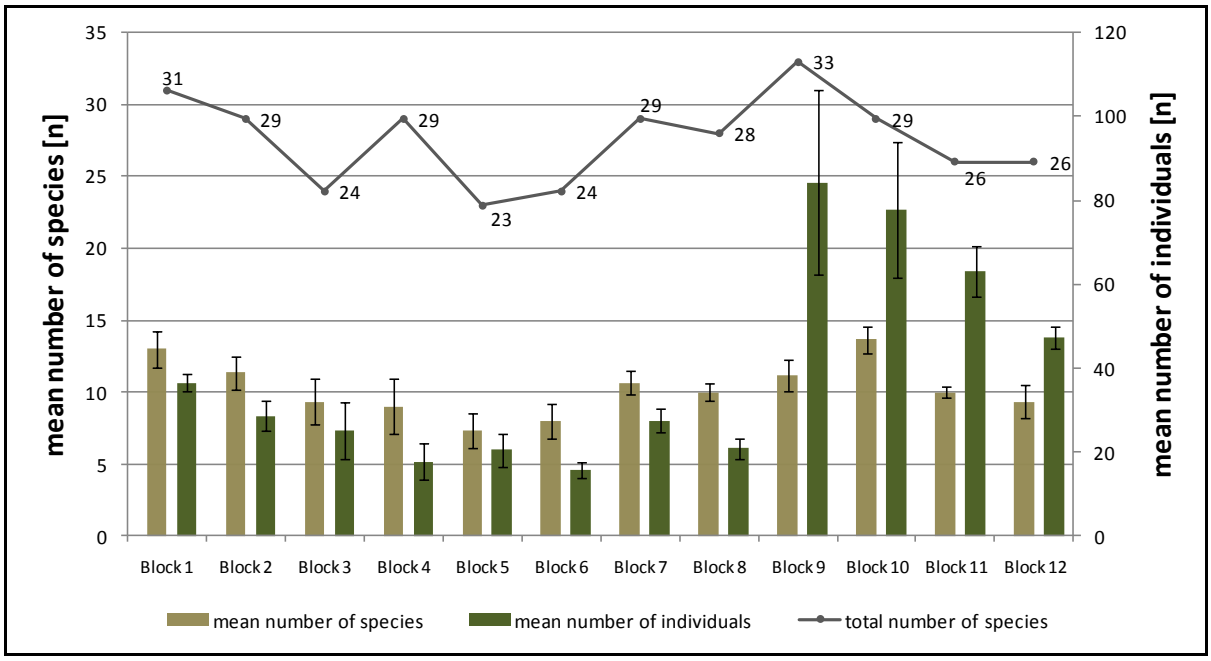


Figure 19: Summary of the total number of species, mean number of species and individuals at each block, Block 1-8=Natural forest; Block 9-12=Managed forest

Looking at the total number of species found in all blocks in the natural forest 17 more species were found compared to the managed forest. Nevertheless, when comparing four blocks of each forest type no statistical differences were observed in the mean number of species (Table 18).

Table 18: Comparison of the number of species in each forest type

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Natural forest	Species [N]	24	2	17	9.83	0.75
Managed forest	Species [N]	24	6	17	11.04	0.55

Alike between the two forest types the mean number of species between the different microhabitat structures is almost equally and differences are not significant (Table 19).

Table 19: Comparison of the number of species between the microhabitats (NF=Natural forest, MF=Managed forest)

Area		N	Minimum	Maximum	Mean	
		Statistic	Statistic	Statistic	Statistic	Std. Error
Herb (NF)	species [N]	8	7	16	11.25	1.16
Dead (NF)	species [N]	8	3	17	9.63	1.44
Litter (NF)	species [N]	8	2	14	8.63	1.30
Herb (MF)	species [N]	8	6	14	10.63	1.13
Dead (MF)	species [N]	8	9	15	11.63	0.86
Litter (MF)	species [N]	8	8	17	10.87	0.97

By far the most abundant species was *Pardosa lugubris-group* with 1,692 individuals, followed by *Haplodrassus silvestris* with 202 individuals. These two made up more than two thirds of the identified adults. Both species were common in the natural forest, as well as in the managed forest and are characteristic forest spiders. Further common species in both forest types were *Haplodrassus soerenseni* as well as *Panamomops mengei* which are also characteristic species in forests. 18 species were only found once in the sample period. Unless it is mentioned, they will not be used in the statistical analysis. Seven species are registered in the *Red list for endangered species* either in the list for *Germany*, the state of *Brandenburg* or even both and a Table with the red list species is attached in the appendix. Table 20 shows a complete list of the found species in the study area.

Table 20: List of all found species, b=found in both forest types, n=unique in the natural forest, m=unique in the managed forest

Family	Species	Σ	Family	Species	Σ
Agelenidae	*Agelena labyrinthica (Clerck, 1757)*	**26** $_b$	***Linyphiidae***	*Tapinocyba praecox (O. P.-Cambridge, 1873)*	**2** $_b$
	Textrix denticulata (Olivier, 1789)	**3** $_b$		*Tenuiphantes flavipes (Blackwall, 1854)*	**57** $_b$
Anyphaenidae	*Anyphaena accentuata (Walckenaer, 1802)*	**2** $_n$		*Troxochrus scabriculus (Westring, 1851)*	**30** $_b$
Araneidae	*Cercidia prominens (Westring, 1851)*	**2** $_m$		*Walckenaeria atrotibialis (O. P.-Cambridge, 1878)*	**20** $_b$
Atypidae	*Atypus affinis (Eichwald, 1830)*	**1** $_n$		*Walckenaeria cucullata (C. L. Koch, 1836)*	**4** $_b$
Clubionidae	*Clubiona marmorata (L. Koch, 1866)*	**1** $_n$		*Walckenaeria dysderoides (Wider, 1834)*	**26** $_b$
	Clubiona terrestris (Westring, 1851)	**3** $_n$		*Walckenaeria furcillata (Menge, 1869)*	**5** $_b$
Corinnidae	*Phrurolithus festivus (C. L. Koch, 1835)*	**8** $_m$	***Liocranidae***	*Agroeca brunnea (Blackwall, 1833)*	**30** $_b$
Dysderidae	*Harpactea hombergi (Scopoli, 1763)*	**1** $_n$	***Lycosidae***	*Pardosa lugubris-group (C. L. Koch, 1833)*	**1,692** $_b$
Gnaphosidae	*Gnaphosa bicolor (Hahn, 1833)*	**12** $_b$		*Trochosa terricola (Thorell, 1856)*	**39** $_b$
	Haplodrassus silvestris (Blackwall, 1833)	**202** $_b$	***Mimetidae***	*Ero furcata (Villers, 1789)*	**1** $_n$
	Haplodrassus soerenseni (Strand, 1900)	**79** $_b$	***Philodromidae***	*Philodromus aureolus (Clerck, 1757)*	**4** $_n$
	Kishidaia conspicua (L. Koch, 1866)	**4** $_m$		*Philodromus dispar (Walckenaer, 1826)*	**10** $_b$
	Zelotes subterraneus (C. L. Koch, 1833)	**33** $_b$	***Pisauridae***	*Pisaura mirabilis (Clerck, 1757)*	**8** $_b$
	Zelotes clivicola (L. Koch, 1870)	**2** $_m$	***Salticidae***	*Marpissa muscosa (Clerck, 1757)*	**1** $_n$
Linyphiidae	*Agyneta conigera (O. P.-Cambridge, 1863)*	**1** $_n$		*Pseudeuophrys erratica (Walckenaer, 1826)*	**1** $_m$
	Abacoproeces saltuum (L. Koch, 1872)	**2** $_n$	***Segestriidae***	*Segestria senoculata (Linnaeus, 1758)*	**28** $_b$
	Anguliphantes angulipalpis (Westring, 1851)	**6** $_n$	***Sparassidae***	*Micrommata virescens (Clerck, 1757)*	**1** $_n$
	Araeoncus humilis (Blackwall, 1841)	**1** $_n$	***Tetragnathidae***	*Metellina merianae (Scopoli, 1763)*	**1** $_n$
	Bathyphantes gracilis (Blackwall, 1841)	**1** $_n$		*Metellina mengei (Blackwall, 1870)*	**1** $_n$
	Centromerus pabulator (O. P.-Cambridge, 1875)	**1** $_n$		*Metellina segmentata (Clerck, 1757)*	**1** $_n$
	Centromerus sylvaticus (Blackwall, 1841)	**13** $_b$	***Theridiidae***	*Crustulina guttata (Wider, 1834)*	**2** $_b$
	Ceratinella brevipes (Westring, 1851)	**1** $_m$		*Enoplognatha thoracica (Hahn, 1833)*	**6** $_b$
	Ceratinella brevis (Wider, 1834)	**4** $_m$		*Episinus angulatus (Blackwall, 1836)*	**2** $_n$
	Diplostyla concolor (Wider, 1834)	**2** $_n$		*Euryopis flavomaculata (C. L. Koch, 1836)*	**12** $_b$
	Erigone atra (Blackwall, 1833)	**1** $_m$		*Robertus lividus (Blackwall, 1836)*	**52** $_b$
	Gongylidiellum latebricola (O. P.-Cambridge, 1871)	**3** $_b$	***Thomisidae***	*Oxyptila praticola (C. L. Koch, 1837)*	**8** $_b$
	Macrargus rufus (Wider, 1834)	**16** $_n$		*Xysticus erraticus (Blackwall, 1834)*	**2** $_n$
	Microneta viaria (Blackwall, 1841)	**35** $_b$		*Xysticus lanio (C. L. Koch, 1835)*	**3** $_b$
	Moebelia penicillata (Westring, 1851)	**1** $_m$		*Xysticus luctator (L. Koch, 1870)*	**89** $_b$
	Neriene clathrata (Sundevall, 1830)	**3** $_n$		*Xysticus luctuosus (Blackwall, 1836)*	**1** $_m$
	Palliduphantes pallidus (O. P.-Cambridge, 1871)	**5** $_n$	***Zodariidae***	*Zodarion germanicum (C. L. Koch, 1837)*	**2** $_m$
	Panamomops mengei (Simon, 1926)	**64** $_b$	***Zoridae***	*Zora nemoralis (Blackwall, 1861)*	**56** $_b$
	Tapinocyba insecta (L. Koch, 1869)	**38** $_b$		*Zora spinimana (Sundevall, 1833)*	**17** $_b$
				Σ Total	**2,791**

Within the identified 22 families, the largest number of species was found in the family of the *Linyphiidae* with 26 species. The families *Gnaphosidae* follows with six species and the families *Theridiidae* and *Thomisidae* are present with five species each (Figure 20). The group of the families with just one species each are summarized to the group *others* in the figure below. Considering the number of individuals instead of the number of species the *Lycosidae* happened to be the most dominant family, representing 60% (n = 1,692) off all identified individuals, due to the high number of *Pardosa lugubris-group* individuals.

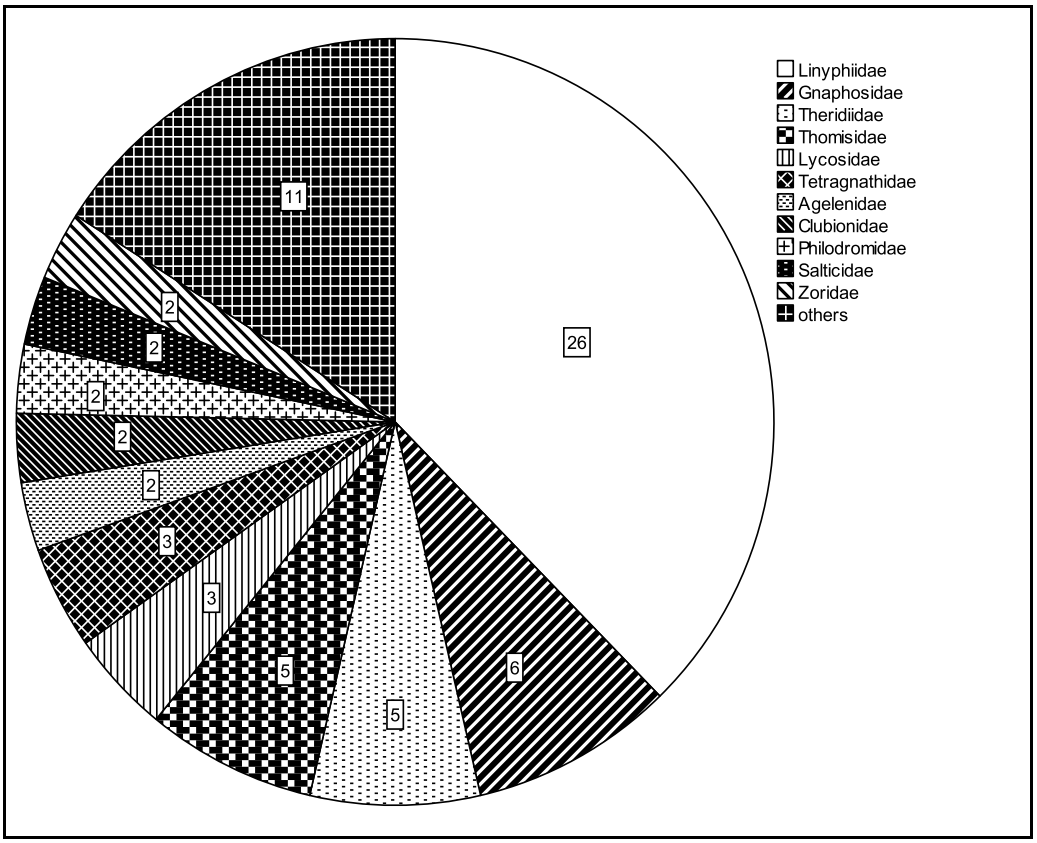


Figure 20: Number of species in the different identified families

3.2.2 Species accumulation

A species accumulation curve for the whole study area was created using the nonparametric estimators Chao 1 and Jacknife 2 to calculate actual species richness. At the total individual number (n = 2,791), the curves are not approaching each other indicating that sampling was not complete in the study area. The estimated total species richness using Chao 1 was 101.63 ± 17.97 (SD) and using Jacknife 2 108.33 ± 2.35 (SD) for the complete sample. The ratio of observed to estimated (Chao 1) number of species was 69%, suggesting that at least 31% more species are to be expected in the study area than actually collected (Figure 21).

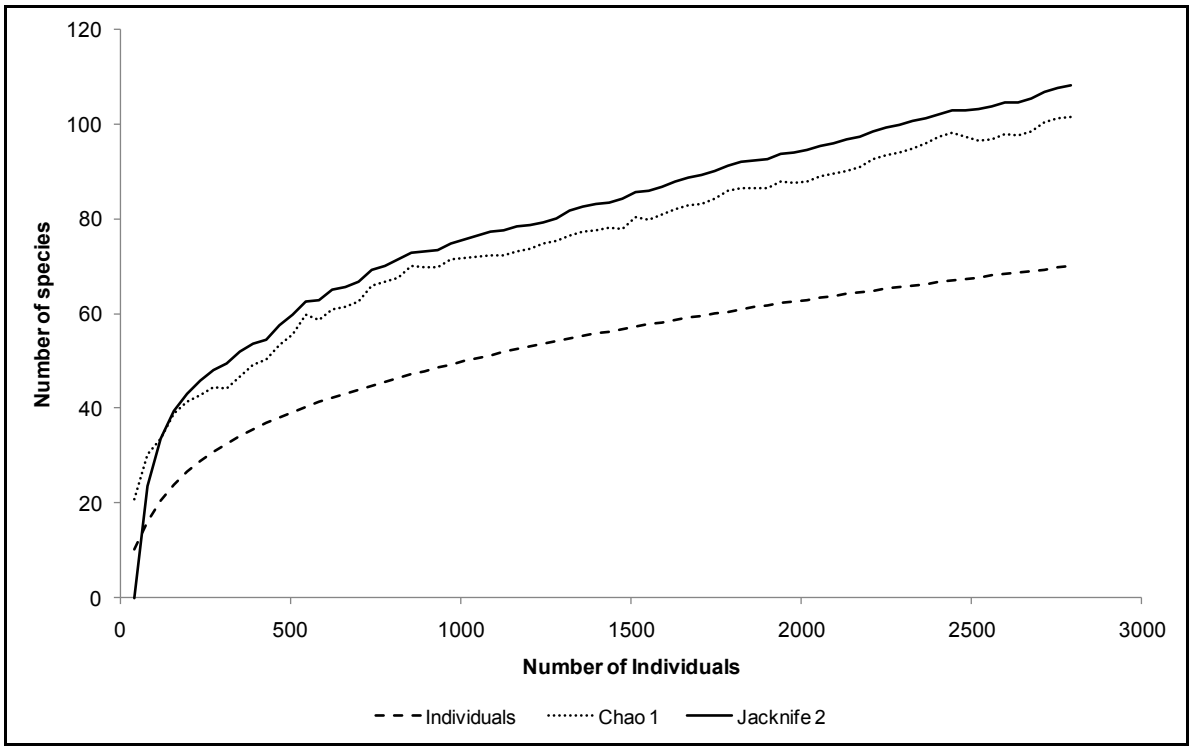


Figure 21: Species-accumulation curve and estimation curves Chao 1 and Jacknife 2 for the whole study area, curves are generated from 100 randomizations

Comparing the natural forest and the managed forest separately in terms of actual species richness higher percentage values were reached in the managed forest. About 80% of the estimated species richness was sampled here, while about 65% were collected in the natural forest (Table 21).

Table 21: Measures of the species richness estimated and inventory completeness for each forest type, richness estimator values (*Chao1 and Jacknife2*) presents the mean of 100 randomizations

	Natural forest	**Managed forest**
Number of specimens	1,155	1,636
Observed richness	57	44
Number of singeltons	21	11
Number of doubletons	7	4
Chao 1	86	54
Jacknife 2	94	60
% completness (Chao1)	66.27	81.48

3.2.3 Dominance

The analyses of the dominance structure revealed differences between the natural forest and the managed forest. In the managed forest the main species (> 3.2%) are characterized through two species, while in the natural forest seven species belong to the main species. Moreover the class *dominant* is not present at the managed forest and the percentage differences between the *eudominant* species *Pardosa lugubris-group* and the second main species *Haplodrassus silvestris* adds up to more than 70%. According to Engelmann (1978) the main species should represent 85% of the captured individuals. This was not found for both forests, because in the natural forest main species presented 70% of the collected individuals, and in managed forest 79%. Thus 30% belong to the secondary species in the natural forest, and 21% in the managed forest (Table 22).

Table 22: Comparison of the dominance classes between both forest types

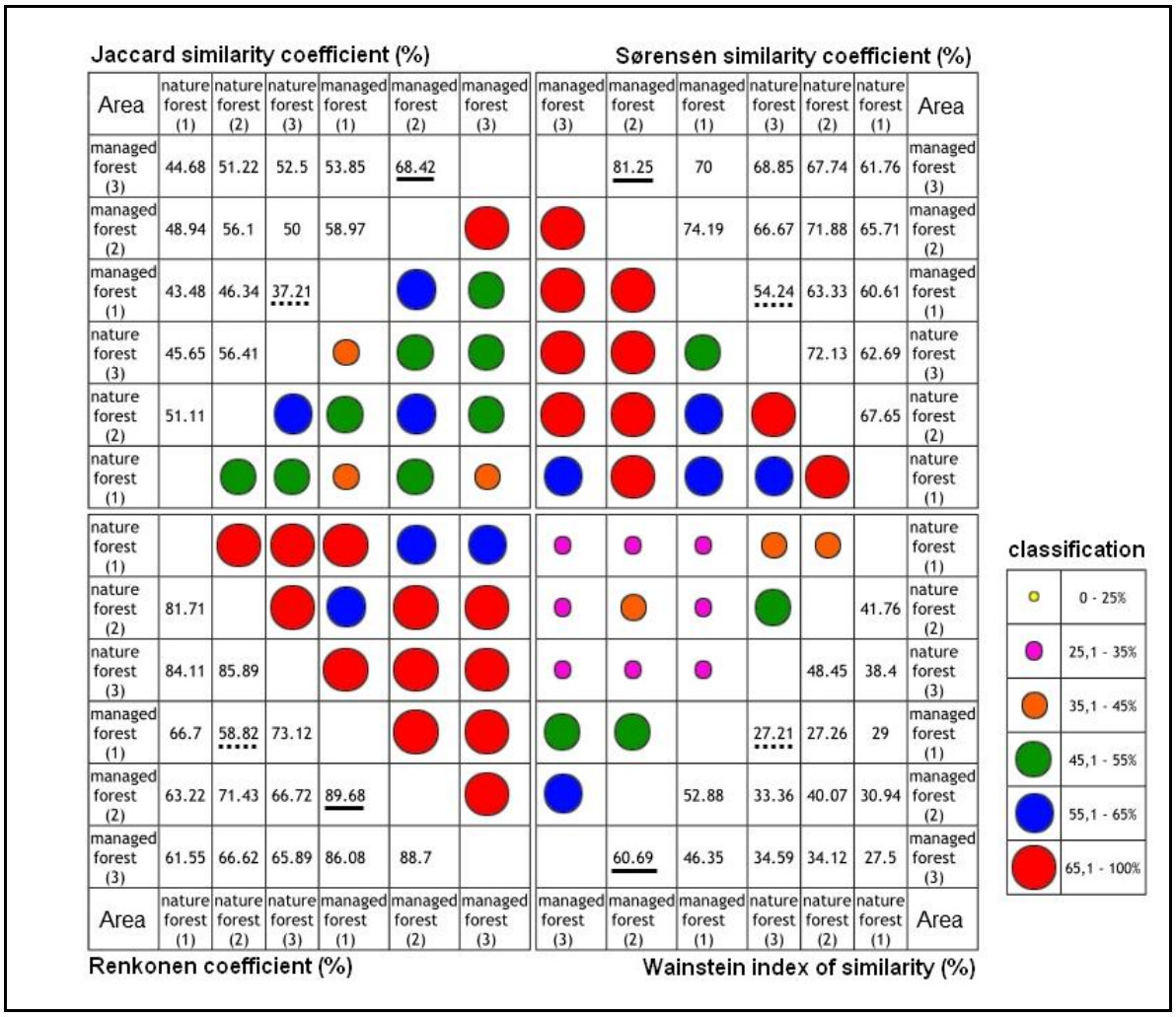
Natural forest	N	%	dominance class
Pardosa lugubris-group	230	40.14	eudominant
Haplodrassus silvestris	82	14.31	dominant
Haplodrassus soerenseni	23	4.01	sub-dominant
Tenuiphantes flavipes	24	4.19	
Xysticus luctator	24	4.19	
Panamomops mengei	20	3.49	
Managed forest	**N**	**%**	**dominance class**
Pardosa lugubris-group	1,240	75.79	eudominant
Haplodrassus silvestris	57	3.48	sub-dominant

Comparing the dominance structure in the microhabitats no changes were observed, since the same species characterize the group with abundance more than three percent. A table of the whole dominance structure in both forest types can be found in the appendix.

