MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master‘s Thesis

„Comparison of Bat Activity and Bat Communities in Montane Old-Growth and Managed Forests“

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2016 / Vienna 2016

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 879
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Naturschutz und Biodiversitätsmanagement
Betreut von / Supervisor:	Univ.-Prof. Mag. Dr. Konrad Fiedler

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1. Introduction

Forests are important habitats for bats (Dietz 2012) and bats play an important role in forest ecosystems (Carter and Menzel 2007). Forests serve as foraging areas for bats (Barclay and Brigham 1996; Dietz 2012; Meschede and Heller 2000; Patriquin and Barclay 2003; Vaughan, Jones et al. 1997) and they also provide roosts for bats (Barclay and Brigham 1996; Meschede and Heller 2000). Moreover, some Central European bats (like *Myotis bechsteinii, Myotis alcathoe*) rely on forests as their primary habitat (Meschede and Heller 2000; pers. comm. G. Reiter).
Bats provide important ecosystem services for humans, such as arthropod suppression (Kunz, de Torrez et al. 2011; Maas, Clough et al. 2013). Therefore it is important to protect them as well as their habitats.

This study focuses on the importance of an old-growth forest area in the montane zone of the northern Alps as a habitat for bats. The Rothwald, Lower Austria, is one of the last mixed spruce-fir-beech old-growth forests persisting in Europe. According to some authors (Coja and Bruckner 2006; Mühlböck 2006; Rauer 1992) the Rothwald is classified as a primeval forest, a term which is not used in this work.

Thomas (1988) studied different management types of forests and their effect on bats. His study was done in different-aged Douglas fir forests in the Pacific Northwest of the United States and showed that old-growth forests had a higher bat activity compared to mature and young forest stands. Similar results were subsequently found by Humes, Hayes et al. (1999), Krusic, Yamasaki et al. (1996), Crampton and Barclay (1996) and Parker, Cook et al. (1996), also reviewed by Miller, Arnett et al. (2003). Furthermore, a higher bat species diversity was repeatedly detected in older forest stands (Huff, Lehmuhl et al. 1993; Parker, Cook et al. 1996; Thomas 1988; Zielinski and Gellman 1999).

Reiter, Plank et al. (2014) investigated bats in the Biosphere Reserve Wienerwald, Austria, where they compared the core areas of the reserve with managed forests surrounding them. This reserve is situated in the foothill zone of the eastern Alps and occupies mainly beech and oak-hornbeam forests (Sauberer, Milasowszky et al. 2007). They observed slightly lower bat activities in managed forests compared to the core zones. However, since timber harvesting in the core areas of the Biosphere Reserve Wienerwald stopped only about ten years ago, larger differences may be expected from the comparison of the Rothwald area with its surrounding managed forests (Reiter, Plank et al. 2014).

The following hypotheses were formulated based on previous knowledge and tested in this study:

1. A high number of tree cavities, the tree species composition, the age of the trees as well as the structure of the forests are important factors for the quality of forests as habitats for bats (Dietz 2012). Therefore old-growth forests provide a higher number of niches (Humes, Hayes et al. 1999). Accordingly, I expect that sampling sites in old-growth forests are characterized by more complex forest structures and are more favourable to bats, relative to sites in managed forests.
2. Given their higher structural complexity, a higher number of bat species and a higher bat activity should occur at sites in old-growth forests.
3. Bat activity will be higher in deciduous and mixed deciduous forests than in coniferous forest stands, because in deciduous forest stands more roosts are available. Woodpeckers prefer broad-leafed trees, which provide a lot of roosts for bats.
4. Habitat factors are locally more variable between sites in old-growth forests. Therefore a higher spatial variation in bat activity between sampling points is expected in old-growth compared to the managed forests.