3.2.4 Faunal similarity

The analyses of the two indices by *JACCARD* and *SØRENSEN*, the dominance identity according to *RENKONEN* as well as the similarity indices by *WAINSTEIN* are presented as a Trellis diagram in Figure 22. The values are given as percentage

values, as well as different coloured circles which differ also in the size of the circle. The community coefficient *JACCARD*, which shows the agreement of the stock of the species, was highest between the microhabitats *Dead wood* and *Litter* in the managed forest with a percentage of 68.42%. The lowest consistence of species was found between the *Herb* microhabitats (1) in the managed forest, and the *Litter* microhabitat (3) in the natural forest with 37.21%.



Area	nature forest (1)	nature forest (2)	nature forest (3)	managed forest (1)	managed forest (2)	managed forest (3)	managed forest (3)	managed forest (2)	managed forest (1)	nature forest (3)	nature forest (2)	nature forest (1)	Area
managed forest (3)	44.68	51.22	52.5	53.85	68.42			81.25	70	68.85	67.74	61.76	managed forest (3)
managed forest (2)	48.94	56.1	50	58.97					74.19	66.67	71.88	65.71	managed forest (2)
managed forest (1)	43.48	46.34	37.21							54.24	63.33	60.61	managed forest (1)
nature forest (3)	45.65	56.41									72.13	62.69	nature forest (3)
nature forest (2)	51.11											67.65	nature forest (2)
nature forest (1)													nature forest (1)
nature forest (1)													nature forest (1)
nature forest (2)	81.71											41.76	nature forest (2)
nature forest (3)	84.11	85.89									48.45	38.4	nature forest (3)
managed forest (1)	66.7	58.82	73.12							27.21	27.26	29	managed forest (1)
managed forest (2)	63.22	71.43	66.72	89.68					52.88	33.36	40.07	30.94	managed forest (2)
managed forest (3)	61.55	66.62	65.89	86.08	88.7			60.69	46.35	34.59	34.12	27.5	managed forest (3)
Area	nature forest (1)	nature forest (2)	nature forest (3)	managed forest (1)	managed forest (2)	managed forest (3)	managed forest (3)	managed forest (2)	managed forest (1)	nature forest (3)	nature forest (2)	nature forest (1)	Area

Figure 22: Trellis diagram with the different indices comparing the microhabitats and the forest types, 1= microhabitat *Herb*, 2=microhabitat *Dead wood*, 3=microhabitat *Litter*

The species identity by *SØRENSEN* reveals a similar picture. The similarity quotient is lowest between the microhabitat *Herb* in the managed forest and the microhabitat *Litter* in the natural forest with 54.24%. Highest agreement is found with 81.25% between the microhabitat *Dead wood* and *Litter* in the managed forest, like

analysed by the *JACCARD* indices. Generally the values by *SØRENSEN* are higher than the values of the JACCARD indices.

The *RENKONEN* coefficient is an index for agreement of the dominance ratio of two species communities. Between the microhabitat *Herb* and *Dead wood* in the managed forest the highest value is found with 89.86%, closely followed by the structures *Dead wood* and *Litter* with 88.7%. With 58.82% the lowest value of the dominance ratio is found between the microhabitat *Herb* in the managed forest and the microhabitat *Dead wood* in the natural forest. Also the similarity indices by *WAINSTEIN* indicate the highest value between the microhabitat *Dead wood* and *Litter* in the managed forest. Lowest values were found again between the microhabitat *Herb* in the managed forest and *Litter* in the natural forest with only 27.21%. In Table 23 the natural forest and the managed forest are compared as a whole by the same similarity indices. As a summary the WAINSTEIN index, a multiplication of the *JACCARD* indices and the *RENKONEN* coefficient, indicates that one third of the species (33.8%) are similar between both forest types.

Table 23: Comparison of the two forest types using four different indices

Faunal similarity indices	
JACCARD coefficient (%)	**50.79**
SØRENSEN coefficient (%)	**67.37**
RENKONEN coefficient (%)	**66.55**
WAINSTEIN index (%)	**33.8**

3.2.5 Multidimensional scaling

Comparing between different forests revealed that species composition was much more similar within the same forest type than within the same microhabitats. Nmds-plots generated from abundance of the different spider species showed that blocks from the different forest types are clearly separated from each other (Figure 23). Pairwise ADONIS test revealed significant differences in the spider composition between both forest types ($R^2 = 0.48$, $p < 0.01$).

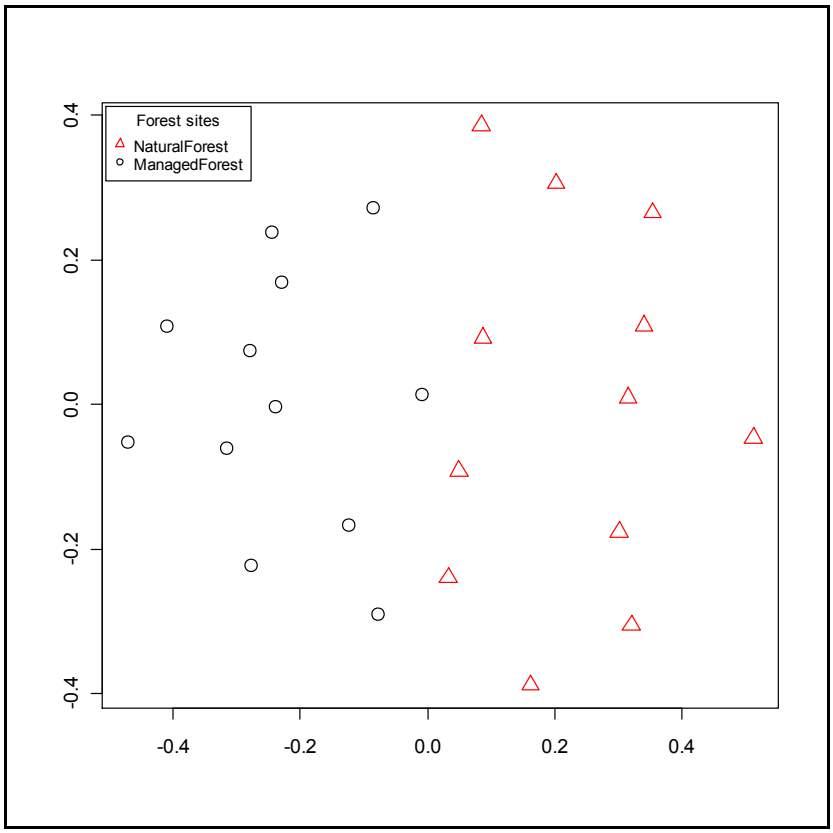


Figure 23: Nmds ordination plots of the forest types generated by the species composition (fourth-root transformed)

Nmds-plots of the microhabitats revealed that the same microhabitat within a certain forest type is not clustered together, but forest types are again clearly separated. Therefore the spider assemblage within one microhabitat is not more similar than between different microhabitats (Figure 24). Mostly equal spider composition was found within the natural forest between the microhabitat *Dead wood* and the *Litter* microhabitat. The biggest differences in the assemblages of spiders were found between the microhabitat *Litter* in the natural forest and *Herb* in the managed forest.

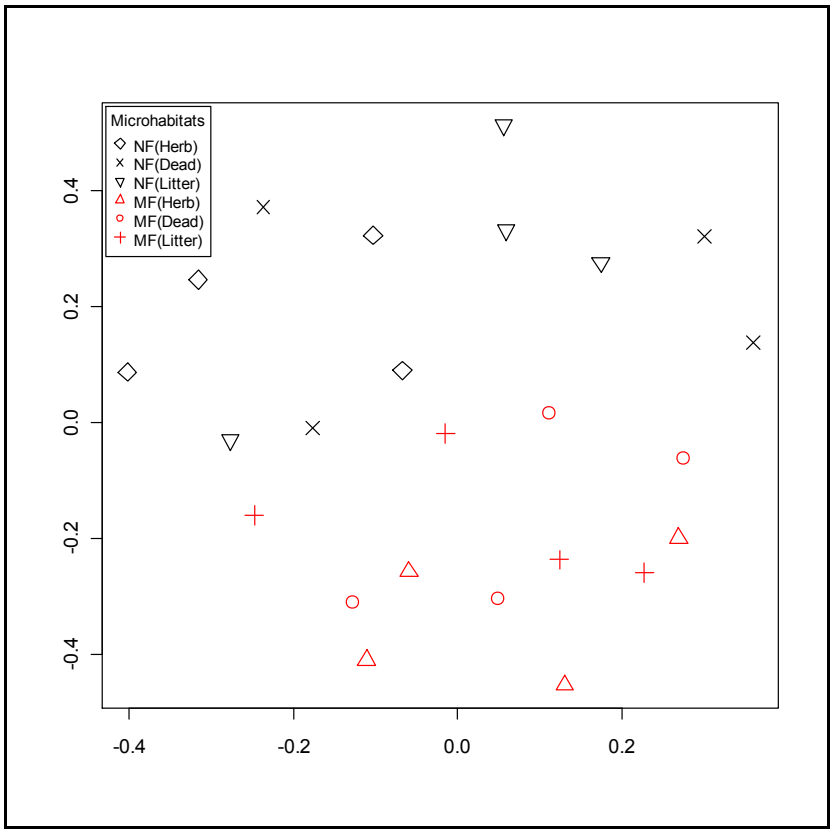


Figure 24: Nmds ordination plots of the microhabitats generated by the species composition (fourth-root transformed) NF=natural forest, MF=Managed forest

Pairwise comparison of the structures, using *ADONIS*, reveals significant differences in spider composition between all structures of the natural forest and all structure of the managed forest. Within the managed forest the *Herb* and the *Litter* microhabitats differ significantly in terms of spider composition (Table 24).

Table 24: R-Values (*Adonis*) generated by the pairwise comparison of the species composition of the different microhabitats representing the mean of 500 permutations, (NF=Natural forest, MF=managed forest)

	Herb (NF)	Dead (NF)	Litter (NF)	Herb (MF)	Dead (MF)	Litter (MF)
Herb (NF)						
Dead (NF)	0.11					
Litter (NF)	0.11	0.07				
Herb (MF)	0.58 *	0.57 *	0.59 *			
Dead (MF)	0.54 *	0.53 *	0.57 *	0.13		
Litter (MF)	0.50 *	0.51 *	0.55 *	0.37 *	0.16	
*** p <0.001	** p <0.01	* p <0.05				

3.2.6 Guild composition

The guild composition Gertsch (1979) in the study area was compared between the two forest types, as well as between the different microhabitats. The wandering-active spiders are dominant in the natural forest, as well as in the managed forest (Figure 25). Nevertheless the guild *wandering-active* was even more abundant in the managed forest with more than 85%, compared to 65% in the natural forest. This was due to the high dominance of the *Pardosa lugubris-group* in the managed forest. The sheet web spiders were also very common in both forests. The comparison of both sites using X^2 test of homogeneity showed significant differences in the guild composition ($X^2 = 12.91$, $p < 0.05$).

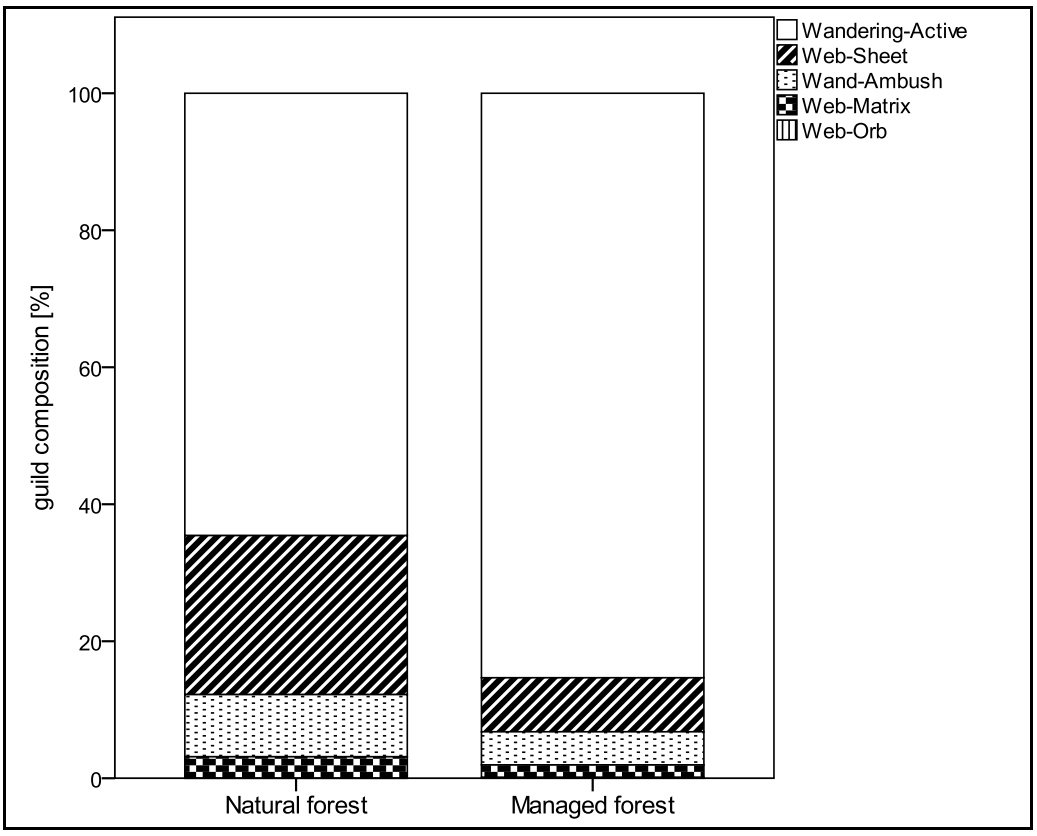


Figure 25: Guild composition compared between the forest types

Comparing the different microhabitats, the guild composition varies most between all microhabitats in the natural forest and almost all microhabitats in the managed forest. The microhabitats within the same forest type were always most similar.

Almost no difference in the guild composition was found between the *Herb* and *Dead wood* habitats in the natural forest (Figure 26). Results of the X^2 test of homogeneity, between each pair of microhabitats, are presented in Table 25.

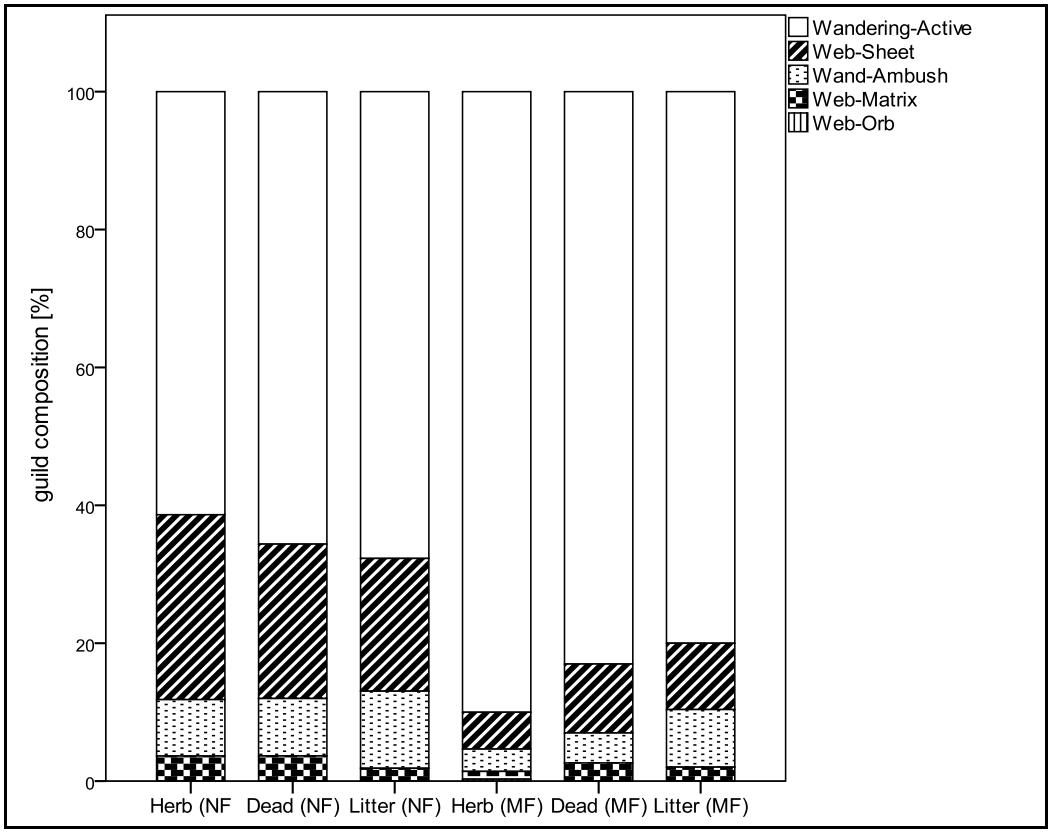


Figure 26: Guild composition compared between the different microhabitats, (NF=Natural forest, MF=Managed forest)

Table 25: Results of the X^2 test of homogeneity between the different microhabitats

	Herb (NF)	Dead (NF)	Litter (NF)	Herb (MF)	Dead (MF)	Litter (MF)
Herb (NF)						
Dead (NF)	0.54					
Litter (NF)	2.58	1.26				
Herb (MF)	23,27 ***	17,92 ***	15,61 **			
Dead (MF)	12,26 **	8,19 *	7.63	2.47		
Litter (MF)	11,03 *	6.98	4.65	4.33	1.41	
*** p<0,001	** p<0,01	* p<0,05				

3.2.7 Ecological type

The 68 identified species belong to ten ecological types. In both forest types, as well as in the microhabitats, species living in dry deciduous and coniferous forests are most dominant. These species are typical forest species, in contrast to the second dominant ecological type which are species common in forest areas as well as woodless areas (Figure 27). Xerobiontic species were also found frequently in both forests.

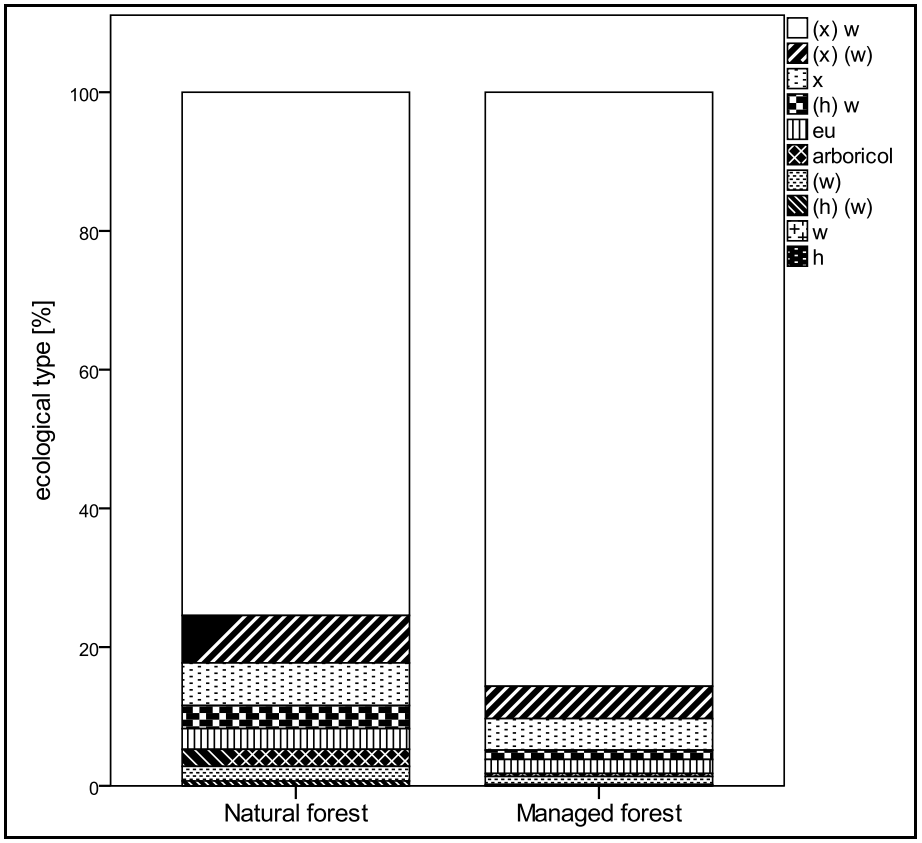


Figure 27: Ecological types compared between the two forest types

Except the ecological type x(w) all other ecological types of characteristic forest spiders (e.g. (w),(h)w or arboricol) are more abundant in the natural forest. The dominance of this ecological type is due to the high abundance of the *Pardosa lugubris-group*. However, the distribution of ecological types was not statistical different, whether between the types of forest nor the varied microhabitats.

3.2.8 Shannon- Weaver Diversity/ Evenness

The diversity indices by *Shannon-Weaver* lie between 1.09 and 2.47 in the investigated forest area. All blocks in the natural forest revealed higher diversity indices than in the managed forest area (Figure 28). Block eight showed the highest value for the *Shannon-Weaver* indices, as well as for the *Evenness* value. Almost equally high values were found for block four in the natural forest. Lowest values were observed at the block nine in the managed forest. Although the two forest types differ especially in the number of unique species and abundance, a randomization test (n = 500) revealed only a marginal trend between the forests to be significant different (p = 0.057).

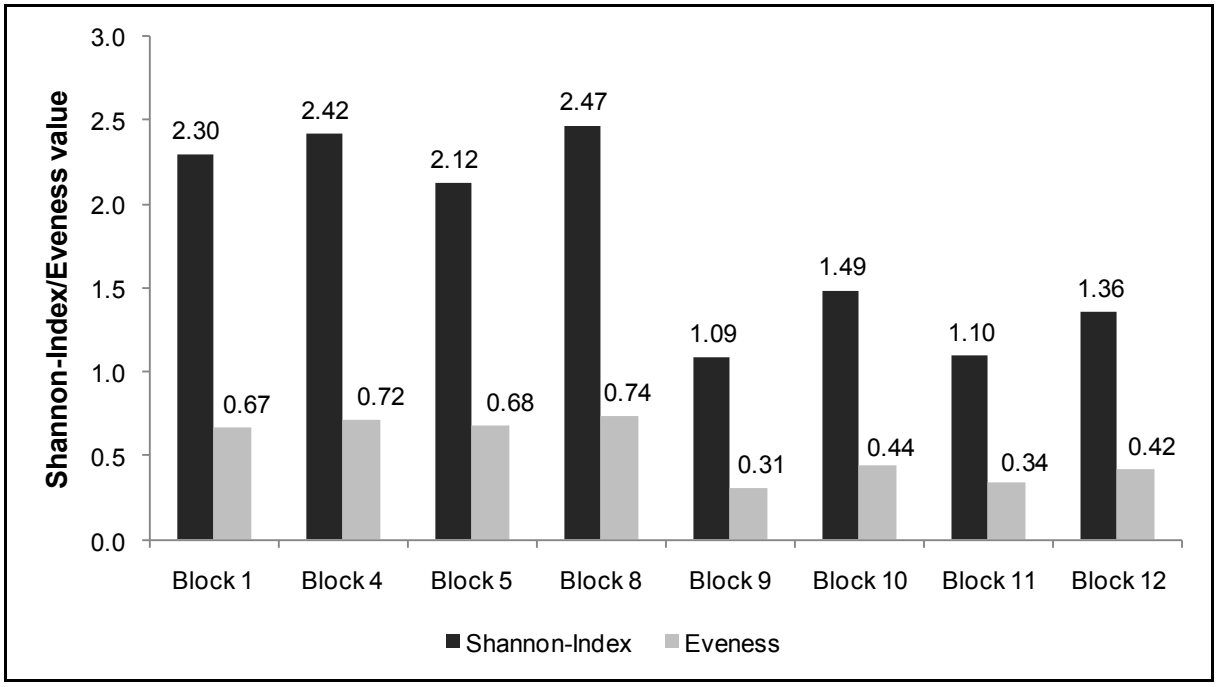


Figure 28: Comparison of the diversity indices between the investigated blocks (Block 1-8= Natural forest, Block 9-12= Managed forest)

Regarding the diversity between the different microhabitats contrary results were found between the forest sites. The diversity indices are highest in the microhabitat *Herb* and lowest in the microhabitat *Litter* in the natural forest, but the opposite was observed in the managed forest. There, the microhabitat *Litter* revealed the highest diversity indices. Equally results were found for the *Evenness* values, among the different microhabitats. Like the comparison of the forest sites in terms of diversity the

pairwise evaluation with a randomization test (n = 500) did not show significant differences between the microhabitats (Figure 29).

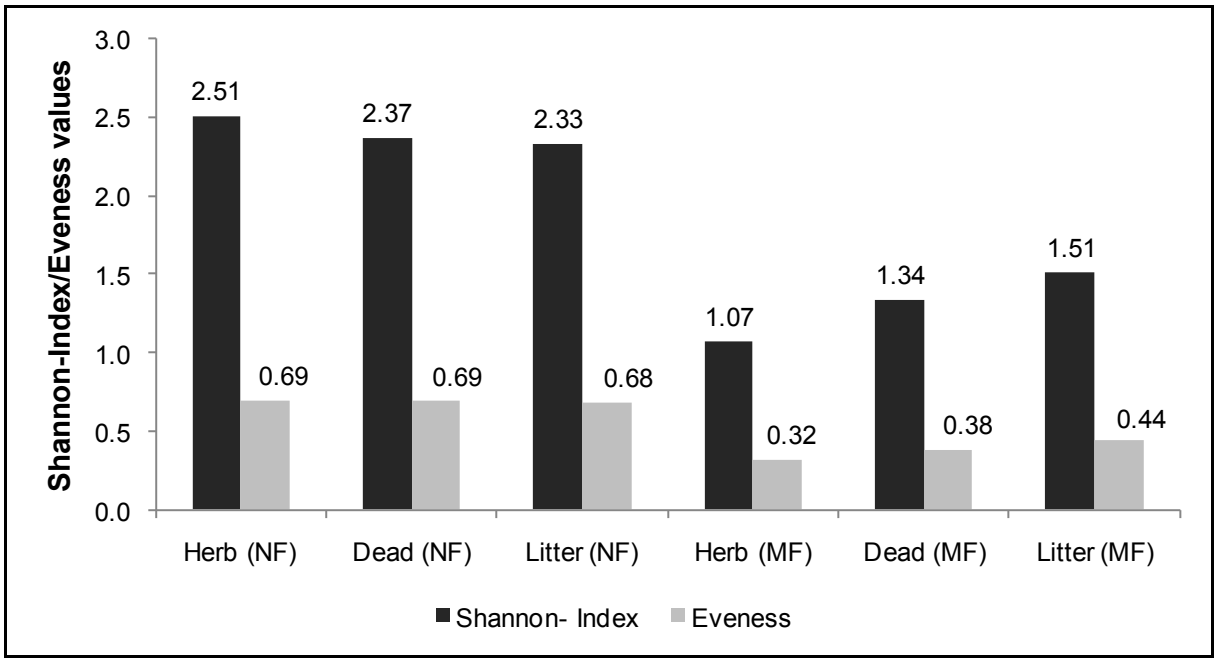


Figure 29: Comparison of the diversity indices between the microhabitats (NF=Natural forest, MF=Managed forest)

3.2.9 Rarefaction

3.2.9.1 HURLBERT curve to examine the α-diversity

Because the activity density between the studied blocks as well as between microhabitats was heterogeneous, diversity was again analyzed using rarefaction. Therefore a defined sample size of 100 individuals was used to estimate species diversity. Comparing four blocks of each forest types the block four in the natural forest revealed the highest rarefaction value (S (n) = 28.10) whereas block eleven, in the managed forest revealed the lowest value (S (n) = 13.55). Results of the rarefaction are presented in Figure 30.

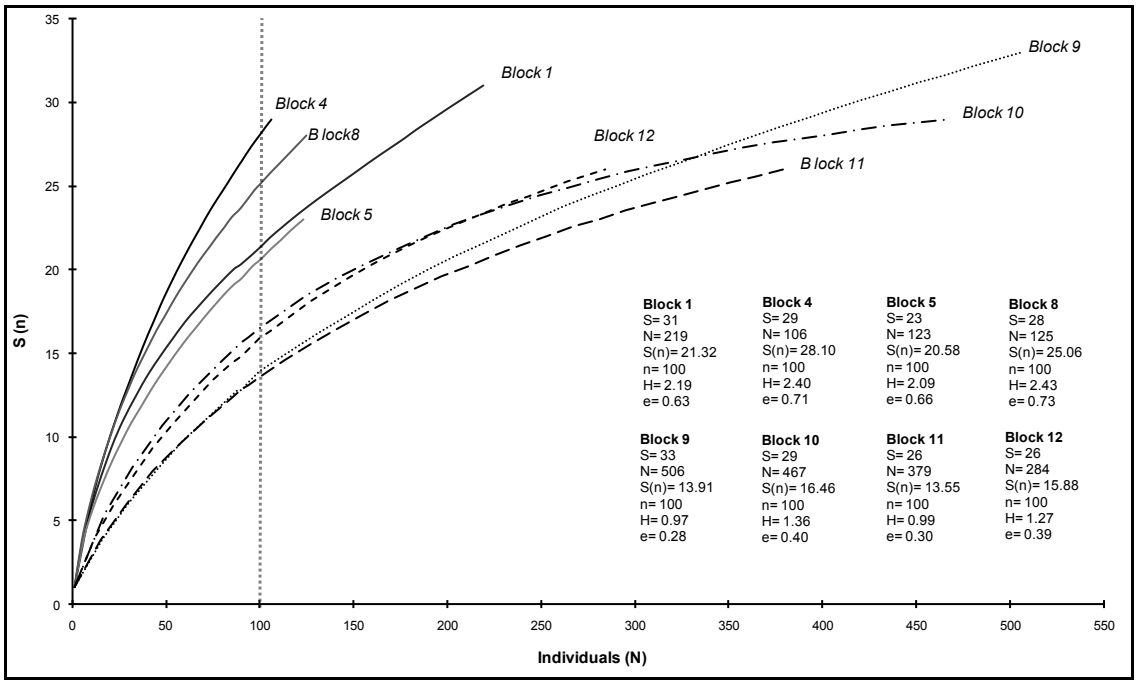


Figure 30: Hurlbert curves for the investigated blocks, S=Number of species, N=Number of individuals S (n) = Rarefaction value (Hurlbert), n= Standardized sample size, H=Shannon-Wiener index, e=Evenness

Having the same sample size (n = 100) all blocks in the natural forest differ significantly from the blocks in the managed forest, because the confidence intervals of richness values are not overlapping between the forest types (Figure 31). The most diverse one is block four, because it is also significantly different from block one and five, considering the same reason mentioned before.

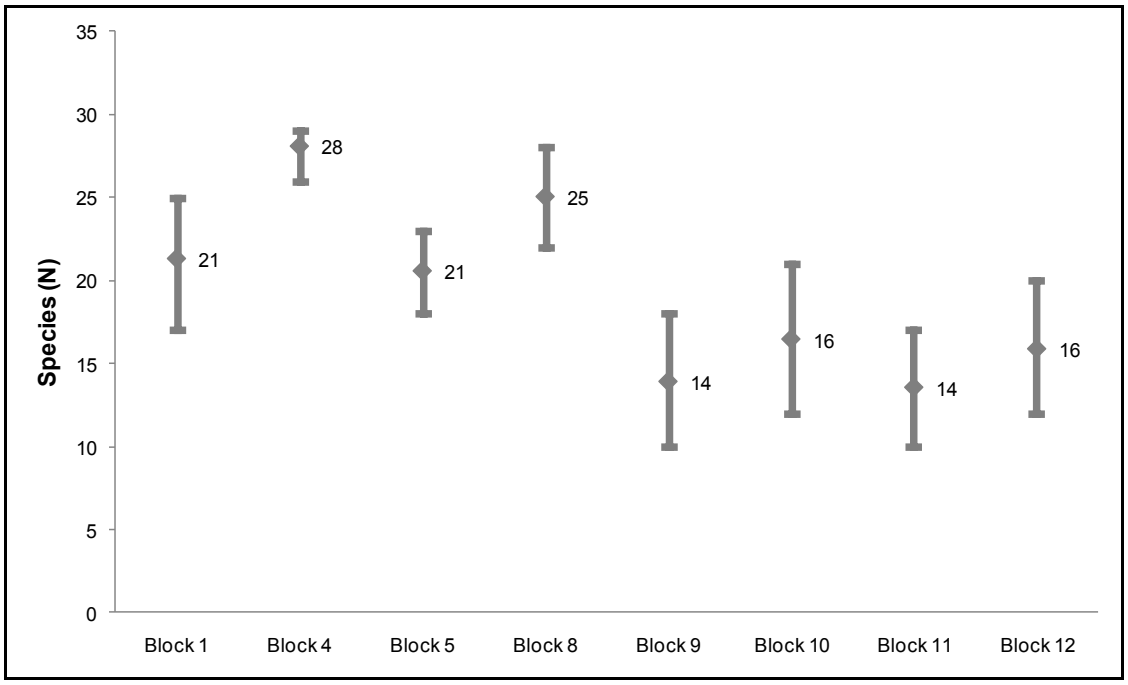


Figure 31: Comparison of mean species richness values (±95% confidence interval) at the lowest number of individuals (100) derived from individuals-based species rarefaction curves of spider assemblages

Similar to the studied blocks the microhabitats were analyzed using rarefaction. The highest value for standardized sample size were found in the microhabitat *Herb* in the natural forest (S (n) = 24.82). The same microhabitat in the managed forest showed the lowest value (S (n) = 12.53). Summing up, the same microhabitat showed opposite values between the forest types, e.g. the microhabitat *Herb* revealed a high rarefaction value in the natural forest, whereas in the managed forest it showed the lowest rarefaction value (Figure 32).

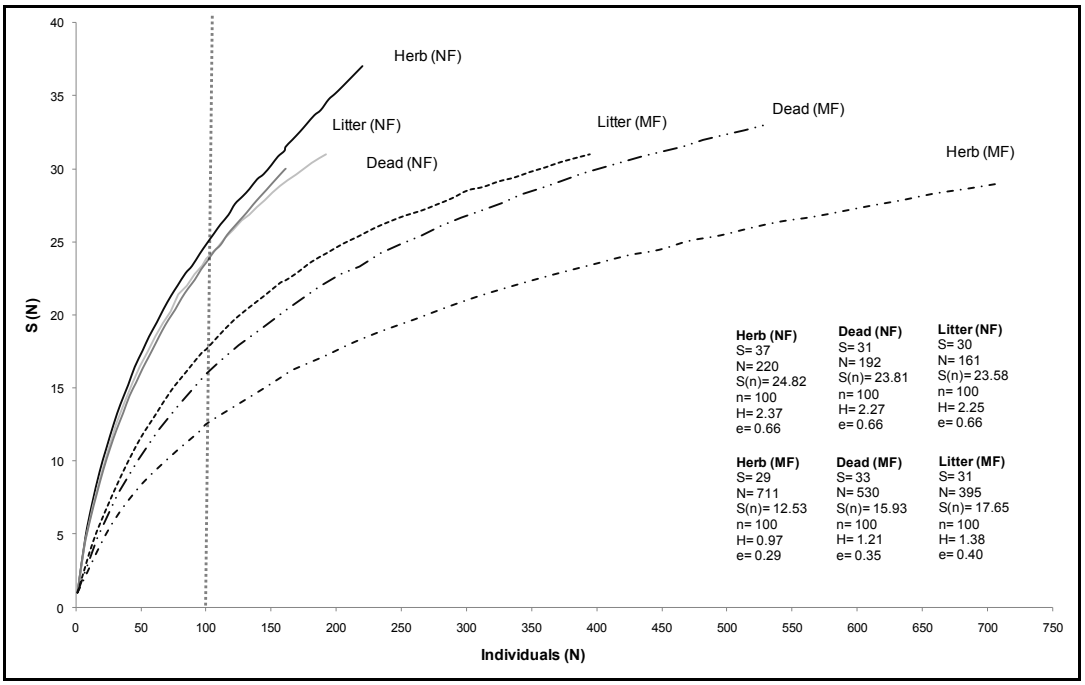


Figure 32: Hurlbert curves for the microhabitats, S=Number of species, N=Number of individuals, S(n)= Rarefaction value (Hurlbert), n= Standardized sample size, H=Shannon- index, e=Evenness

Having the same sample size (n = 100), all microhabitats in the natural forest are showing significantly higher species richness values than in the managed forest. Within one forest type the species richness between the microhabitat did not varying notably.

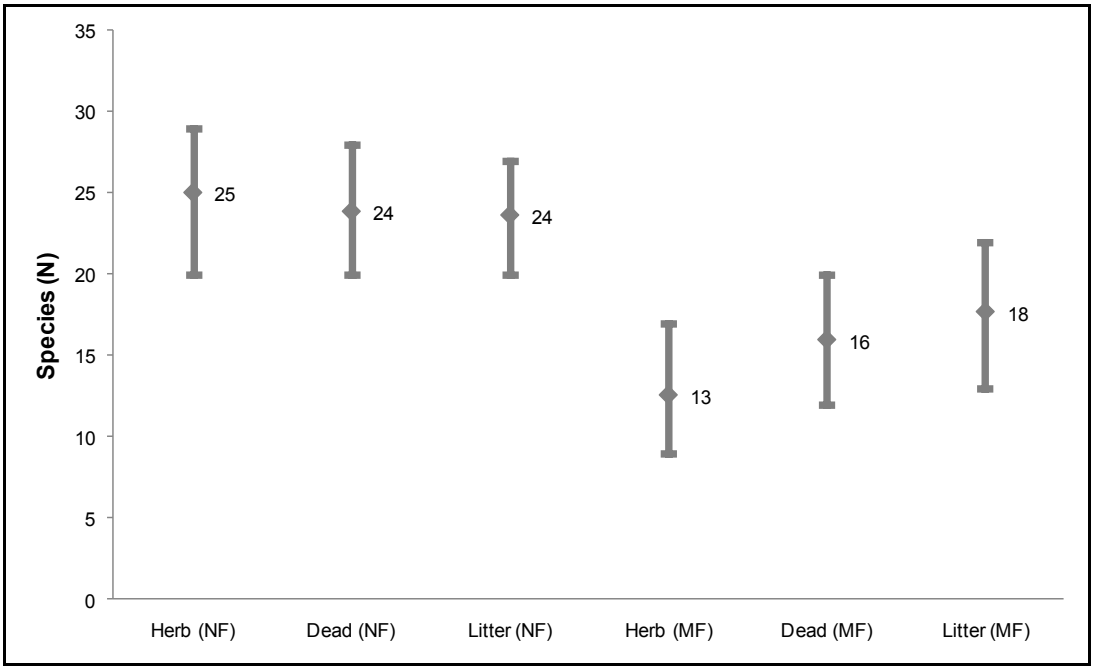


Figure 33: Comparison of mean species richness values (±95% confidence interval) at the lowest number of individuals (n = 100) derived from individuals-based species rarefaction curves of spider assemblages in the different microhabitats

3.2.10 Species correlation to environmental parameters

Numerous species are showing significant ($p < 0.05$) positive and negative correlations to environmental parameters. Using the Spearman rank correlation coefficient the canopy cover, the visible sky, the leaf area index, and the soil moisture contributed most to the distribution pattern of all spider species. Even more a mentionable number of the spiders were significantly correlated with the vegetation cover, the DBH of the trees, the variance of the humidity, as well as the amount of dead wood in different size classes (Figure 34).

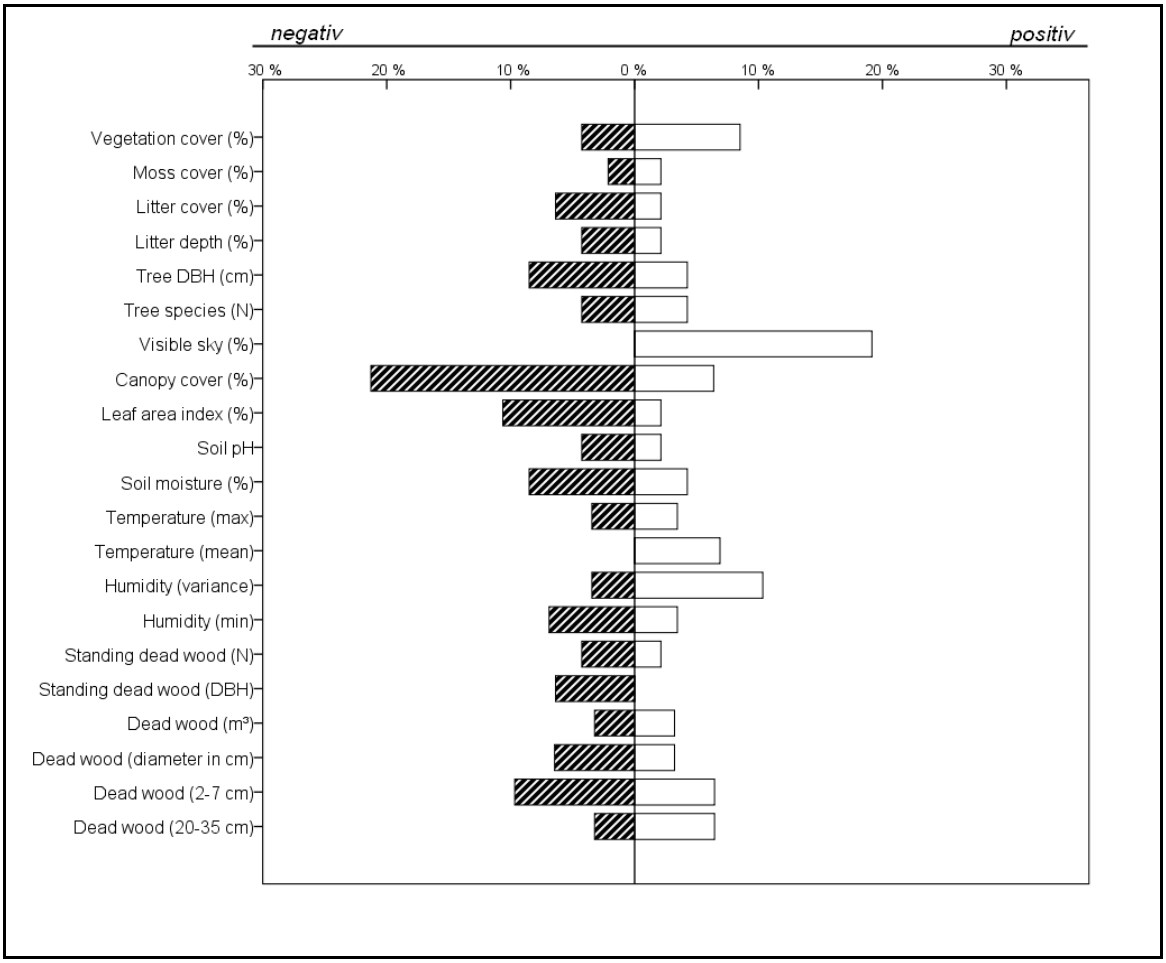


Figure 34: Environmental parameters explaining the distribution pattern of spider species: results of the Spearman rank correlations expressed as the percentage of spiders species showing significantly negative or positive correlations to the respective microhabitat factors.

3.2.11 Habitat preference of species

A non parametric *ANOVA*, testing the mean differences in spider abundance, was done between the forest types (four blocks each) and the different microhabitats. The results examining abundance of the most dominant spiders (n > 10) between the forest types indicate that the species *Pardosa lugubris-group*, *Xysticus luctator, Robertus lividus, Zelotes subterraneus* and *Troxochrus scabriculus* tended to be more abundant in the managed forest. The species *Haplodrassus soerenseni* and *Tenuiphantes flavipes* are significantly more abundant in the natural forest (Table 26).