2. Study Sites and Methods

2.1. Study area

The study was conducted in and up to ten kilometres around the wilderness area Dürrenstein. This is the first "Area of the Wild" (Category I, IUCN) recognized in Austria (Wildnisgebiet Dürrenstein 2014b), located in the southwest of Lower Austria, at the border to Styria, within the northern limestone zone of the Alps. Its total size is 3500 ha after the last extension in 2013 (Wildnisgebiet Dürrenstein 2014b), whereof 460 ha are represented by the old-growth forest Rothwald. This is one of the last mixed montane spruce-fir-beech old-growth forests persisting in Europe (Leditznig and Pekny 2009). It is dominated by *Fagus sylvatica*, *Abies alba* and *Picea abies*. Beech is forming the second tree layer, because they are about ten to fifteen meters smaller than the conifers (Splechtna and Gratzer 2005).

The Rothwald was first protected by Albert Rothschild, who sheltered the intact forests from timber harvest in 1875. 120 years later 2400 ha of forests were protected by law and from 1997 till 2001 a LIFE project of the EU established the "Wilderness Dürrenstein". Since 2002 the whole area is designated as a conservation area and was awarded "Area of the Wild" (Category I, IUCN) in 2003 (Wildnisgebiet Dürrenstein 2014b).

The annual average temperature is 3.9°C and the annual average precipitation is up to 2300 mm (Splechtna and Gratzer 2005; Wildnisgebiet Dürrenstein 2014a), most of which is falling as snow (Ellmauer 2011). The area ranges from 670 to 1878 m in elevation above sea level (Ellmauer 2011).

2.2. Sampling design

Two hundred random points were defined in the "Wilderness Dürrenstein" and up to ten kilometres around it, using ArcGIS (ArcMap 10.1, ESRI, Redlands, California, USA). Of these random points all lying in rocky areas, in settlement areas, on meadows or in lakes were excluded. All other points were sorted after their altitude. From these points 19 pairs, comprising one sampling point in old-growth forest and one sampling point in managed forest at approximately the same elevation above sea level, were randomly selected.

Due to the large elevational extent of the area, points were only chosen if they were situated at altitudes between 900 and 1,250 m (viz. in the lower montane forest belt). This should make the results more comparable, because altitude plays an important role in shaping bat communities (Grindal, Morissette et al. 1999; Kaňuch and Krištín 2006).

During 23 nights I recorded bat calls at the 19 site pairs (four site pairs were visited twice, 15 were visited just once). The surveys were conducted in August 2013 and from May to September 2014.

2.3. Mounting technique and data acquisition

For measuring bat activity I chose an acoustic method using automated recording devices (batcorder, ecoObs, Nuremberg, Germany). In recent years, many studies (Cristina, Clarke et al. 2008; Murray, Britzke et al. 1999; O'Farrell and Gannon 1999; Plank, Fiedler et al. 2012) revealed that acoustic methods are more suitable to represent the species composition in a certain habitat compared to mist netting.

At the selected sampling points the exact location of the batcorder was optimised if large tree stumps or bushes occurred in a two metre radius, because this can cause reflexions of the bat calls, reducing the detection rate and hampering the later automatic analysis of the calls (Reiter, Plank et al. 2014). Subsequently the batcorder was assembled regarding the manual (ecoObs 2010; ecoObs 2013; Runkel, Marckmann et al. 2008) and programmed to start recording one hour before sunset and to stop one hour after sunrise. The batcorder was placed on top of an extendible stake. The stake was extended to a height of 2.5 m above ground and then fixed to the ground with two strings and four tent pegs.

At each recording site, the following parameters of forest structure were documented (Table 1). More information on these parameters can be found in 6.3. Checklists, page 35.

Parameters, which were initially recorded using a verbal chart, were later transformed into ranks as followed:

1. texture, density of large trees (> 50 cm BHD = breast height diameter) and dead wood:
   - non/low = 0
   - few = 1
   - moderate = 2
   - high = 3
   - very high = 4

2. forest composition around the recording site:
   - coniferous forest = 1
   - mixed forest, coniferous trees dominating = 2
   - mixed forest, deciduous trees dominating = 3
   - deciduous forest = 4

If sites were classified as intermediate between two categories, I scored them using mean ranks (e.g. 1-2 = 1.5).