Table 26: Results of the Mann-Whitney U-Test examining the forest preference of the most abundant spider species (>10 individuals)

Species	Abundance (N)	Percentage (%)	Adults in each forest site		Mann-Whitney-U	Significance level
			Natural forest	Managed forest		
Pardosa lugubris-group	1470	66.54594839	230	1240	144.00	***
Haplodrassus silvestris	139	6.292440018	82	57	43.50	NS
Xysticus luctator	73	3.304662743	24	49	107.50	*
Haplodrassus soerenseni	33	1.493888637	23	10	33.00	*
Panamomops mengei	42	1.901312811	19	23	73.50	NS
Tenuiphantes flavipes	30	1.358080579	24	6	29.50	*
Zora nemoralis	34	1.53915799	18	16	73.00	NS
Robertus lividus	34	1.53915799	12	22	107.00	*
Trochosa terricola	34	1.53915799	11	23	104.50	NS
Tapinocyba insecta	16	0.724309642	12	4	50.50	NS
Microneta viaria	26	1.177003169	13	13	70.00	NS
Zelotes subterraneus	32	1.448619285	3	29	116.00	**
Troxochrus scabriculus	25	1.131733816	6	19	108.50	*
Agroeca brunnea	17	0.769578995	9	8	71.00	NS
Segestria senoculata	13	0.588501584	8	5	59.00	NS
Agelena labyrinthica	24	1.086464464	8	16	86.50	NS
Walckenaeria dysderoides	22	0.995925758	9	13	83.50	NS
Walckenaeria atrotibialis	14	0.633770937	3	11	90.50	NS
Zora spinimana	12	0.543232232	6	6	75.00	NS
Gnaphosa bicolor	11	0.497962879	2	9	98.00	NS

*P<0.05; **P<0.01; ***P<0.001; NS: Not significant at the α =0.05 level

The same most abundant species were chosen to prove if they appear more often in one of the different microhabitats. The non parametric *Kruskal-Wallis* test revealed that four species are found to be significantly ($p < 0.05$) more abundant in one of the six microhabitats (Table 27). Besides being more abundant in the managed forest, the species *Pardosa lugubris-group* and *Zelotes subterraneus* show higher abundance in the microhabitat *Herb* in this forest. Although not being more present in the managed forest, *Gnaphosa bicolour* tended to prefer the *Herb* microhabitat in this

forest type. Within the natural forest *Tenuiphantes flavipes* is significantly more present in the *Herb* microhabitat. No species were found to be more present in the microhabitat *Dead wood* or *Litter*, neither in the natural nor in the managed forest. Nevertheless *Agelena labyrinthica* occurs in both forest types more often in the microhabitat *Dead wood* and *Walckenaeria dysderoides* seems to prefer the *Litter* microhabitats, especially in the managed forest.

Table 27: Results of the Kruskal Wallis test examining the microhabitat preferences of the most abundant (>10individuals) spider species (NF=Natural forest, MF=Managed forest)

Species			Adults in each structure						F- ratio	pairwise	Significance-
			Herb (NF)	Dead (NF)	Litter (NF)	Herb (MF)	Dead (MF)	Litter (MF)			
	N	%	1	2	3	4	5	6	(Kruskal Wallis)	comparison	levels
Pardosa lugubris group	1470	66.55	86	79	65	566	396	278	18.57	4 > 3	**
Haplodrassus silvestris	139	6.29	26	29	27	29	18	10	5.77	1=2=3=4=5=6	NS
Xysticus luctator	73	3.30	9	7	8	15	13	21	5.35	1=2=3=4=5=6	NS
Haplodrassus soerenseni	33	1.49	8	9	6	0	3	7	10.84	1=2=3=4=5=6	NS
Panamomops mengei	42	1.90	6	8	5	8	11	4	2.52	1=2=3=4=5=6	NS
Tenuiphantes flavipes	30	1.36	15	4	5	0	1	5	12.79	1>4,5	*
Zora nemoralis	34	1.54	5	5	8	5	6	5	0.36	1=2=3=4=5=6	NS
Robertus lividus	34	1.54	7	4	1	7	11	4	9.33	1=2=3=4=5=6	NS
Trochosa terricola	34	1.54	5	3	3	11	5	7	6.28	1=2=3=4=5=6	NS
Tapinocyba insecta	16	0.72	7	2	3	0	1	3	6.06	1=2=3=4=5=6	NS
Microneta viaria	26	1.18	7	2	4	2	7	4	3.65	1=2=3=4=5=6	NS
Zelotes subterraneus	32	1.45	0	1	2	19	7	3	10.82	4 > 1	*
Troxochrus scabriculus	25	1.13	2	3	1	5	9	5	6.17	1=2=3=4=5=6	NS
Agroeca brunnea	17	0.77	5	2	2	2	3	3	2.27	1=2=3=4=5=6	NS
Segestria senoculata	13	0.59	4	2	2	0	3	2	4.70	1=2=3=4=5=6	NS
Agelena labyrinthica	24	1.09	1	7	0	4	8	4	5.54	1=2=3=4=5=6	NS
Walckenaeria dysderoides	22	1.00	3	4	2	3	2	8	3.42	1=2=3=4=5=6	NS
Walckenaeria atrotibialis	14	0.63	3	0	0	9	1	1	9.02	1=2=3=4=5=6	NS
Zora spinimana	12	0.54	1	4	1	1	2	3	5.27	1=2=3=4=5=6	NS
Gnaphosa bicolor	11	0.50	1	0	1	6	2	1	10.08	4 > 2	*

*P<0.05; **P<0.01; ***P<0.001 (Bonferroni correction); NS: Not significant at the α =0.05 level

3.2.12 Indicator species analysis

Indicator species analysis was done to identify species that were strongly associated with either one of the forest types or one of the structures. *Macragus rufus*, *Tenuiphantes flavipes* and *Haplodrassus soerenseni* were found to be significantly more abundant in the natural forest and are therefore indicator species for this forest type (Table 28). These three species are typical forest spiders. In contrast to the natural forest more species were identified to be strongly associated with the managed forest. In particular *Pardosa lugubris-group, Zelotes subterraneus*, *Robertus lividus*, *Trochosa terricola*, *Troxochrus scabriculus, Phrurolithus festivus and Ozyptila praticola* had higher abundance values within this forest type. These

species are found in dry forest areas, but two of them namely *Troxochrus scabriculus* and *Phrurolithus festivus* are typical woodless area species.

Table 28: Results of the indicator analyses showing the association values of different species to one of the forest types

Species	Association value	
	Natural forest	Managed forest
Pardosa lugubris- group		0.91***
Zelotes subterraneus		0.82**
Robertus lividus		0.80*
Trochosa terricola		0.78*
Troxochrus scabriculus		0.75*
Phrurolithus festivus		0.70*
Ozyptila praticola		0.64*
Tenuiphantes flavipes	0.82 **	
Haplodrassus soerenseni	0.80 *	
Macrargus rufus	0.65 *	

*P<0.05; **P<0.01; ***P<0.001

Indicator species within the different structures were found for the microhabitat *Herb* in both forest types whereas for the *Dead wood* microhabitat indicator species were only observed for the natural forest (Table 29). *Tenuiphantes flavipes* was associated with the *Herb* microhabitat in the natural forest and *Zelotes subterraneus, Gnaphosa bicolor and Pardosa lugubris-group* were significantly more abundant within the same microhabitat but in the managed forest. The only indicator species, associated with the microhabitat *Dead wood*, was *Anguliphantes angulipalpis* within the natural forest.

Table 29: Results of the indicator analyses showing the association values of different species to one of the forest types

Species	Association value					
	Herb (NF)	Dead (NF)	Litter (NF)	Herb (MF)	Dead (MF)	Litter (M)
Anguliphantes angulipalpis		0.86 *				
Tenuiphantes flavipes	0.71 *					
Zelotes subterraneus				0.77*		
Gnaphosa bicolor				0.74*		
Pardosa lugubris-group				0.62 *		

*P<0.05; **P<0.01; ***P<0.001

3.2.13 TWINSPAN

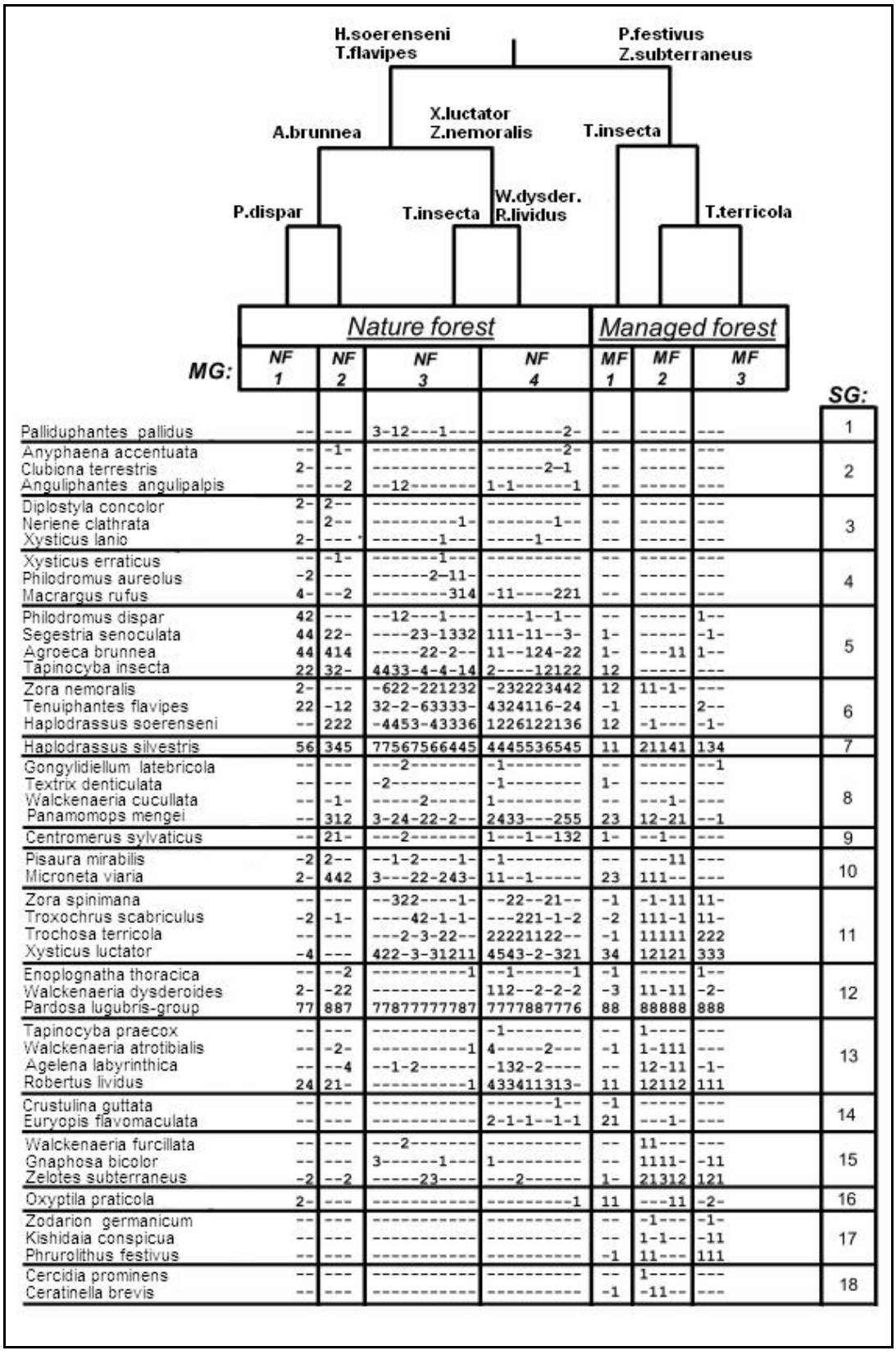
The TWINSPAN classification separated seven microhabitat groupings *(MG)* and 18 species groupings *(SG).* Although some species occurred in more than one microhabitat grouping or were widespread like *Pardosa lugubris-group (SG 12)* and *Haplodrassus silvestris (SG 7),* the species composition of the microhabitat grouping was clearly separated from each other (Figure 35).

The classification of microhabitat groupings was clearly separated by the forest type.

All traps of the natural forest were arranged on the left side in four microhabitat groupings *(NF1-4)*. Almost all traps of the managed forest were grouped on the right side *(MF1-MF3)* except two traps which were arranged in the microhabitat grouping *NF4* within the natural forest.

In the first division the analysis separated microhabitat groupings *MF1-MF3* (managed forest) from the first four microhabitats, which were the pitfall traps from the natural forest. The separation was mainly due to the absence of the species of the microhabitats one to four in the managed forest, as well as the mostly exclusive presence of species of the microhabitat grouping 16 to 18 in the managed forest. Several of the species missing in the managed forest prefer mesophile habitat conditions like *Diplostyla* concolor and *Palliduphantes pallidus*.

In the second division of the natural forest microhabitat groupings one and two were separated from the microhabitats three and four. The separation was due to the absence of most of the species of microhabitat 11 in the *TWINPAN* groupings *NF1* and *NF2*. Moreover, the species of the microhabitat grouping six were more dominant in the groupings *NF3* and *NF4*. These species e.g. *Zora nemoralis* and *Haplodrassus soerenseni* prefer dry habitat conditions. The separation of the microhabitat grouping *MF1* in the second division from the groupings *MF2* and *MF3* in the managed forest was mainly characterized through differences in the species groups five, six and seven. Moreover the species *Tapinocyba insecta* was only found in the species group *MF1* when comparing *MF1-MF3*.



Palliduphantes pallidus	--	---	3-12---1---	--------2-	--	-----	---	1
Anyphaena accentuata	--	-1-	----------	--------2-	--	-----	---	2
Clubiona terrestris	2-	---	----------	------2--1	--	-----	---	
Anguliphantes angulipalpis	--	--2	--12-------	1-1------1	--	-----	---	
Diplostyla concolor	2-	2--	----------	----------	--	-----	---	3
Neriene clathrata	--	2--	---------1-	-------1--	--	-----	---	
Xysticus lanio	2-	---	-------1---	-----1----	--	-----	---	
Xysticus erraticus	--	-1-	-------1---	----------	--	-----	---	4
Philodromus aureolus	-2	---	------2--11-	----------	--	-----	---	
Macrargus rufus	4-	--2	--------314	-11----221	--	-----	---	
Philodromus dispar	42	---	--12---1---	----1--1--	--	-----	1--	5
Segestria senoculata	44	22-	----23-1332	111-11--3-	1-	-----	-1-	
Agroeca brunnea	44	414	-----22-2--	11--124-22	1-	---11	1--	
Tapinocyba insecta	22	32-	4433-4-4-14	2----12122	12	-----	---	
Zora nemoralis	2-	---	-622-221232	-232223442	12	11-1-	---	6
Tenuiphantes flavipes	22	-12	32-2-63333-	4324116-24	-1	-----	2--	
Haplodrassus soerenseni	--	222	-4453-43336	1226122136	12	-1---	-1-	
Haplodrassus silvestris	56	345	77567566445	4445536545	11	21141	134	7
Gongylidiellum latebricola	--	---	---2-------	-1--------	--	-----	--1	8
Textrix denticulata	--	---	-2---------	-1--------	1-	-----	---	
Walckenaeria cucullata	--	-1-	-----2-----	1---------	--	---1-	---	
Panamomops mengei	--	312	3-24-22-2--	2433---255	23	12-21	--1	
Centromerus sylvaticus	--	21-	---2-------	1---1--132	1-	--1--	---	9
Pisaura mirabilis	-2	2--	--1-2----1-	-1--------	--	---11	---	10
Microneta viaria	2-	442	3---22-243-	11--1-----	23	111--	---	
Zora spinimana	--	---	--322----1-	--22--21--	-1	-1-11	11-	11
Troxochrus scabriculus	-2	-1-	----42-1-1-	---221-1-2	-2	111-1	11-	
Trochosa terricola	--	---	---2-3-22--	22221122--	-1	11111	222	
Xysticus luctator	-4	---	422-3-31211	4543-2-321	34	12121	333	
Enoplognatha thoracica	--	--2	----------1	--1------1	-1	-----	1--	12
Walckenaeria dysderoides	2-	-22	----------	112--2-2-2	-3	11-11	-2-	
Pardosa lugubris-group	77	887	77877777787	7777887776	88	88888	888	
Tapinocyba praecox	--	---	----------	-1--------	--	1----	---	13
Walckenaeria atrotibialis	--	-2-	----------1	4-----2---	-1	1-111	---	
Agelena labyrinthica	--	--4	--1-2------	-132-2----	--	12-11	-1-	
Robertus lividus	24	21-	----------1	433411313-	11	12112	111	
Crustulina guttata	--	---	----------	-------1--	-1	-----	---	14
Euryopis flavomaculata	--	---	----------	2-1-1--1-1	21	---1-	---	
Walckenaeria furcillata	--	---	---2-------	----------	--	11---	---	15
Gnaphosa bicolor	--	---	3------1---	1---------	--	1111-	-11	
Zelotes subterraneus	-2	--2	-----23----	---2------	1-	21312	121	
Oxyptila praticola	2-	---	----------	---------1	11	---11	-2-	16
Zodarion germanicum	--	---	----------	----------	--	-1---	-1-	17
Kishidaia conspicua	--	---	----------	----------	--	1-1--	-11	
Phrurolithus festivus	--	---	----------	----------	-1	11---	111	
Cercidia prominens	--	---	----------	----------	--	1----	---	18
Ceratinella brevis	--	---	----------	----------	-1	-11--	---	

Figure 35: TWINSPAN classification of spider assemblages for the study area. Character species for the different groups are displayed, The relative frequency of each species is indicated by numbers from 1 to 8 (1= 0-1.9%,2=2-3.9%,3=4-5.9%,4=6-9.9%,5=10-14.9%,6=15-24.9%,7=25-44.9%,8 ≥ 45%), MG=microhabitat grouping, *SG*=species groupings

In the last division, within the natural forest, the microhabitat grouping one *(NF1)* was separated from the second *(NF2)* because of deviating pattern in the species composition within the species groups five, eight and nine. The character species of the microhabitat grouping one *Philodromus dispar* is not present in the microhabitat grouping *NF2*. Moreover in the natural forest the group *NF3* is separated from *NF4* resulting from different species compositions within the species groupings 12 and 13. *Walckenaeria dysderoides* is not present in *NF3* and *Robertus lividus* is more present in *NF4*, compared to *NF3*. Within the managed forest the group *MF2* was separated from *MF3* in the last division of this microhabitat cluster mainly due to differences in species groups ten and 11. *Trochosa terricola,* preferring dry forest, areas is the character species of the microhabitat grouping *MF3* and is less presented in the group *MF2*.

3.2.14 Discriminant analysis

A forward stepwise discriminant analyses was examined and significant environmental parameters were revealed explaining the arrangement of the Twinspan microhabitat grouping (Figure 36).

For the first division which separates the natural forest (*NF1-NF4*) from the managed forest *(MF1-MF3)* the significant variables were the degree of canopy closure ($F = 84.376$, $p < 0.0001$), the maximum temperature ($F = 54.711$, $p < 0.0001$) and the mean temperature ($F = 37.297$, $p < 0.0001$). There is a gradient of these variables with the canopy closure decreasing from microhabitat group *NF1* to microhabitat group *MF3*. The maximum temperature, the mean temperature and the visible sky are increasing from the first microhabitat group *NF1* to the last microhabitat group *MF3* (see Figure 37 and 38).

Discriminant variables in the second division of the natural forest were the plant diversity ($F = 5.82$, $p < 0.01$), the canopy closure ($F = 5.55$, $p < 0.05$), the mean diameter at breast height ($F = 5.08$, $p < 0.05$), the amount of dead wood (class five) ($F = 5.19$, $p < 0.05$), and the maximum temperature ($F = 8.12$, $p < 0.05$). The managed forest was separated in the second division due to the significant

discriminating variables standing dead wood (F = 13.33, p < 0.01) and the mean diameter at breast height (F = 6.18, p < 0.05).

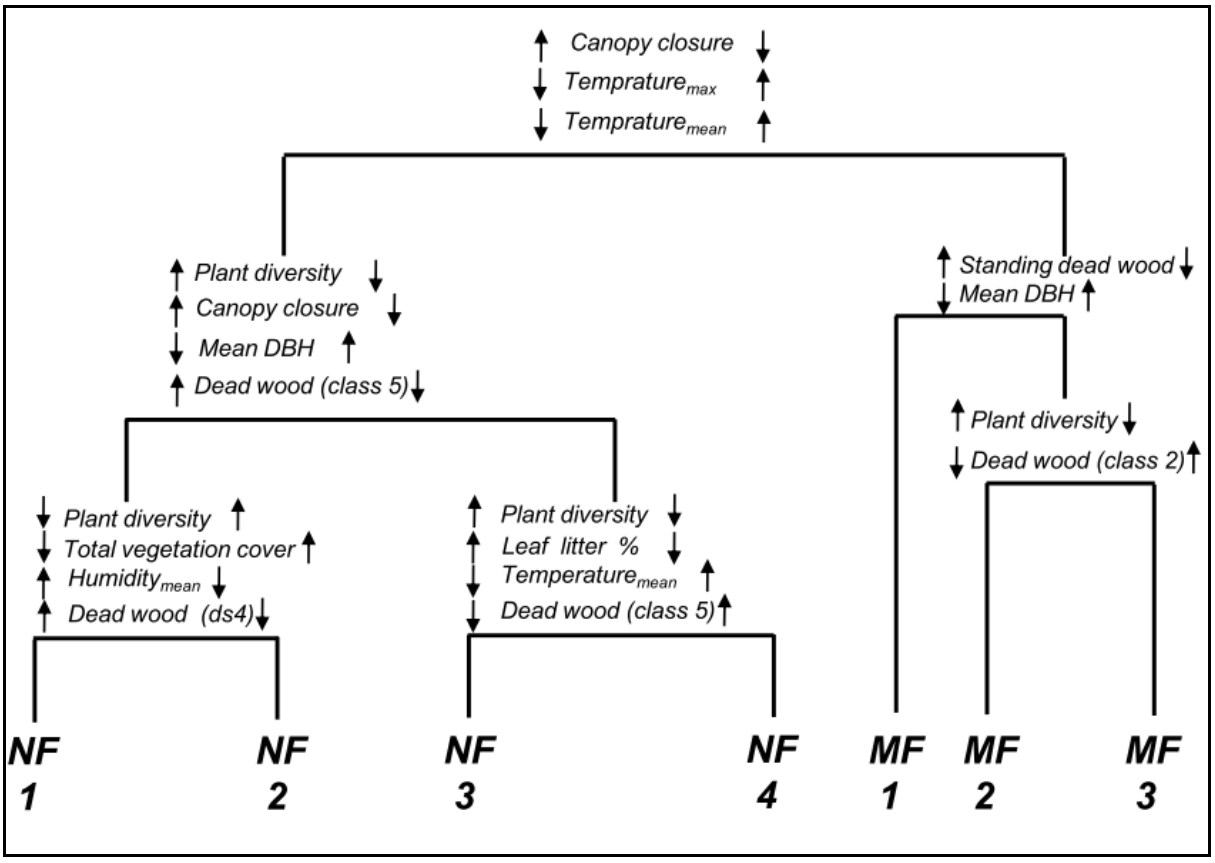


Figure 36: Structure of the TWINSPAN analyses showing the discriminating environmental parameters determined the discriminant analyses

Table 30: Mean values of the environmental variables for the seven TWINSPAN groupings

	Natural Forest				Managed forest		
	NF1	*NF2*	*NF3*	*NF4*	*MF1*	*MF2*	*MF3*
Total Vegetation (%)	17.13	34.13	27.45	30.95	27.19	45.65	36.75
Moss and Lichen (%)	7.00	8.67	5.05	7.05	10.75	5.90	4.83
Plant diversity (N)	6.75	11.67	8.91	7.30	5.50	8.50	5.67
Leaf Litter (%)	79.63	63.71	69.00	65.25	66.06	49.35	59.75
Visible mineral soil (%)	3.25	2.17	3.55	3.80	6.75	5.00	3.50
Depth of the leaf litter (cm)	1.75	2.08	1.93	2.13	1.88	1.85	1.92
Canopy cover (%)	72.50	65.00	64.32	59.25	42.50	33.50	36.67
Mean DBH (cm)	15.29	18.41	22.63	21.10	15.34	18.80	18.75
Standing dead wood (N)	2.88	3.53	1.05	0.80	1.50	0.30	0.17
Soil moisture (%)	30.31	25.34	27.56	30.90	31.94	26.65	31.66
pH- value	3.44	3.57	3.63	3.51	3.71	3.57	3.49
Visible sky	0.15	0.16	0.16	0.16	0.17	0.17	0.17
$Temperature_{mean}$ (°C)	18.09	18.05	18.06	18.40	18.72	18.69	18.77
$Temperature_{max}$ (°C)	31.32	31.12	31.53	31.79	33.22	33.27	33.51
$Humidity_{mean}$ (%)	82.43	74.70	74.18	73.78	74.28	73.66	72.24
Dead wood per hectare (m^3)	24.48	17.35	8.74	18.76	16.09	18.23	10.77

In the first final partition, variables which separated the microhabitat *NF1* from the microhabitat *NF2*, were the plant diversity ($F = 22.95$, $p < 0.05$), the total vegetation cover ($F = 217.98$, $p < 0.01$), the mean humidity ($F = 35.46$, $p < 0.05$) and the amount of dead wood of the decomposition stage four ($F = 282.29$, $p < 0.05$). The plant diversity ($F = 4.91$, $p < 0.05$), the percentage of leaf litter ($F = 6.39$, $p < 0.01$), the mean temperature ($F = 9.27$, $p < 0.05$) and the amount of dead wood of the class five ($F = 185.82$, $p < 0.0001$) separated the microhabitat *NF3* from the microhabitat *NF4* within the natural forest. The final partition in the managed forest was due to the discriminating variables plant diversity ($F = 7.13$, $p < 0.05$) and the amount of dead wood of the class two ($F = 9.15$, $p < 0.05$). The mean values of the most important discriminating variables are presented in Table 30.

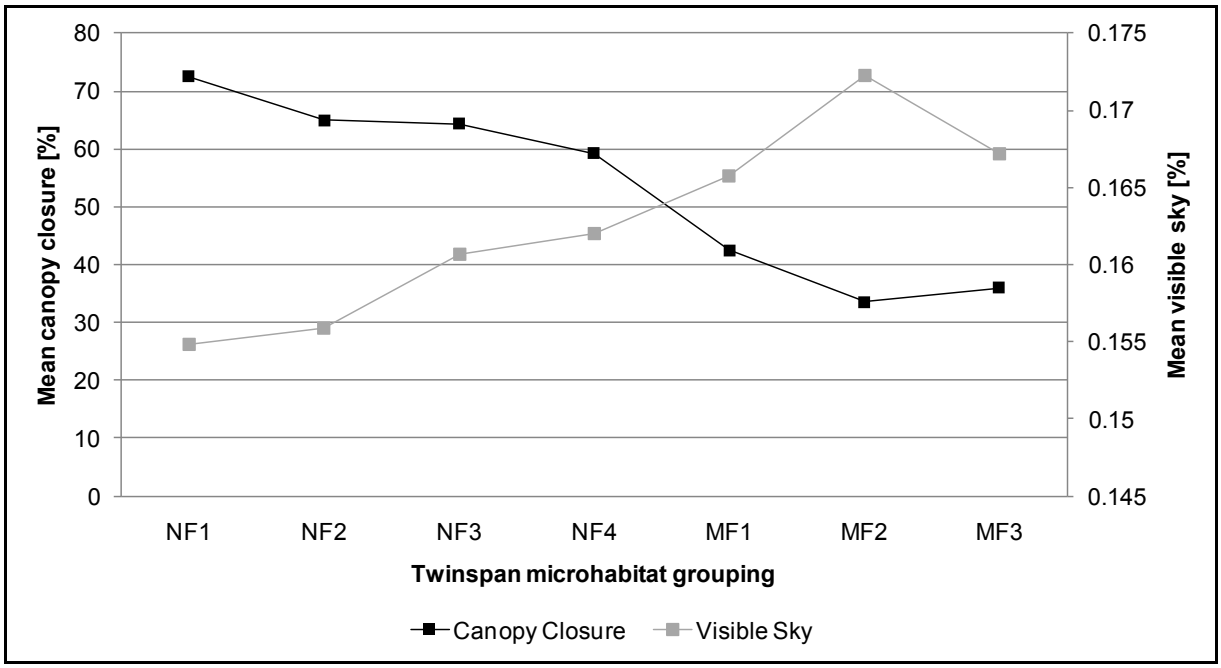


Figure 37: Changing of the canopy closure as well as the visible sky from the microhabitat grouping *NF1* to the microhabitat grouping *MF3* from the TWINSPAN analyses

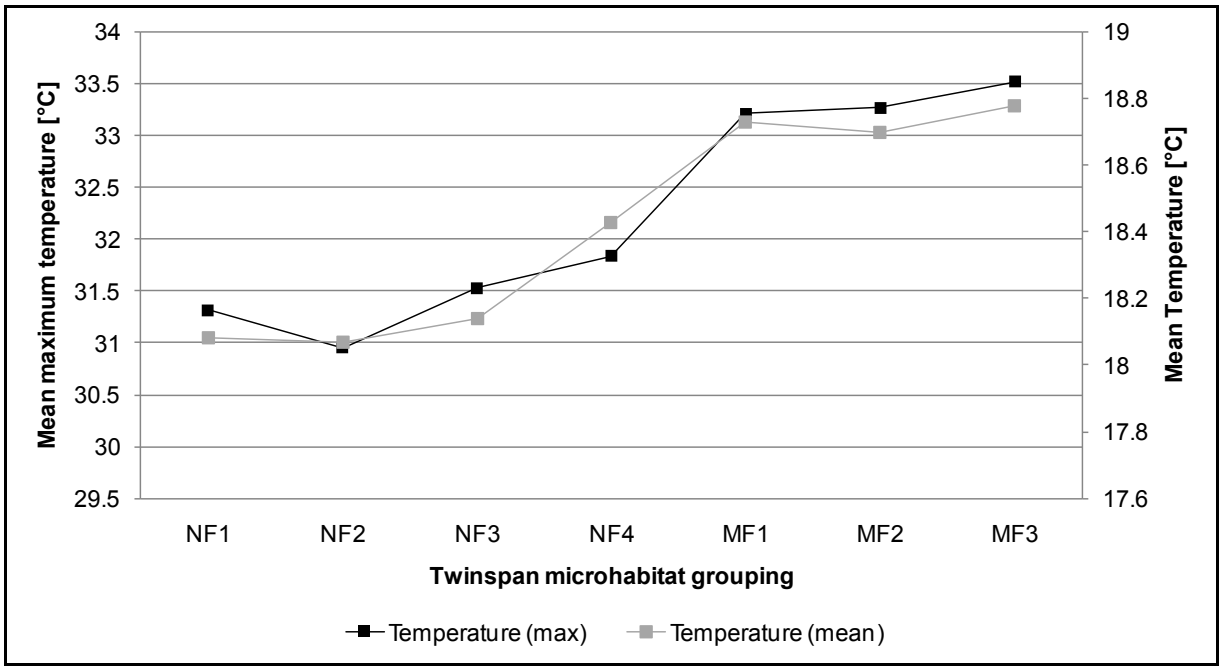


Figure 38: Gradient of the increasing temperature variables from *NF1* to *MF3* from the TWINSPAN analyses

3.2.15 RDA analysis

The multivariate analyses revealed a distinct distribution pattern of species and forest types (Figure 39). The redundant analyses resulted in a good separation of microhabitats and corresponded mostly with results of the *TWINSPAN* analyses. Thus, microhabitats were arranged mainly according to the forest type. Together the first four axes explained 76.2% of the correlations between species and environmental factors chosen in the RDA (Figure 39). The first axis was mainly related to the parameter visible sky, mean temperature and vegetation diversity, the second axis to soil moisture, litter depth and the mean diameter at breast height (Table 31). Thus, the first axis separated the natural forest (*NF1-NF4*) from the managed forest (*MF1-MF3*), with visible sky and the mean temperature increasing towards the managed forest. Otherwise, the plant diversity is increasing towards the natural forest. Along the second axis microhabitats with different values of soil moisture, litter depth, mean diameter at breast height and vegetation coverage was separated. Thus, microhabitats with a high ground vegetation cover in percent and low soil moisture are found in the lower right side.

Regarding species distribution two groups were obvious. At both right quadrants species which are common in forested as well woodless areas are aggregated. The only exception is *Walckenaeria dysderoides*, which is a typical forest spider, and was found within this group. Within the left quadrant typical forest spiders are aggregated, among a few exceptions of spiders which are common in forests as well woodless areas.

Table 31: Impact strength of environmental variables selected by unrestricted permutation (single and cumulative out of the forward stepwise analysis) in the RDA

	Explained variance (%)			Correlation coefficients			
	Single	Cumulative	p-value	Axis 1	Axis 2	Axis 3	Axis 4
Mean Temperature	0.08	0.08	<0.0002	**0.754**	-0.061	-0.259	0.042
Soil moisture	0.04	0.12	<0.01	-0.026	**0.574**	0.215	0.198
Visible Sky	0.04	0.16	<0.02	**0.588**	0.239	0.067	-0.122
Litter depth	0.04	0.20	<0.05	-0.041	**0.491**	-0.302	-0.318
Plant diversity	0.04	0.24	<0.08	**-0.374**	-0.173	-0.386	0.273
Moss cover	0.03	0.27	<0.10	-0.155	0.121	**-0.450**	-0.116
Mean DBH	0.03	0.30	<0.25	-0.035	**0.260**	0.441	0.467

Table 32: Species environmental coefficients for the first four axes obtained by the RDA

	Axis			
	1	2	3	4
Correlation coefficients				
RDA	**0.809**	**0.852**	**0.875**	**0.805**

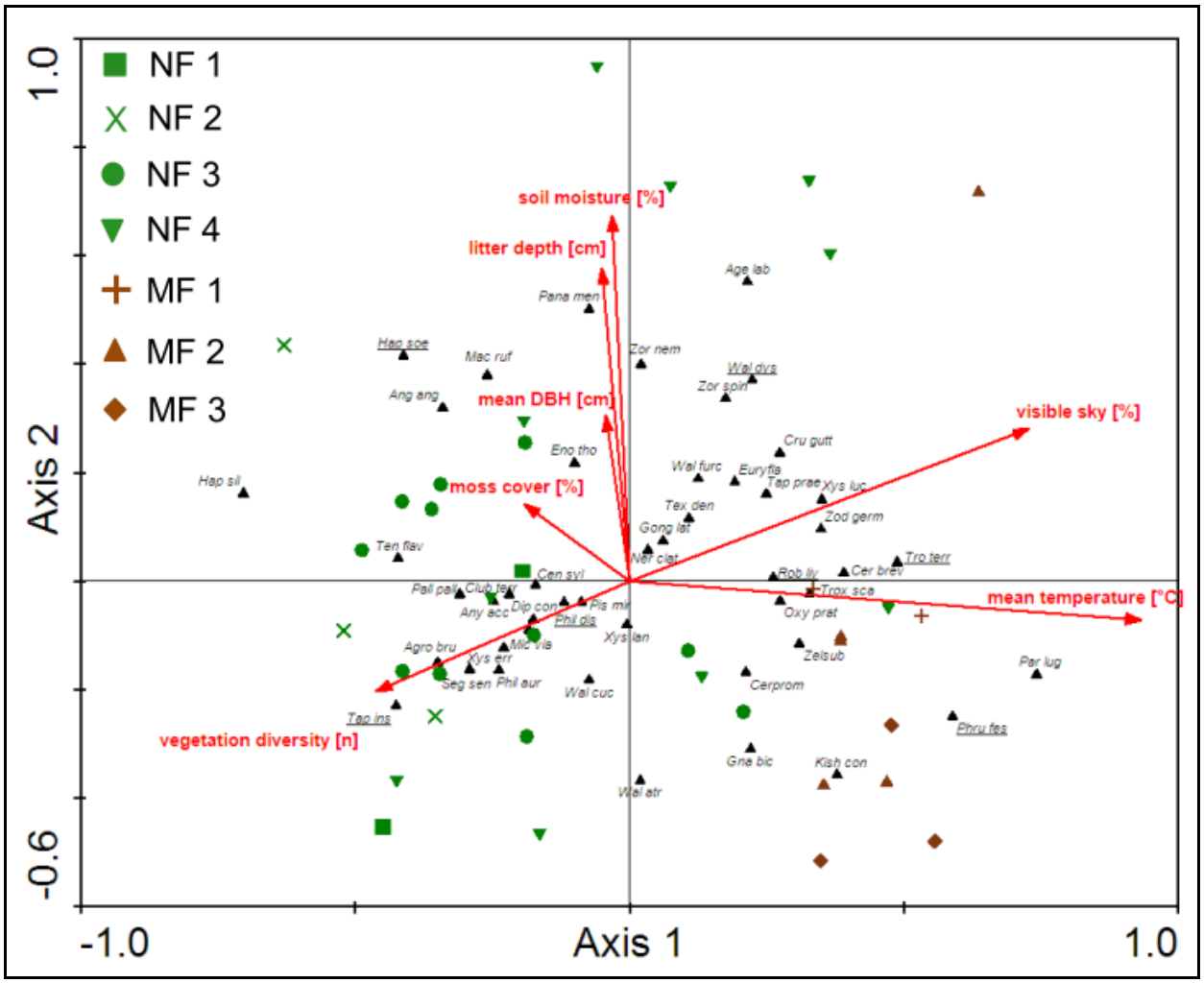


Figure 39: RDA ordination fur the study area. Species are represented as points, environmental variables as arrows, the microhabitat groupings defined by the TWINPAN are indicated as different symbols (legend above left), the character species are underlined

4 Discussion

4.1 Relevance

Considering the potential natural forest community, oaks (*Quercus petraea*, *Quercus robur*) would be, the second most important deciduous tree species, beside beeches (*Fagus sylvatica*), in the northeast German plain (BfN, 2007). Studies on predicted climate change are assuming that the potential natural distribution area of mixed oak forests (as the main forest stage) will increase in *East Germany* in the future (Hofmann, 1997). Most of the northeast German oak forests are managed. Extensive decomposition and advanced aging stages are not existing (BfN, 2007). Depending on the age of the oak trees, they are providing a high structural diversity, which could lead to many reaction processes and autocorrelations. However, both reaction processes and autocorrelations are not acceptably reviewed yet (BfN, 2007). Therefore, the investigation of strict forest reserves is increasingly important to enhance the knowledge within this field. This thesis concentrates on the comparison of a strict oak forest reserve and a managed oak forest in the state of Brandenburg, with respect to the consequences of forest management as well as small-scale heterogeneity to the biodiversity. The SFR is excluded from management for more than sixty years, and former influence of management on the biodiversity can be therefore estimated as very low. The impact of forest management on the potential natural biodiversity was assessed by using the epigeal spider assemblages of both forest types. Moreover, the influence of small scale heterogeneity on the spider community was investigated.

4.2 Criticism of the tools

Pitfall traps are widely used in ecological studies of the epigeal fauna. They are a permanent and easy to use method to collect a high number of individuals, independent from the weather conditions (Mühlenberg, 1993). Moreover, this method has no subjective errors, is independent from the fortune of the collector and can be used at the same time in different habitats.

Nevertheless, the result is influenced by certain factors and the use of pitfall traps was occasionally criticised (e.g. Topping & Sunderland, 1992). Instead of the effective frequency, for instance, the activity density will be measured and therefore the ratio of the catch depends on the activity of the individuals as well as on the population size. Additionally, the activity within a certain species can be influenced by gender as well as weather or seasonal aspects. Huhta (1971) stated that pitfall traps rather capture wandering spiders (*Lycosidae)* than web-building spiders like *Linyphiidae*. The immediate surroundings of the traps and the size of the gap between soil and trap are further influencing variables (Blick, 2009), which makes it necessary to control the trap casually. Due to the limited time frame, the epigeal fauna was sampled for a total of eight weeks from 25th of May till 20th of July 2010. According to Riecken (1999), investigations with pitfall traps should be done over the entire vegetation period in order to get an adequate and meaningful pattern of the epigeal spider community within a certain area. Therefore, species having their maximum of activity early in the vegetation period and later than mid of July could be underrepresented in this study. Anyway, pitfall traps seemed to be the most applicable and widely used sample method, and showed meaningful results in this study. However, due to the remoteness of the study area the pitfall traps could only be cleared every four weeks. Particularly the dung beetles (*Geotrupidae*) were attracted by the traps which ended up in overcrowded traps in a very few cases. This might have influenced the sampling result, and could have been avoided by shorter clearance periods. Another challenge occurred with respect to the sampling of the different microhabitats. It could not be avoided, that e.g. in the *Litter* microhabitat sporadic vegetation was found. Even more it was impossible, that dead wood was absolutely absent in other microhabitats than the *Dead wood* microhabitat. Together with the short sampling period, this could explain the very few found species which were associated with a certain microhabitat.

4.3 Amount of individuals and spectrum of species

A total number of 4,620 individuals were captured in the study period. Thereof, 2,791 individuals were adults and could therefore be identified up to the species level. Significantly more individuals were found in the managed forest, mainly due to the high number of individuals of the *Pardosa lugubis-group*. Overall a total number of 68 species, out of 22 families, was found in the study area, with 57 species occurring in the natural forest (24 unique species) and 44 (11 unique species) in the managed forest. In *Germany* 992 species are recorded so far (Blick et al., in preparation, status December 2007 as cited in Blick, 2009) and in the *State of Brandenburg* about 560 species are already described (Sacher, 1992). Thus, 12.5% of the spiders occurring in the state of *Brandenburg* were captured in this study. The total number of reordered species (n = 68) is barely comparable with other studies of the epigeal spider assemblages, due to the different study design (e.g. number of pitfall traps, more diverse trap systems), different investigation time periods. Generally, the number of species identified is lower than in other studies, where more than 100 species in mostly forested areas were found (Chumak *et al.*, 2005; Hsieh *et al.*, 2003; Pearce *et al.*, 2004; Hore & Uniyal, 2008). In 2007, the epigeal spider community within the strict forest reserve *Fünfeichen* was already analyzed and 61 species were found (BfN, 2007). The study, however, only considered the strict forest reserve, and excluded the managed forest. The most species (n = 29) within this investigation were found in the family of the *Linyphiidae*, which is supported by other studies determining spider diversity in different forest types (e.g. Jiang & Li, 2006; Hsieh *et al.*, 2003). Seven species were present on the *Red list of Germany* (Binot *et al.*, 1998), the *Red list of the state of Brandenburg* (Platen *et al.*, 1999) or were even present at both lists.

(Scharff *et al.*, 2003) recommend using the estimator CHAO1 for measuring/ estimating/ determining inventory completeness values, whereas completeness is the ratio between observed and estimated richness. According to the results given by this estimator, this inventory was not complete, neither in the natural forest nor in the managed forest. There are at least 30% more species expected in the natural forest and 20% more in the managed forest. Examining the whole vegetation period together with using different trap systems (e.g. log-eclectors)

assumedly would increase the inventory completeness value. Nevertheless, the completeness values utilized here, provided a sufficient thorough sample of the study area, allowing for an accurate comparison of the fauna of both forest types and of the different microhabitats.

4.4 Comparison of the forest types

In both forest types the Pardosa lugubris-group was eudominant (>32%), but within the managed forest the dominance of this species was exorbitant high (>75%). Therefore only two species are belonging to the main species (>3.2%) in the managed forest, whereas in the natural forest six species were part of the main species. The main species normally comprises of 85% of the collected individuals (Engelmann, 1978), which was not the case in both forest types. According to Stöcker & Bergmann (1977), the highly competitive main species are characterized as leading organisms and therefore describing the ecosystem. Due to very high dominance values of one species in the managed forest, and therefore a one-sided dominated species distribution, the habitat can be considered as disturbed (Bonn *et al.*, 1997). The high dominance of the eurytopic species *Pardosa lugubris-group*, especially in the managed forest, can partly be explained by the high activity of the male adults, who are sexually mature at the beginning of the growing season and trying to reproduce (Höfer *et al.*, 2010). Being a typical forest spider (Heimer & Nentwig, 1991) the *Pardosa lugubris-group* made up almost 76% of all individuals in the managed forest. According to Riecken (2000) this species can have extremely different activity densities caused by clearings, even in the same forest habitat. The main species in the natural forest are all typical forest spiders, and their relative abundance within the managed forest is reduced to <3.2%. They are therefore grouped as secondary species because the Pardosa lugubris-group is extremely dominant. It can, however, also be assumed that the preconditions of the habitat for typical forest spiders are not fully met within the managed forest. Categorized through a relative frequency of <3.2%, the amplitude of the ecological niche of secondary species is limited, and they respond particularly distinctive to disturbances and are therefore often indicative species (Schliemann, 2007). This could be observed in the managed forest were some of the rezedent (>1%)

secondary species of the natural forest (typical forest spiders like *Macrargus rufus*) disappeared or the activity density was clearly reduced such as for *Tapinocyba insecta*. Within the managed forest, the group of the rezedent secondary species consist of an increased number of the xerophilous species *Troxochrus scabriculus* or the eurytopic species *Robertus lividus*. Moreover, the eurytopic species *Zelotes subterraneus*, preferring dry forest or open areas, was part of the rezedent secondary species with 29 individuals in the managed forest while in the natural forest it only occurred with three individuals. Nevertheless, previous information's can also be ascribed to the fact that the probability of trapping a species depends on the individual and species-specific level of activity (Schliemann, 2007).

The four dominance indices *(JACCARD, SØRENSEN, RENKONEN* and *WAINSTEIN*) were used to analyse the community structure of the species. Due to the considerably different number of individuals between both forest types, the *WAINSTEIN* index is used to discuss the similarity results, since this index considers the number of individuals. With slightly more than 30% the similarity and dominance of the spider assemblages between both forest types is small and was proven to be significantly different. Beside the existence of exclusive species in both forest types, the significant different numbers of individuals is responsible for the low Wainstein similarity index value. The higher numbers of individuals results from the demanded activity density of the eurytopic *Pardosa lugubris-group* within the managed forest. Many of the species, which are unique in the natural forest (n = 27), were typical forest spiders. On the other hand, the species which were exclusive in the managed forest (n = 10) were mostly species inhabiting open areas or forests. For example the species *Phrurolithus festivus*, which is an element of xerothermous habitats (Bauchhenss, 1990) was exclusively found in the managed forest. Both forest types vary in many abiotic and biotic conditions, while many of them, in turn, are affected by the degree of the canopy closure like the temperature and the humidity. The results of this study are supported by the findings of Ziesche & Roth (2008) that the canopy cover influences the small-scale regime of climatic conditions on the forest floor. Thus, the mean temperature at the forest floor rises, while the mean humidity decreases. Due to the higher decomposition rate the litter depth was reduced within the managed forest. Nevertheless, coverage of ground vegetation was higher. Therefore, thinning activities resulted in habitat alteration and changed the

composition of the spider community, which is also supported by other studies (Pearce *et al.*, 2004; Oxbrough *et al.*, 2005; Ziesche & Roth, 2008). A more profound discussion of influencing variables to the spider community will be followed in the discussion of the causal analytical analysis.

The total number of species differed between the natural and the managed forest with 60 and 43 species respectively. Studies determining the arthropod diversity between natural forests and managed forests are still rare and show heterogeneous results in terms of species richness. Whereas Blick (2009) for instance found more species in a nature reserve, compared to a reference surface in the *Federal state Hessen*, several others found more species in managed forest respectively the reference surface (Chumak *et al.*, 2005; Dorow *et al.*, 2001, 1999; Dorow & Kopelke, 2007). Using rarefaction (n = 100 individuals), due to a big imbalance of the number of individuals between the forest types, all blocks in the natural forest revealed significantly higher species numbers and diversity indices. The different diversity indices suggest that the community structure of both forest types is quite different. While the natural forest consist of several main species, numerous rare species and many unique species, the managed forest only consist of two main species, numerous rare species and a lower number of unique species. Thus, lower species numbers and greatly unbalanced dominance structure resulted in lower diversity indices in the managed forest. There is statistical evidence that habitats exhibiting a high level of spatial heterogeneity are associated with a high species richness of spiders (Greenstone, 1984; Doebel *et al.*, 1990; Gunnarsson, 1992) and lower spider species diversity are characteristics of areas receiving a high level of disturbance like forestry activities (Pettersson, 1996). However, the number of species, or the diversity indices of a certain area, did not have any qualitative information value without considering the ecological differentiation of the proven species (Riecken, 1992). For instance Pospischil (1982) mentioned that the decline of a species can be covered through an increase of another species, and a special and extraordinary species community might change more and more to a common species community with widespread species. Thus, qualitative comparison of coenosises of investigated structures can only be done when considering ecological requirements of the species.

Ecological needs were analysed using the guild composition (Gertsch, 1979) as well as the ecological typification of the spiders (Platen *et al.*, 1999). Whereas the guild composition was significantly different between the natural and the managed forest, the ecological classification was not. The massive activity density of the *Pardosa lugubris-group* (*Lycosidae*) is responsible for the increase of wandering-active spiders in the managed forest, due to the fact that other families of this guild, like the *Gnaphosidae*, are less active in the managed forest. The high activity of *Pardosa lugubris-group* was already discussed above. A reason for the lower activity of the family of the *Gnaphosidae* could be the structure of the litter. According to Uetz (1991), *Gnaphosidae*, which are known to forage in a less active manner, or even occupy hidden retreats, are more common in deeper or more complex litter. Due to a higher decomposition rate in the managed forest, the litter is more compact than in the natural forest and thus not as deep and complex. This would also explain the smaller amount of web-sheet spider families in the managed forest, which mainly consists of the family *Linyphiidae* in this study. Web-building spiders, such as the *Linyphiidae*, require a three-dimensional structure for web attachment and are generally more common in complex leaf litter (Bultman & Uetz, 1984). Although there is no significant difference with respect to the ecological typification, a few aspects should be considered. In both forest types, characteristic forest spiders for acid soil mixed forests are the most dominant ecological type *((x) w)*. The second ecological type characterised species of forest as well as open areas. Similar values were observed when comparing the ratio of ecological types with other studies (Blick, 2009; Dorow & Kopelke, 2007) where typical forest spider made up the majority of different ecological types. Alike in this investigation, they did not observed huge differences, in terms of the ecological type, between the strict forest reserve and the reference area.

The associations of species was analysed by two methods, namely *ANOVA* and *Indicator species analysis*. Considering the indicator analysis, seven species were associated with the managed forest and three species with the natural forest. Being associated with the managed forest, *Pardosa lugubris-group* is characterized by Heimer & Hiebsch (1982) as a photophil species of mesophilic mix forests. Furthermore Baehr (1985) stated that this species prefers high temperature and light intensity. Especially the females are trying to conserve a high temperature within their

cocoons by exposing themselves to the direct sun (Hasselberg, 1979 as cited in Sührig, 1996).

The significantly higher number of individuals, especially females, found in the managed forest in the scope of this study, supports the characterization as photophil. The species *Zelotes subterraneus* was characterized by Loch (2002) as a euryoecious species without preferred habitat conditions, but best matches the description of Dumpert & Platen (1985), who characterized this species as thermophilous. *Robertus lividus* is characterized by Loch (2002) as a species of open areas. This can also be approved by the results of this study, showing that this species is associated with the managed forest, which is generally characterized as more open. Opposed to this study Loch (2002) described *Ozyptila praticola* as a species of humid forest, whereas in this study it was a unique species of the managed forest. Nevertheless, in the managed forest the species was more abundant in the *Litter* microhabitats, characterized through higher soil moisture values than the other microhabitats. As already mentioned before, *Phrurolithus festivus* was characterized as an element of xerothermous habitats (Bauchhenss, 1990), which can also be confirmed by this study. The skotophilous species *Tenuiphantes flavipes* was associated with the natural forest, whereas Loch (2002) described this species as a typical forest spider without habitat preferences. Living mainly in the litter layer, this species was also associated with the microhabitat *Herb* in the natural forest, assuming that this species prefers more constant microclimate conditions under the ground vegetation layer. Another species associated with the natural forest was *Macrargus rufus*, which is a common species in deciduous forests (Loch, 2002). Moreover, it was a unique species in the natural forest and there mostly in the microhabitat *Litter*. It seems that the environmental conditions in the managed forest (higher temperature, lower humidity and more compact leaf litter) are limiting this species to being an inhabitant of the natural forest only.

4.5 Microhabitats

By trend, the different similarity indices provide congruent results for the different investigated microhabitats in terms of species composition and dominance. All microhabitats differ significantly between the forest types. Moreover, even within the managed forest the microhabitats *Herb* and *Litter* differ considerably. In purely statistical terms, this would allow for the assumption that abiotic parameters responsible for differences between the forest types are more important for the species composition than small scale structural differences within a forest type. The spider assemblages and dominance are also differing between the microhabitats within the same forest type. All investigated microhabitats are characterized trough huge small-scale structural differences, which are independent of the parameters separating the forest types, like coverage of ground vegetation, coverage of leaf litter, soil moisture or the amount of dead wood. Therefore, each of these microhabitat types provides different structural and even microclimatic conditions for spiders. Dissimilarity was highest within the managed forest between the microhabitat *Herb* and *Litter* (46.3%) and within the natural forest between identical structures (38.4%). Lowest dissimilarity was found within the managed forest between the microhabitat *Dead wood* and *Litter*, where two-third of the assemblage and the dominance are equally. The microhabitat characteristics, influencing community composition of spiders, were surveyed by many authors. Samu *et al.*, (1999) cited that spiders are selecting a microhabitat which is suitable for their specific biological need. This could be a potential web site, oviposition site, overwintering site, or even as a shelter from predators during an inactive phase.

Uetz (1991) stated, that the prey capture techniques and spiders sensory perceptions are strongly influencing the habitat association of spiders. It means that spiders that build webs for prey capture require specific architectural features for web attachment. As well, all spiders recognizing their environment using tactile and vibratory cues and, therefore, mostly depend heavily on vibratory stimuli especially for prey detection and courtship. The characteristics of the microhabitat *Herb* holds the structures for three-dimensional webs, which is important for several spiders of the family *Linyphiidae*, *Araneidae* or *Tetragnathidae* (Baehr, 1983), whereas the microhabitat *Litter* mainly lacks of these possibilities. In contrast, mainly nocturnal

respectively permanent active spiders that settle in the leaf litter (Löser, 1980 as cited in Baehr, 1983) are attaching their webs inside or upon the litter layer. Inside the litter layer only small webs (e.g. *Microneteae*, *Centromereae*) can be attached (Baehr, 1983). Consequently, ecological demands of the spiders are responsible for the composition of the spider assemblages between different microhabitats and could be demonstrated in this study. It was also obvious that the same microhabitats, compared between the forest types, resulted in higher similarity and dominance values, than other pairwise comparison. Therefore, similar microhabitats are supporting a more similar spider assemblage, even between the two investigated forest types.

The reduced structural heterogeneity from the microhabitat *Herb* to the microhabitat *Litter*, especially the vertical structure of the vegetation, was also reflected in terms of the number of species, at least for the natural forest. The species number (n=37) as well as the number of unique species (n = 9) was highest at the *Herb* microhabitat in the natural forest. Consequently, the calculated diversity indices (*Shannon-Weaver* and *Evenness*) were highest at these plots and decreasing towards the litter plot in the natural forest. The species number between the microhabitats is similar within the managed forest, but diversity values are highest in the plot *Litter*. This can be explained by the high number of species of the *Pardosa lugubris-group*, especially in the microhabitat *Herb*, which greatly influences the dominance ratio.

When using rarefaction (n = 100), all microhabitats in the managed forest were characterized through significantly lower diversity indices than the natural forest. This was caused by a significantly higher number of individuals in the managed forest. Except the microhabitat *Herb* in the natural forest, all others had similar species numbers. Nevertheless, the managed forest was distinguished with a more imbalanced dominance, leading to decreased diversity indices.

A lower number of species was found to be associated with a certain microhabitat compared to species which were associated with one of the forest types. The species *Anguliphantes angulipalpes* is living in the leaf litter and was associated with the microhabitat *Dead wood* in the natural forest in this study. This microhabitat was characterized through the highest mean humidity of all microhabitats, a high percentage of moss cover, as well as a deep leaf litter layer, compared to the other microhabitats. It seems that this species need a certain level of humidity to colonize a

specific habitat and a deeper and complex leaf litter layer, due to the fact that this species was unique in the natural forest. The skotophilous species *Tenuiphantes flavipes* is associated with the natural as well as with the managed forest with the microhabitat *Herb*. As a skotophilous forest species living in the leaf litter layer it prefers dark areas. But several individuals of this species were also observed in the managed forest in the *Litter* microhabitat, excluding the possibility that the additional dimming effect of the ground vegetation is supporting the occurrence of this species. Possibly, this species is not depended on the special microclimate condition which is defined by the vegetation (Loch, 2002). It rather seems that it influences the colonization of a habitat by this species. Three other species, namely Zelotes subterraneus, *Gnaphosa bicolour* and *Pardosa lugubris-group* are associated with the microhabitat *Herb* in the managed forest. As already mentioned, all three species prefer more open forests, which is generally the case in each analysed microhabitat of the managed forest. The association of these species to the microhabitat *Herb* in the managed forest could not clearly be identified by the ecology of this species. But according to Platen *et al.,* (1999), all three are common in the grass layer, beside other microhabitats. Summing up, only a few species were found to be associated with a certain microhabitat. It can be assumed, however, that a longer sample period (the whole vegetation period) would reveal more species associated to a certain microhabitat.

4.6 Causal-analytical evaluation

Environmental variables influencing the microhabitat grouping were examined using a discriminant analysis. Most of the discriminant variables, separating the microhabitat grouping, also explained a great part of the species variation determined by the redundant analysis. Additionally, many species showed positive respectively negative correlations to the parameters affecting the distribution of spiders. Among the key habitat factors affecting the microhabitat distribution of spiders were environmental parameters such as irradiation, temperature, humidity, soil moisture, the depth of the litter as well as the plant diversity. The influence of these variables on the composition of the spider community will be discussed below.

4.6.1 Microclimate conditions

Apparently, many abiotic microhabitat characteristics were affected by the degree of canopy closure, which in this case was the influence of forestry activities within the managed forest. Influencing the microclimatic conditions of the lower forest strata in a diverse way, the canopy closure can be regarded as an important factor in forests (Lindh & Muir, 2004). The degree of canopy cover was shown to be one important factor in the discriminant analysis as well as in the ordination, resulting in alterations of species composition of spider assemblages. A continuous gradient of the canopy cover, decreasing toward the managed forest, was apparently separating both forest types in the first division of the discriminant analysis. Mostly, 30% of the species either correlated to the canopy cover or the counterpart, which is the visible sky.
Influencing the irradiation, the decreasing canopy closure was connected with a rise in the temperature but decreased air humidity. Therefore, the variance of the air humidity was bigger in the managed forest, and consequently the climate within the natural forest was more balanced. Thus, species of the managed forest need to tolerate bigger amplitude of the air humidity. The mean as well as the maximum temperature were highly significant factors within the discriminant analysis, explaining the separation of the natural and the managed forest within the TWINSPAN analysis. Moreover, the mean temperature was the most important factor explaining the species variation within the graphical ordination and mostly 30 % were either positive or negative correlated with the temperature. Situated in a hollow, the microhabitat grouping *NF1* (*TWINSPAN*) is characterized through a high mean humidity. Among other variables, the mean humidity separates this group from the microhabitat grouping *NF2*. The rare euryphilous species *Diplostyla concolor* was found in the relatively dark and humid microhabitat grouping *NF1*. This goes in line with Loch, (2002), who found this species also mainly in more humid forests. The main occurrence of the character species *Philodromus dispar* for the microhabitat *NF1* could be correlated with the higher mean humidity as well as the lower variance of the humidity, compared with other microhabitats. The effect of humidity on the adhesion of hairy attachment of *Philodromus dispar*, which is living on the lower ground vegetation or coniferous trees, was studied by Wolff & Gorb (2011). They found that performance of hairy attachment devices in spiders varied strongly with

environmental humidity, and highest traction forces were found at 70% relative humidity. However, this microhabitat is influenced by spruce, because a small accumulation of spruces boarders this habitat, and could also influence the appearance of *Philodromus dispar*. Being highly significant discriminant factors explaining the microhabitat grouping, this study showed that parameters directly affected by the degree of the canopy cover, e.g. the mean temperate and the mean humidity, strongly influenced the spider assemblages between certain microhabitats. This is also supported by other studies (Wise, 1993; Riechert & Tracy, 1975) and furthermore Huhta (1971) prescribed burning, solar radiation, temperature and moisture as well as the spatial structure of the soil surface as the most important factors in determining the occurrence of species. Nevertheless, it can be assumed that the direct effect of irradiation and rising of the temperature is influencing many biotic conditions, like the vegetation cover or the depth of the litter, which then results in an alteration of the species composition.

4.6.2 Vegetation and soil surface characteristics

Beside the already discussed abiotic environmental factors (e.g. temperature, moisture) the biological factors are also influencing the colonization of a certain habitat by spiders (Foelix, 1992). In general, these are different layers of vegetation, prey availability, competition, antagonists and others, while many of them are forming or influencing one another. Tretzel (1952) mentioned that the specific special arrangement of spiders is an adaptation to interspecific competition, respectively a strategy to avoid even this. The aspect of competition will be unconsidered here, and it is assumed that rather environmental conditions than interspecific competition are influencing the spider distribution. In this study essential factors affecting epigeal spider assemblages were the litter depth and the percentage of litter at a certain plot, the soil moisture, the mean diameter at breast height, the plant diversity, and the moss cover.

4.6.3 Litter layer

Especially the litter layer has particular relevance for the investigated epigeal spider community. While the percentage of the litter was one of the discriminant factors separating the microhabitat groupings *NF3* and *NF4*, the depth of the litter was a major influencing variable within the graphical ordination. Some of the spiders associated with the surface forests, like *Tenuiphantes flavipes* or *Palliduphantes pallidus*, are significantly correlated with the litter layer, while others at least showed higher abundance (e.g. *Macrargus rufus*). As confirmed by many authors and as outlined above, the depth of the litter is important for spiders, because it influences the microclimate, the prey abundance or even provides structural support for web attaching (Uetz, 1979; Bultman & Uetz, 1982; Samu *et al.*, 1999). The influence for the microclimate was proofed within this study, because the depth of the leaf litter is significantly correlated with the soil moisture and obviously evaporation is reduced due to a higher layer of litter. The leaf litter was thicker and more complex in the natural forest, were many more species were found, than in the managed forest. A higher diversity with increasing depth and complexity of the litter was also approved by certain authors (Huhta, 1971; Bultman & Uetz, 1982). Furthermore, the structure and the quality of the litter in forests are very important variables for the colonization of epigeal spiders (Sührig, 1996). Especially deciduous leaf litter provides multiple pathways due to large interstitial spaces between the curled leaves (Pearce *et al.*, 2004), which can be used by many spiders in a diverse way. Beside more niches for prey availability (Bultman & Uetz, 1984), the more complex deciduous litter layer provides more stable microclimate conditions (Uetz, 1979). Nearly 50% of the unique species found in the natural forest belonged to the family *Linyphiidae* and, according to Bultman & Uetz (1984), they used to be more common in complex leaf litter. It can be assumed that the reduced depth of the leaf litter might have influenced the species diversity at least at the family level of the *Linyphiidae*.

4.6.4 Dead wood and moss cover

The two influencing variables *percentage of moss cover* and *the amount of dead wood* cannot be discussed separately. Both variables are significantly correlated to each other, because an increasing amount of dead wood comes along with a growing coverage of moss. While the moss cover is an important factor explaining the species distribution in the redundant analyses, different size classes of dead wood were identified in the discriminate analysis, beside others, as separating variable. Additionally, the plots with a high amount of dead wood were characterized through a high mean humidity, at least in the natural forest. The indicator analysis revealed the species *Anguliphantes angulipalpis* as significantly associated with the *Dead wood* microhabitat in the natural forest. The species *Robertus lividus* is positively correlated with dead wood of the class 5, which results in absence of this species in the microhabitat grouping *NF3*. Although course woody debris is an essential element in forest ecosystems, as it for example provides habitat for many invertebrate taxa (Martikainen *et al.*, 1999), the function of dead wood for epigeal spiders is still not very clear. Buddle (2001) studied spiders associated with downed woody material. He mentioned that, even though spider species found on dead wood are largely a subset of species which are regularly collected from the forest floor, diversity was remarkably high on wood surfaces and spiders frequently utilize downed wood material. Furthermore, he suggested that there might be dependence on dead wood at the population level for certain species (Buddle, 2001).

The amount of dead wood per hectare is not significantly different between both forests, but size classes are different. Loch (2002) mentioned that spiders are not direct correlated by force with dead wood. But he also considered indirect correlations of dead wood and zoophage, for example in terms of accumulated leaf litter on lying dead wood, through windward and leeward effects, which would increase the density of collembola (e.g. *Springtails*). Nevertheless, straight impact of the amount of dead wood on the spider communities could not be confirmed, and correlated variables need to be considered to detect a further indirect relationship. As a vegetation characteristic, the moss cover provides a microhabitat with special light and moisture conditions, which are suitable for small spiders attaching their web between the stems of mosses (Pajunen *et al.*, 1995). Huhta (1971) stated that

several linyphiid spiders are using the different interstitial spaces within the moss vegetation to attach vertically arranged net constructions. Only *Centromerus sylvaticus*, a common forest spider species of moderate humid forests, is significantly positive correlated with the moss coverage. But because the moss cover was mainly on top of the lying dead wood, it is unlikely that potential moss *inhabiting species* are sampled adequately with pitfall traps. However, although it seems that spiders are not directly associated with dead wood, the significantly higher moss coverage on top of the dead wood increases structural diversity and provides more niches, which in turn supports the ecological needs of certain species.

4.6.5 Soil moisture

Although soil moisture is not an influencing factor in the discriminant analyses, it was a major factor explaining the species composition in the redundant analyses. The highest soil moisture was measured in the plots with mostly no ground vegetation cover (*Litter*). Nevertheless, the range between the plots with less soil moisture (*Herb*) and increased soil moisture (*Litter*) was brighter in the natural forest, which is an effect of the forests activities in the managed forest. Two aspects will probably additionally influence the differences in soil moisture values between the microhabitat plots: the uptake of soil water by the ground vegetation and the evaporation of water through the stomata are influencing the soil water content. Mainly plots with less ground vegetation are arranged in the two upper quadrates of the ordination. The species *Macrargus rufus* tends to be more abundant in the more moisture plots and the species *Crustulina guttata* and *Zora spinimana* are significantly positive correlated with the soil moisture. The importance of the soil moisture to the spider assemblages was supported by studies determining different habitats (e.g. Rushton & Eyre, 1992; Entling *et al.*, 2007; Ziesche & Roth, 2008). Thus, it can be assumed that the soil moisture affects the microclimate especially inside the leaf litter and therefore influencing the spider assemblage in the different microhabitats.

4.6.6 Diameter at breast height (DBH)

As a discriminating factor the mean diameter at breast height separated the microhabitat groupings *NF1* and *NF2* from the groupings *NF3* and *NF4*, which was due to the influence of several old oak trees mainly in the grouping *NF4*. The microhabitat group *NF4* was widely scatted within the ordination, with the *old oak plots* in the upper right part of the ordination. These plots are also characterized through a decreased forest stand density. This supports furthermore the higher structural diversity within the natural forest, because in the managed forest the diameter at breast height was more homogenous. Varies environmental conditions were influenced through the old oak trees. These plots were characterized through a considerable reduction in ground vegetation (even in the *Herb* plots not more than 7% coverage) and thus through mainly leaf litter, highest soil moisture values of all plots and deepest leaf litter compared to all other plots. It is obvious that the plots with old oak trees are differing in key parameters compared to the other plots which therefore affect the spider assemblage. Loch (2002) found also differences in the composition of spiders when comparing different age stands, but he stated that these effects of stand age are more indirect by changing the habitat structures, the microclimate, and influencing chemical processes within the soil. Similar results were found by Niemelä *et al.*, (1996), who analyzed young and old forest stands and found more differences within the young stand than within the old forest stands, but mainly when the young stands were more than ten meter away from each other. Therefore, the age of the stand is important on a regional scale, but within a radius of 10 m at a local scale the small-scale differences are the crucial factor for the heterogeneity of the spider community (Niemelä *et al.*, 1996).

4.6.7 Plant diversity

The number of plants (plant diversity) was found to be an important variable within the ordination as well as in the discriminant analysis. This parameter was equalized with an increase in structural diversity of a certain habitat. Generally, the vegetation influences the distribution of spiders in two different aspects. First of all it defines the microclimate of the habitat and secondly it creates a tree-dimensional structure and

offers further habitat differentiations for spiders (Loch, 2002). The correlation of many spiders with the degree of ground vegetation layer was approved by Bonn & Kleinwächter (1999) and importance of the vegetation structure was also confirmed by many authors (e.g. Duffey, 1978; Schäfer, 1978; Coulson & Butterfield, 1986; F. ter Braak, 1987). Especially the vertical structure is more diverse due to the fact that the different plant species reach different heights. According to Dennis *et al.*, (1998) the development of a diverse vegetation structure might increase the niche differentiation. And Riechert & Gillespie (1986) uncovered the importance of the vegetation structure for the horizontal and vertical separation and segmentation of a certain habitat, at least for web building spiders. In this investigation the number of plant species was an important influencing variable which is partly supported by Loch (2002) and Cherrill *et al.*, (1997), who also found influences of the plant diversity on the spider assemblages. Beside the direct effect throughout structural diversity and definition of the microclimate, there might be also indirect effects to the spider community due to prey densities. The density of herbivorous invertebrates, for example, is correlated with more diverse habitats, because they benefit from a greater selection of resources (Crist *et al.*, 2006). Thus, plant diversity influences the spider community either in a direct way throughout structural parameters or indirectly throughout for example the prey density.

4.7 Conclusion

It was showed in this investigation, that the composition of the spider assemblages was significantly different between managed and natural forest. The diversity was significantly higher in the natural forest and most of the rare species (singletons, doubletons) were found within the natural forest. Therefore the natural forest supported more species, and forest management influences the diversity at the species level. Differences in the composition of spiders were also observed between the investigated microhabitats *Herb, Dead wood,* and *Litter*. Although differences were not significant (at least within a forest type) the importance of the small-scale habitat heterogeneity was still shown in this study. It can be concluded that the limited sampling period and the use of only a single sampling technique restricted the

microhabitat association in this study to only a few species. The most important environmental factors influencing the spider assemblages were attributed to the canopy cover respectively are influenced by the canopy cover (e.g. light, moisture, vegetation or microclimatic conditions). Therefore, the changing of key habitat factors through forest management affects the spider communities and causes a considerable shifting in the composition of epigeal spider communities.

The ecology of certain spiders is still not well understood, studies such as this, which correlates species abundance with many structural parameter of a certain habitat, increases the knowledge within this field. Further investigations need to be done, to get a sufficient understanding of biological parameters, like the life history of spiders. Subsequently conclusions can be drawn of which habitat characteristics are correlated with the survival and reproduction of a certain species. Moreover the small-scale heterogeneity of forest habitats need to be considered more in future studies, since many recent studies concentrated mainly on the comparing of different forest stands. The gained knowledge will further enhance the possibilities to reduce the negative impact of forest management on the spider communities.

5 References

Achtziger, R., Nigmann, U. & Zwölfer, H. (1992). Rarefaction-Methoden und ihre Einsatzmöglichkeiten bei der zooökologischen Zustandsanalyse und Bewertung von Biotopen. *Zeitschrift für Ökologie und Naturschutz*, **1**, 89–105.

Albrecht, L. (1990). Grundlagen, Ziele und Methodik der waldökologischen Forschung in Naturwaldreservaten. *Schriftenreihe Naturwaldreservate in Bayern*, **1**, 219.

Albrecht, L. (1992). Die Bedeutung der Naturwaldreservate für den Artenschutz im Wald. *Forstwissenschaftliches Centralblatt*, **111**, 214–224.

Ammer, U. (1992). Naturschutzstrategien im Wirtschaftswald. *Forstwissenschaftliches Centralblatt*, **111**, 255–265.

Baehr, B. (1983). *Vergeichende Untersuchungen zur Struktur der Spinnengemeinschaften (Araneae) im Bereich stehender Kleingewässer und der angrenzenden Waldhabitate im Schönbuch bei Tübingen*. Dissertation, Tübingen.

Baehr, B. (1985). Vergleichende Untersuchungen zur Temperatur-,Feuchtigkeits-und Helligkeitspräferenz bei einigen Arten der Lycosidae,Hahniidae und Linyphiidae (Araneae). *Spixiana*, **8**, 101–118.

Baltanás, A. (1992). On the use of some methods for the estimation of species richness. *Oikos*, **65**, 484–492.

Barber, H.S. (1931). Traps for cave-inhabiting insects. *Journal of the Elisha Mitchell Scientific Society*, **46**, 259–266.

Bauchhenss, E. (1990). Mitteleuropäische Xerotherm-Standorte und ihre epigäische Spinnenfauna- eine autökologische Betrachtung. *Abh. naturwiss. Ver. Hamburg (NF)*, **31/32**, 153–162.

Bauer, L. & Niemann, E. (1965). Methodische Fragen zur wissenschaftlichen Erschließung von Naturschutzgebieten. *Archiv Naturschutz und Landschaftsforschung*, **5**, 89–106.

BfN (2007). *Eichenbiodiversität in Eichenwäldern Nordostdeutschlands (FKZ 80584001)*. Phase1- Schaffung von Grundlagen zur Erarbeitung von naturschutzfachlichen Empfehlungen zur Bewirtschaftung von stabilen, artenreichen, naturnahen Eichenwäldern im nordostdeutschen Tiefland.

Binot, M., Bless, R., Boye, P., Gruttke, H. & Pretscher, P. (1998). Rote Liste gefährdeter Tiere Deutschlands. Bundesamt für Naturschutz. *Schriftenreihe für Landschaftspflege und Naturschutz*, pp.434.

Blick, T. (2009). Die Spinnen (Araneae) des Naturwaldreservats Goldbachs- und Ziebachsrück (Hessen). Untersuchungszeitraum 1994-1996. *Naturwaldreservate in Hessen. Band 11/2.1. Goldbachs- und Ziebachsrück. Zoologische Untersuchungen 1994-1996, Teil 1.* (ed. by W.H. Dorow, T. Blick and J.P. Kopelke), pp. 57–138. Mitteilungen der Hessischen Landesforstverwaltung 45.

Bonn, A., Hagen, K. & Helling, B. (1997). Einfluß des Überschwemmungsregimes auf die Einfluß des Überschwemmungsregimes auf die Laufkäfer – und Spinnengemeinschaften in den Uferbereichen der mittleren Elbe und Weser. *Arbeitsberichte Landschaftsökologie Münster*, **18**, 177–191.

Bonn, A. & Kleinwächter, M. (1999). Microhabitat distribution of spider and ground beetle assemblages (Araneae, Carabidae) on frequently inundated river banks of the River Elbe. *Zeitschrift für Ökologie und Naturschutz*, **8**, 109–123.

Brash, A.R. (1987). The history of avian extinction and forest conversion on Puerto Rico. *Biological Conservation*, **39**, 97–111.

Braun-Blanquet, J. (1964). *Pflanzensoziologie*, 2nd edn., Wien 1959, pp 631,3.Aufl. 1964, pp. 865.

Buddle, C.M. (2001). Spiders (Araneae) associated with downed woody material in a deciduous forest in central Alberta, Canada. *Agricultural and Forest Entomology*, **3**, 241–251.

Bultman, T.L. & Uetz, G.W. (1984). Effect of Structure and Nutritional Quality of Litter on Abundances of Litter-dwelling Arthropods. *American Midland Naturalist*, **111(1)**, 165–172.

Bultman, T.L. & Uetz, G.W. (1982). Abundance and community structure of forest floor spiders following litter manipulation. *Oecologia*, **55**, 34–41.

Cherrill, A., Rushton, S., Sanderson, R. & Byrne, J. (1997). Comparison of TWINSPAN classifications based on plant bugs, leafhoppers, ground-beetles, spiders and plants. *Entomologist*, **116**, 73–83.

Chumak, V., Duelli, P., Rizun, V., Obrist, M.K. & Wirz, P. (2005). Arthropod biodiversity in virgin and managed forests in Central Europe. *Forest Snow and Landscape Research*, **79**, 101–109.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of ecology*, **18**, 117–143.

Colwell, R.K. (2009). EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.2. http://viceroy.eeb.uconn.edu/estimates.

Corlett, R.T. (1992). The ecological transformation of Singapore, 1819-1990. *Journal of Biogeography*, **19**, 411–420.

Coulson, J.C. & Butterfield, J. (1986). The Spider Communities on Peat and Upland Grasslands in Northern England. *Holarctic Ecology*, **9(3)**, 229–239.

Crist, T.O., Pradhan-Devare, S.V. & Summerville, K.S. (2006). Spatial variation in insect community and species responses to habitat loss and plant community composition. *Oecologia*, **147**, 510–521.

De Caceres, M. & Jansen, F. (2010). *Package 'indicspecies'*. Functions to assess the strength and significance of relationship of species site group associations.

Dennis, P., Young, M.R. & Gordon, I.J. (1998). Distribution and abundance of small insects and arachnids in relation to structural heterogeneity of grazed, indigenous grasslands. *Ecological Entomology*, **23**, 253–264.

Doebel, H.G., Denno, R.F. & Coddington, J.A. (1990). Spider (Araneae) Community Structure in an Intertidal Salt Marsh: Effects of Vegetation Structure and Tidal Flooding. *Environmental Entomology*, **19**, 1356–1370.

Dormann, C.F. & Kühn, I. (2009). *Angewandte Statistik für die biologischen Wissenschaften*, 2., durchgesehene, aktualisierte, überarbeitete und erweiterte Auflage.

Dorow, W.H., Flechtner, G. & Kopelke, J.P. (2001). Naturwaldreservate in Hessen No.6/2.1 Schönbuche. Zoologische Untersuchungen 1990-1992. Herausgeber: Hessen-Forst-Forsteinrichtung,Information,Versuchswesen, Gießen & Forschungsinstitut Senckenberg, Frankfurt am Main. *FIV Ergebnis- und Forschungsbericht 28/1*, pp.310.

Dorow, W.H. & Kopelke, J.P. (2007). Naturwaldreservate in Hessen. Band 7/2.2. Hohestein. Zoologische Untersuchungen 1994-1996, Teil 2. *Mitteilungen der Hessischen Landesforstverwaltung*, **42**, 1–341.

Downie, I., Coulson, J. & Butterfield, J. (1996). Distribution and dynamics of surface dwelling spiders across a pasture–plantation ecotone. *Ecography*, **19**, 29–40.

Draney, M.L. (1997). Ground-Layer Spiders (Araneae) of a Georgia Piedmont Floodplain Agroecosystem: Species List, Phenology and Habitat Selection. *Journal of Arachnology*, **25**, 333–351.

Duffey, E. (1978). Ecological strategies in spiders including some characteristics of species in pioneer and mature habitats. *Symposium of the Zoological Society of London*, **42**, 109–123.

Dufrêne, M. & Legendre P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs*, **67**, 345–366.

Dumpert, K. & Platen, R. (1985). Zur Biologie eines Kalkbuchenwaldes.4.Die Spinnenfauna. *Carolinea*, **42**, 75–106.

Engelmann, H.D. (1978). Zur Dominanzklassifizierung von Bodenarthropoden. *Pedobiologia*, **18**, 378–380.

Entling, W., Schmidt, M.H., Bacher, S., Brandl, R. & Nentwig, W. (2007). Niche properties of Central European spiders: shading, moisture and the evolution of the habitat niche. *Global Ecology and Biogeography*, **16**, 440–448.

FAO (2005). Global Forest Resources Assessment. Progress towards sustainable forest management. ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E00.pdf.

Ferris, R., Peace, A.J., Humphrey, J.W. & Broome, A.C. (2000). Relationships between vegetation, site type and stand structure in coniferous plantations in Britain. *Forest Ecology Management*, **136**, 35–51.

Flechtner, G., Dorow, W.H. & Kopelke, J.P. (1999). Naturwaldreservate in Hessen 5/2.1 Niddahänge Östlich Rudingshain. Zoologische Untersuchungen 1990-1992. Hessisches Ministerium für Umwelt, Landwirtschaft und Forsten, pp.752.

Foelix, R.F. (1992). *Biologie der Spinnen. 6 Tabellen*, 2., überarb. und erw. Thieme, Stuttgart [u.a.].

Gertsch, W.J. (1979). *American spiders*, 2d. Van Nostrand Reinhold Co., New York.

Goslee, S.C. & Urban, D.L. (2007). The ecodist package for dissimilarity-based analysis of ecological data. *Journal of Statistical Software*, **22(7)**, 1–19.

Gotelli, N.J. & Entsminger, G.L. (2011). *EcoSim: Null models software for ecology*. Acquired Intelligence Inc. & Kesey-Bear. Jericho, VT 05465.

Greenstone, M.H. (1984). Determinants of web spider species diversity: Vegetation structural diversity vs. prey availability. *Oecologia*, **62**, 299–304.

Gunnarsson, B. (1992). Fractal Dimension of Plants and Body Size Distribution in Spiders. *Functional Ecology*, **6(6)**, 636–641.

Hamerle, A. & Pape, H. (1984). Grundlagen der mehrdimensionalen Skalierung. *Multivariate statistische Verfahren* (ed. by L. Fahrmeir and A. Hamerle), pp. 663–688. Walter de Gruyter, Berlin,New York.

Heimer, S. & Nentwig, W. (1991). *Spinnen Mitteleuropas.* Blackwell Wissenschafts-Verlag, 543 S.

Heimer, S. & Hiebsch, H. (1982). Beitrag zur Spinnenfauna der Naturschutzgebiete Großer und Kleiner Hakel unter Einbeziehung angrenzender Waldgebiete. *Hercynia*, **19**, 74–84.

Hesmer, H. (1934). Naturwaldzellen. *Der Deutsche Forstwirt*, **13-14**, 133-135(13),141-143(14).

Heydemann, B. (1953). *Agrarökologische Problematik, dargetan an Untersuchungen über die Tierwelt der Bodenoberfläche der Kulturfelder*. Dissertation, Kiel, 76 pp.

Heydemann, B. (1960). Die biozonotische Entwicklung vom Vorland zum Koog. - Vergleichend-oko- logische Untersuchungen an der Nordseeküste I. Spinnen (Araneae). *Abh.-Akad.Wiss.Lit.Wiesbaden*, **11**, 744–913.

Hill, M.O. (1979). *TWINSPAN:. A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes,* Cornell University,Ithaca.

Höfer, H., Blick, B., Muster, C. & Paulsch, D. (2010). Artenvielfalt und Diversität der Spinnen (Araneae) auf einem beweideten Allgäuer Grasberg (Alpe Einödsberg) und unbeweideten Vergleichsstandorten im Naturschutzgebiet Allgäuer Hochalpen. *Andrias*, **18**, 53–78.

Hofmann, G. (1997). Natürliche Waldgesellschaften Brandenburgs als Grundlage waldbaulicher Zielstellungen. Tagungsbericht des Brandenburgischen Forstvereins zur Jahrestagung 1997 "Waldbewirtschaftung und Naturschutz im Wald-Einheit oder Widerspruch?" Eberswalde, 33–53.

Hore, U. & Uniyal, V.P. (2008). Diversity and composition of spider assemblages in five vegetation types of the Terai Conservation Area, India. *Journal of Arachnology*, **36**, 251–258.

Hsieh, Y.-L., Lin, Y.-S. & Tso, I.-M. (2003). Ground spider diversity in the Kenting uplifted coral reef forest, Taiwan: a comparison between habitats receiving various disturbances. *Biodiversity and Conservation*, **12**, 2173–2194.

Hueck, K. (1937). Mehr Waldschutzgebiete. *Jahrbuch für Naturschutz,Berlin*.

Huhta, V. (1971). Succession in the Spider Communities of the Forest Floor after Clear-cutting and Prescribed Burning. *Annales Zoologici Fennici*, **8**, 483–542.

Huhta, V. (2002). Soil macroarthropod communities in planted birch stands in comparison with natural forests in central Finland. *Applied Soil Ecology*, **20**, 199–209.

Humphrey, J., Hawes, C., Pearce, A., Ferris-Kaan, R. & Jukes, M. (1999). Relationships between insect diversity and habitat characteristics in plantation forests. *Forest Ecology Management*, **113**, 11–21.

Jiang, S.-l. & Li, B.-p. (2006). Composition and Distribution of Soil Spider Assemblages in Three Natural Secondary Forests in Ziwuling, Gansu. *Zoological Research*, **27(6)**, 569–574.

Kooch, Y., Jalilvand, H., Bahmanyar, M.A. & Pormajidian, M.R. (2008). Application of Two Way Indicator Species Analysis in Lowland Plant Types Classification. *Pakistan Journal of Biological Sciences*, **11 (5)**, 752–757.

Kruskal, J.B. (1964). Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika*, **29**, 1–27.

Lawrence, K.L. & Wise, D.H. (2000). Spider predation on forest-floor Collembola and evidence for indirect effects on decomposition. *Pedobiologia*, 33–39.

Leyer, I. & Wesche, K. (2007). *Multivariate Statistik in der Ökologie: Eine Einführung*, 1.Auflage. Springer,Berlin.

Liepold, K. (2003). *Vergleichende Untersuchungen zur faunistischen und genetischen Diversität von Käferzönosen in genutzten und ungenutzten Bergmischwäldern des Bayerischen Waldes. Dissertation*.

Lindh, B.C. & Muir, P.S. (2004). Understory vegetation in young Douglas-fir forests: does thinning help restore old-growth composition? *Forest Ecology and Management*, **192**, 285–296.

Loch, R. (2002). *Statistisch-ökologischer Vergleich der epigäischen Spinnentierfauna von Bann-und Wirtschaftswäldern. Beitrag zur Erforschung der Biodiversitöt heimischer Wälder. Berichte Freiburger Forstliche Forschung*.

Lohse, G.A. (1981). Bodenfallen im Naturpark Wilseder Berg mit einer kritischen Beurteilung ihrer. *Jb. naturwiss. Verh. Wuppertal*, 70–77.

Lozán, J.L. & Kausch, H. (2007). *Angewandte Statistik für Naturwissenschaftler. Mit 39 Tabellen*, 4., überarb. u. erg. Wissenschaftliche Auswertungen, Hamburg.

Marc, P., Canard, A. & Ysnel, F. (1999). Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture, Ecosystems & Environment*, 229–273.

Martikainen, P., Siitonen, J., Kaila, L., Punttila, P. & Rauh, J. (1999). Bark beetles (Coleoptera, Scolytidae) and associated beetle species in mature managed and old-growth boreal forests in southern Finland. *Forest Ecology and Management*, **116**, 233–245.

McCune, B., Grace, J.B. & Urban, D.L. (2002). *Analysis of ecological communities. Mjm Software Design*. Gleneden Beach,OR,US.

Mesdaghi, M. (2001). *Vegetation Description and Analysis:a Practical Approach.* Jehad Daneshgahi of Mashhad, Mashhad, **1st Edn**, pp. 161-179 (in Persian).

Meyer, P., Bücking, W., Gehlhar, U., Schulte, U. & Steffens, R. (2007). Das Netz der Naturwaldreservate in Deutschland: Flächenumfang, Repräsentativität und Schutzstatus im Jahr 2007. *Forstarchiv*, 188–196.

Mühlenberg, M. (1993). *Freilandökologie*, 3rd edn., Quelle & Meyer, Uni Taschenbücher, Heidelberg, Wiebaden, 512pp.

Müller-Kroehling, S. (2007). Laufkäfer unterschiedlich bewirtschafteter fränkischer Eichenwälder, unter besonderer Berücksichtigung der Bedeutung von Mittelwäldern für die Biodiversität. *Angewandte Carabidologie*, 51–68.

Niemelä, J., Haila, Y. & Punttila, P. (1996). The importance of small-scale heterogeneity in boreal forests: variation in diversity in forest-floor invertebrates across the succession gradient. *Ecography*, **19**, 352–368.

Oksanen, J., Guillaume Blanchet, F., Kindt, R., Legendre, P., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H. & Wagner, H. (2011). *vegan: Community Ecology Package.R package version 1.17-8.*

Oliver, I., Mac Nally R. & York, A. (2000). Identifying performance indicators of the effects of forest management on ground-active arthropod biodiversity using hierarchical partitioning and partial canonical correspondence analysis. *Forest Ecology Management*, 21–40.

Otto, S. (2004). *Die Spinnengemeinschaften in Baumkronen von Urwäldern und Wirtschaftswäldern unterschiedlichen Alters in Ostpolen (Bialowieza)*. Diplomarbeit, Würzburg.

Oxbrough, A.G., Gittings, T., Halloran, J.O., Giller, P.S. & Smith, G.F. (2005). Structural indicators of spider communities across the forest plantation cycle. *Forest Ecology Management*, 171–183.

Pajunen, T., Haila, Y., Halme, E., Niemela, J. & Punttila, P. (1995). Ground-dwelling spiders (Arachnida, Araneae) in fragmented old forests and surrounding managed forests in southern Finland. *Ecography*, **18**, 62–72.

Palmer, M.W. (1990). The estimation of species richness by extrapolation. *Ecology*, 1195–1198.

Pawelka, S. (1997). *Vergleich der Spinnenfauna des Kronenraumes und des unteren Stammbereiches an Buchen in Natur- und Wirtschaftswäldern*. Diplomarbeit, München.

Pearce, J.L., Venier, L.A., Eccles, G., Pedlar, J. & McKenney, D. (2004). Influence of habitat and microhabitat on epigeal spider (Araneae) assemblages in four stand types. *Biodiversity and Conservation*, **13**, 1305–1334.

Pettersson, R.B. (1996). Effect of Forestry on the Abundance and Diversity of Arboreal Spiders in the Boreal Spruce Forest. *Ecography*, **19(3)**.

Platen, R. (1999). Ökologische Klassifizierung von Arten in Roten Listen als Instrument für den Naturschutz. *Schriftenreihe für Landschaftspflege und Naturschutz*, **59**.

Platen, R., Broen, B.v., Herrmann, B. & Sacher, B. (1999). Gesamtartenliste der Webspinnen, Weberknechte und Pseudoskorpione des Landes Brandenburg (Arachnida: Araneae, Opiliones, Pseudoscorpiones) mit Angabe zur Häufigkeit und Ökologie. *Naturschutz und Landschaftspflege in Brandenburg*, **8 (2)**, 1–25.

Platnick, N.I. (2011). The World Spider Catalog, Version 11.5. http://research.amnh.org/iz/spiders/catalog/index.html.

Pospischil, R. (1982). Käfer als Indikatoren für den Wasserhaushalt des Waldes. *Decheniana-Beihefte*, **26**, 158–170.

R Development Core Team (2011). *R: A language and environment for statistical computing.,* R Foundation for Statistical Computing,Vienna,Austria.

Raths, U., Riecken, U. & Ssymank, A. (1995). Gefährdung von Lebensraumtypen in Deutschland und ihre Ursachen. Auswertung der Roten Liste gefährdeter Biotoptypen. *Natur und Landschaft*, **70**, 202–212.

Rau, J. (1993). Faunistisch-ökologische Bewertung von Naturwaldreservaten anhand repräsentativer Tiergruppen. *Naturwaldreservate in Bayern*, **2**.

Riechert, S.E. & Tracy, C.R. (1975). Thermal Balance and Prey Availability: Bases for a Model Relating Web-Site Characteristics to Spider Reproductive Success. *Ecology*, **56**, 265–284.

Riechert, S.E. & Gillespie, R.G. (1986). Habitat choice and Utilization in Web-Building Spiders. *Spiders--webs, behavior, and evolution* (ed. by W.A. Shear), pp. 23–48. Stanford University Press, Stanford, Calif.

Riecken, U. (1999). Effects of short-term sampling on ecological characterization and evaluation of epigeic spider communities and their habitats for site assessment studies. *Journal of Arachnology*, **27**, 189–195.

Riecken, U. (2000). Raumeinbindung und Habitatnutzung epigäischer Arthropoden unter den Bedingungen der Kulturlandschaft. Tierwelt in der Zivilisationslandschaft, Teil IV. *Schriftenreihe für Landschaftspflege und Naturschutz*, **61**, pp.196.

Riecken, U. (1992). Planungsbezogene Bioindikation durch Tierarten und Tiergruppen. Grundlagen und Anwendung. *Schriftenreihe für Landschaftspflege und Naturschutz*, **36**, pp.187.

Roberts, M.J. (1985). *The spiders of Great Britain and Ireland.* E.J. Brill, Leiden.

Rossi, J.P. (2011). rich: An R Package to Analyse Species Richness. *Diversity*, **3(1)**, 112–120.

Rüffer, O. (unknown year). Naturwälder-Erste Erfahrungen aus der Sicht der Naturwaldforschung in Brandenburg. http://berlin.nabu.de/Downloads/Pdf/naturwald-rueffer.pdf.

Rushton, S. & Eyre, M.D. (1992). Grassland Spider Habitats in North-East England. *Journal of Biogeography*, **19(1)**, 99–108.

Sacher, P. (1992). Rote Liste Webspinnen (Araneae). MUNR: Gefährdete Tiere im Land Brandenburg. Rote Liste. Unze Verlag, Potsdam, 229–234.

Samu, F., Sunderland, K.D. & Szinetár, C. (1999). Scale-dependent dispersal and distribution patterns of spiders in agricultural systems: a review. *Journal of Arachnology*, **27**, 325–332.

Sanders, H.L. (1968). Marine Benthic Diversity: A comparative Study. *The American Naturalist*, **102**, 243–282.

Schäfer, M. (1978). Some experiments on regulation of population density in the spider Floronia bucculenta (Araneidae:Linyphiidae). *Symposium of the Zoological Society of London*, **42**, 203–210.

Scharff, N., Coddington, J.A., Griswold, C.E., Hormiga, G. & Bjørn, P.d.P. (2003). When to quit? Estimating spider species richness in a northern European deciduous forest. *Journal of Arachnology*, **31**, 246–273.

Schliemann, S. (2007). *Zum Einfluss der Beweidung auf Laufkäfergesellschaften (Coleoptera, Carabidae) in den Küstenüberflutungsmooren der südlichen Ostseeküste*. Dissertation, Greifswald.

Schubert, H. (1998). *Untersuchungen zur Arthropodenfauna in Baumkronen – Ein Vergleich von Natur- und Wirtschaftswäldern (Araneae, Coleoptera, Heteroptera, Neuropteroidea; Hienheimer Forst, Niederbayern).*Dissertation, Wissenschaft und Technik Verlag, Berlin.154 pp.

Schubert, R. (1986). *Lehrbuch der Ökologie*, 2.Auflage. 595 pp. VEB Gustav Fischer Verlag, Jena.

Schubert, R. (1991). *Bioindikation in terrestrischen Ökosystemen. Mit 38 Tabellen*, 2., überarb. Gustav Fischer Verlag, Jena.

Schulz, U. (1996). *Vorkommen und Habitatanforderungen von Bodenmakroarthropoden in Natur- und Wirtschaftswäldern: ein Vergleich. Coleoptera,Nematocera:Sciaridae,Araneae:Linyphiidae im Hienheimer Forst, Niedernbayern*. Dissertation, München.

Shepard, R.N. (1962). The analysis of proximities: Multidimensional scaling with an unknown distance function. II. *Psychometrika*, **27**, 219–246.

Sørensen, L.L., Coddington, J.A. & Scharff, N. (2002). Inventorying and estimating subcanopy spider diversity using semi-quantitative sampling methods in an Afromontane forest. *Environmental Entomology*, **31**, 319–330.

Ssymank, A. (1994). Forderungen des Naturschutzes an den Waldbau. *Schriftenreihe.Landesanstalt für Ökologie Bodenordnung und Forsten NRW*, **1**, 13–27.

Stöcker, G. & Bergmann, A. (1977). Ein Modell der Dominanzstruktur und seiner Anwendung.1.Modellbildung,Modellrealisierung,Dominanzklassen. *Archiv für Naturschutz und Landschaftsforschung*, **17**, 1–26.

Sührig, A. (1996). *Untersuchungen zum räumlichen Verteilungsmuster von Spinnen (Araneae) der Bodenzone in einem Kalkbuchenwald: Eine Analyse auf der Ebene der Makroskala*. Diplomarbeit, Göttingen.

ter Braak, C.J. F. (1987). The analysis of vegeation -environment relationships by canonical correspondence analysis. *Vegetatio*, **69**, 69–77.

Topping, C.J. & Sunderland, K.D. (1992). Limitations to the Use of Pitfall Traps in Ecological Studies Exemplified by a Study of Spiders in a Field of Winter Wheat. *Journal of Applied Ecology*, **29 (2)**, 485–491.

Torgerson, W.S. (1958). *Theory and methods of scaling*, 13. [print.]. Wiley, New York, NY [u.a.].

Trautmann, W. (1976). Stand der Auswahl und Einrichtung von Naturwaldreservaten in der Bundesrepublik Deutschland. *Natur und Landschaft*, **51**, 67–72.

Treiber, R. (2003). Genutzte Mittelwälder – Zentren der Artenvielfalt für Tagfalter und Widderchen im Südelsaß. *Naturschutz und Landschaftsplanung*, **35(1)**, 50–63.

Tretzel, E. (1952). Zur Ökologie der Spinnen (Araneae). Autökologie der Arten im Raum von Erlangen. *Sitzungsber. phys.-med. Soz. Erlangen*, **75**, 36–131.

Turner, I.M., Tan, H.T., Wee, Y.C., Ali bin Ibrahim, Chew, P.T. & Corlett, R.T. (1994). A study of plant species extinction in Singapore: lessons for the conservation of tropical biodiversity. *Conservation Biology*, **8**, 705–712.

Uetz, G. (1991). Habitat structure and spider foraging. *Habitat Structure: The Physical Arrangement of Objects in Space.* (ed. by S. Bell, E. McCoy and H. Mushinsky), Chapman and Hall, London.

Uetz, G.W. (1979). The influence of variation in litter habitats on spider communities. *Oecologia*, **40**, 29–42.

Welzholz, J.C. & Johann, E. (2007). History of protected forest areas in Europe. *Cost Action E27. Protected forest areas in Europe - analysis and harmonisation (PROFOR): results, conclusions and recommendations.* (ed. by A. Frank, J. Parviainen, K. Vandekerkhove, J. Latham, A. Schuck and D. Little), pp. 17–40.

Wise, D.H. (1993). *Spiders in ecological webs.* Cambridge University Press, Cambridge ;New York.

Wohlgemuth, T., Bürgi, M., Scheidegger, C. & Schütz, M. (2002). Dominance reduction of species through disturbance – a proposed management principle for central European forests. *Forest Ecology Management*, **166**, 1–15.

Wolff, J.O. & Gorb, S.N. (2011). The influence of humidity on the attachment ability of the spider Philodromus dispar (Araneae, Philodromidae). *Proceedings of the Royal Society B: Biological Sciences*.

Ziesche, T.M. & Roth, M. (2008). Influence of environmental parameters on small-scale distribution of soil-dwelling spiders in forests: What makes the difference, tree species or microhabitat? *Forest Ecology Management*, **255**, 738–752.

6 Appendices

Appendix 1: Table showing the complete dominance structure of the natural and the managed forest

Natural forest											
	B1	B2	B3	B4	B5	B6	B7	B8	total	sum	classes
main species											
Pardosa lugubris-group	95	65	75	44	47	30	52	44	452	39.13	***eudominant***
Haplodrassus silvestris	21	15	12	13	29	17	19	19	145	12.55	***dominant***
Haplodrassus soerenseni	5	12	4	3	6	2	28	9	69	5.97	
Tenuiphantes flavipes	6	9	10	3	9	3	5	6	51	4.42	
Xysticus luctator	16	8	1	2	4	3	4	2	40	3.46	***sub-dominant***
Panamomops mengei	11	10	3	3	1	0	8	4	40	3.46	
Zora nemoralis	12	5	5	0	3	6	6	4	41	3.55	
secondary species											
Tapinocyba insecta	1	3	6	4	1	4	9	6	34	2.94	
Robertus lividus	9	12	1	1	2	4	1	0	30	2.60	
Segestria senoculata	2	3	6	2	1	4	2	3	23	1.99	
Microneta viaria	1	1	7	6	1	1	0	5	22	1.90	***rezedent***
Agroeca brunnea	1	2	5	3	4	4	2	1	22	1.90	
Trochosa terricola	6	3	2	0	1	0	0	4	16	1.39	
Macrargus rufus	4	1	1	1	0	2	5	2	16	1.39	
Walckenaeria dysderoides	6	1	0	3	0	1	2	0	13	1.13	
Troxochrus scabriculus	1	1	2	1	3	1	1	1	11	0.95	
Zora spinimana	3	1	1	0	2	0	3	1	11	0.95	
Agelena labyrinthica	5	1	0	2	1	0	1	0	10	0.87	
Walckenaeria atrotibialis	0	5	0	2	1	0	1	0	9	0.78	
Centromerus sylvaticus	1	3	1	1	0	0	2	1	9	0.78	
Philodromus dispar	1	0	0	0	0	3	1	2	7	0.61	
Zelotes subterraneus	0	1	1	1	2	1	0	0	6	0.52	***subrezedent***
Euryopis flavomaculata	2	3	1	0	0	0	1	0	7	0.61	
Pisaura mirabilis	1	0	2	0	1	1	1	0	6	0.52	
Anguliphantes angulipalpis	1	1	0	1	0	0	2	1	6	0.52	
Palliduphantes pallidus	0	1	0	1	0	0	1	2	5	0.43	
Enoplognatha thoracica	1	0	0	1	0	0	2	0	4	0.35	
Philodromus aureolus	0	0	1	0	1	1	1	0	4	0.35	
Gnaphosa bicolor	0	1	0	1	0	0	0	1	3	0.26	
Walckenaeria cucullata	0	1	1	1	0	0	0	0	3	0.26	
Clubiona terrestris	0	0	0	0	1	1	1	0	3	0.26	
Neriene clathrata	1	0	2	0	0	0	0	0	3	0.26	
Oxyptila praticola	0	0	0	0	0	1	1	0	2	0.17	
Gongylidiellum latebricola	1	0	0	0	0	0	0	1	2	0.17	
Textrix denticulata	1	0	0	0	0	1	0	0	2	0.17	
Xysticus lanio	0	0	0	0	0	1	0	1	2	0.17	
Anyphaena accentuata	0	1	0	1	0	0	0	0	2	0.17	
Diplostyla concolor	0	0	1	0	0	1	0	0	2	0.17	
Xysticus erraticus	0	0	0	1	0	0	0	1	2	0.17	
Abacoproeces saltuum	0	0	0	0	1	0	1	0	2	0.17	
Episinus angulatus	1	0	0	1	0	0	0	0	2	0.17	
Ero furcata	0	0	0	0	0	0	1	0	1	0.09	
Harpactea hombergi	1	0	0	0	0	0	0	0	1	0.09	***sporadic***
Agyneta conigera	0	0	0	0	0	0	0	1	1	0.09	
Metellina mengei	0	0	0	1	0	0	0	0	1	0.09	
Metellina merianae	0	0	0	0	0	1	0	0	1	0.09	
Marpissa muscosa	0	0	0	0	1	0	0	0	1	0.09	
Metellina segmentata	0	0	0	1	0	0	0	0	1	0.09	
Micrommata virescens	0	1	0	0	0	0	0	0	1	0.09	
Centromerus pabulator	0	0	0	0	0	0	0	1	1	0.09	
Walckenaeria furcillata	0	0	0	0	0	0	0	1	1	0.09	
Crustulina guttata	1	0	0	0	0	0	0	0	1	0.09	
Tapinocyba praecox	1	0	0	0	0	0	0	0	1	0.09	
Atypus affinis	0	0	0	0	0	0	0	1	1	0.09	
Araeoncus humilis	0	1	0	0	0	0	0	0	1	0.09	
Bathyphantes gracilis	0	0	0	1	0	0	0	0	1	0.09	
Clubiona marmorata	0	0	0	0	0	0	1	0	1	0.09	

Managed forest							
	B9	B10	B11	B12	total	sum	classes
main species							
Pardosa lugubris-group	407	327	301	205	1,240	75.79	***eudominant***
Haplodrassus silvestris	10	19	7	21	57	3.48	***dominant***
secondary species							
Xysticus luctator	14	21	8	6	49	3.00	
Zelotes subterraneus	11	3	14	1	27	1.65	
Panamomops mengei	6	14	2	1	23	1.41	***rezedent***
Trochosa terricola	8	6	4	5	23	1.41	
Robertus lividus	3	8	7	4	22	1.34	
Troxochrus scabriculus	4	6	5	4	19	1.16	
Zora nemoralis	3	7	0	6	16	0.98	
Agelena labyrinthica	1	9	3	3	16	0.98	
Microneta viaria	4	6	1	2	13	0.79	
Walckenaeria dysderoides	2	6	3	2	13	0.79	
Walckenaeria atrotibialis	5	4	2	0	11	0.67	
Haplodrassus soerenseni	1	4	1	4	10	0.61	***subrezedent***
Gnaphosa bicolor	1	3	4	1	9	0.55	
Agroeca brunnea	2	2	1	3	8	0.49	
Phrurolithus festivus	4	2	1	1	8	0.49	
Tenuiphantes flavipes	3	1	0	2	6	0.37	
Zora spinimana	1	3	2	0	6	0.37	
Oxyptila praticola	1	2	3	0	6	0.37	
Segestria senoculata	1	0	1	3	5	0.31	
Euryopis flavomaculata	2	1	0	1	4	0.24	
Tapinocyba insecta	1	2	0	1	4	0.24	
Centromerus sylvaticus	1	0	1	2	4	0.24	
Walckenaeria furcillata	1	3	0	0	4	0.24	
Ceratinella brevis	0	2	2	0	4	0.24	
Kishidaia conspicua	1	0	2	1	4	0.24	
Philodromus dispar	1	0	0	2	3	0.18	
Enoplognatha thoracica	1	2	0	0	3	0.18	
Pisaura mirabilis	0	1	1	0	2	0.12	
Cercidia prominens	2	0	0	0	2	0.12	
Zodarion germanicum	0	1	1	0	2	0.12	***sporadic***
Zelotes clivicola	0	0	2	0	2	0.12	
Walckenaeria cucullata	0	1	0	0	1	0.06	
Gongylidiellum latebricola	0	0	0	1	1	0.06	
Textrix denticulata	1	0	0	0	1	0.06	
Xysticus lanio	0	0	0	1	1	0.06	
Crustulina guttata	0	1	0	0	1	0.06	
Tapinocyba praecox	1	0	0	0	1	0.06	
Ceratinella brevipes	1	0	0	0	1	0.06	
Erigone atra	0	0	1	0	1	0.06	
Moebelia penicillata	1	0	0	0	1	0.06	
Pseudeuophrys erratica	0	0	0	1	1	0.06	
Xysticus luctuosus	0	0	1	0	1	0.06	
				Σ	**1,636**		

Appendix 2: Spearman rank correlation of the determined environmental parameters (Vegetation: n=72;Climate & Dead wood: n=18; *p<0.05,p<0.01)**

	Vegetation cover %	*Moos/Lichen %*	*Plant Diversity N*	*Leaf litter %*	*Depth of the Litter cm*	*Canopy Closure %*	*Mean DBH cm*	*Soil moisture %*	*pH-Value*	*Temperature max °C*	*Temperature mean °C*	*Humidity mean %*	*Dead wood m³/ha*	*Visible sky*
Vegetation cover (%)	1.000													
Moos/Lichen (%)	.071	1.000												
Plant Diversity (N)	.441**	.030	1.000											
Leaf litter (%)	-.912**	-.284*	-.414**	1.000										
Depth of the Litter (cm)	-.293*	.158	-.181	.190	1.000									
Canopy Closure (%)	-.269*	-.163	.266*	.257*	.058	1.000								
Mean DBH (cm)	-.022	-.264*	.049	.033	-.082	.136	1.000							
Soil moisture (%)	-.308**	-.084	-.449**	.394**	.239*	.027	-.109	1.000						
pH-Value	.372**	.107	.520**	-.418**	-.208	.035	-.041	-.303**	1.000					
Temperature max (°C)	.382	.202	-.068	-.413	.184	-.723**	-.009	-.506*	.309	1.000				
Temperature mean (°C)	.387	.143	-.040	-.392	-.018	-.740**	-.110	-.358	.389	.857**	1.000			
Humidity mean (%)	-.127	.020	-.002	.119	.123	.349	-.054	.216	-.413	-.494*	-.412	1.000		
Dead wood m³/ha	-.187	.658**	-.352	-.088	-.056	-.238	.040	.098	.205	.493	.657	.371	1.000	
Visible Sky	.124	-.135	.022	-.043	.049	-.312**	-.036	-.105	-.029	.497*	.257	-.740**	-.071	1.000

Appendix 3: GPS coordinates for each investigated block

Natural forest	***Latitude***	***Longgitude***
Block 1	52° 9'55.50"N	14°29'0.87"E
Block 2	52° 9'55.56"N	14°28'57.30"E
Block 3	52° 9'58.30"N	14°28'53.00"E
Block 4	52° 9'58.16"N	14°28'58.90"E
Block 5	52° 9'55.35"N	14°28'55.07"E
Block 6	52°10'1.00"N	14°28'52.12"E
Block 7	52° 9'55.70"N	14°28'52.87"E
Block 8	52° 9'57.75"N	14°28'54.90"E
Managed forest	***Latitude***	***Longgitude***
Block 9	52°10'7.23"N	14°28'53.70"E
Block 10	52°10'8.20"N	14°28'52.70"E
Block 11	52°10'9.47"N	14°28'52.04"E
Block 12	52°10'11.11"N	14°28'50.50"E

Appendix 4: Status of the *Red List* species found in the study area (n=unique in the natural forest, m=unique in the managed forest, b=in both forests, cf. Platen, 1999 and Binot *et al.,* 1998)

	Red List Germany	Red List for the State of Brandenburg	Forest
Atypus affinis	3	-	n
Clubiona marmorata	R	-	n
Gnaphosa bicolor	3	3	b
Micrommata virescens	-	R	n
Xysticus luctator	3	2	b
Xysticus luctuosus	3	2	m
Zodarion germanicum	3	R	m

Declaration of independent work on this Master thesis

With this statement, I declare that this Master thesis was prepared by me, only using references in this paper. The connections with companies, governmental organizations and similar was only made with the agreement of my Master thesis adviser.

Potsdam, 10th of June 2011