Table 1: Habitat parameters and the radius in which they were measured; trees were defined as woody plants higher than 5 m; BHD = breast height diameter.

parameter	radius	method
inclination	at batcorder location	measured with compass
exposition	at batcorder location	measured with compass
tree height und BHD	10 m	estimation/measuring
cover of plant layers (trees, shrubs, herbs)	15 m	estimation in %
cover of broad-leaved trees	15 m	estimation in %
estimation of the extent of forest stratification	15 m	counting of forest layers
forest type	30 m	forest type 1: < 25 % deciduous trees in canopy cover; "coniferous forest" hereafter forest type 2: 26-75 % deciduous trees in canopy cover; "mixed forest" hereafter forest type 3: >76 % deciduous trees; "deciduous forest" hereafter forest type 4: clear cuts or avalanche slopes in forests
upright and lying dead wood	30 m	classifying (1 = none until 4 = very high)
quantity estimation of large trees (> 50 cm BHD)	30 m	classifying (1 = none until 4 = very high)
estimation of the forest texture	100 m	classifying (1 = low until 4 = very high)
distance to next water body, settlement, forest edge and forest road	variable	in metre; measured with AMap Fly 5.0 (© EDAS Germany)

2.4. Recording and analysis of bat calls

Batcorders (ecoObs, Nuremberg, Germany) of the versions 1, 2 and 3 were used in this study. To guarantee comparability with other studies only calibrated equipment was used. All batcorders were operated with the standard adjustments: quality = 20, post trigger = 400 ms, threshold level = -27 dB, critical frequency = 16 Hz.

The recorded bat calls were analysed using the software tools bcAdmin 3.2.3 (ecoObs, Nuremberg, Germany) and batIdent 1.5 (ecoObs, Nuremberg, Germany). All results obtained from batIdent were subsequently manually checked (bcAnalyze 1.11, ecoObs Nuremberg, Germany) using Barlow and Jones (1997), Hammer and Zahn (2009), Pfalzer (2002), Skiba (2003) as well as Zingg (1990) and eventually upgraded to a certain species or downgraded to the next OTU (operational taxonomic unit). The following rules were applied when screening the automated identifications:

Myotis bechsteinii was rejected and set to Mkm (the next higher OTU), if this was another suggestion of batIdent and/or the percentage of agreement was < 65 %.

Myotis dasycneme was discarded because this species was so far only found at the eastern border of Austria (Reiter, Pöhacker et al. 2010) and habitats for this species are missing in the study area (Dietz, Nill et al. 2009). Records of this species were set to *Myotis* ssp.

Pipistrellus nathusii was downgraded to the OTU Pmid, because the search calls cannot be reliably separated from those of *Pipistrellus kuhlii*. However, *Pipistrellus kuhlii* is very unlikely to occur in the study area, but cannot be excluded completely.

All other species and/or OTU designations were accepted from the programme output, if the manual checking also agreed with the results.

2.5. Statistical analyses

Descriptive methods were applied to analyse bat activity in old-growth and managed forest and these could explain some of the variance in the data. For sampling points that were sampled during two nights, the mean number of call sequences per night was used as response variable for further analysis.

I used Mann-Whitney U tests, Spearman und Pearson correlations (all done with SPSS 22, IBM, Armonk) as well as dbRDA (distance-based redundancy analysis; calculated with PRIMER 7, Primer-e, Plymouth). Other statistical methods used were principal component analysis (PCA; SPSS 22, IBM, Armonk), NMDS (non-metric multidimensional scaling) ordinations (PRIMER 7, Primer-e, Plymouth), two-way ANOVA (analysis of variance; Statistica 7.1, Statsoft, Tulsa) as well as Chi-squared tests (Statistica 7.1, Statsoft, Tulsa).

A principal component analysis was used to reduce the multiple, but often inter-correlated variables which describe the different forest stands.

For unconstrained NMDS ordinations and constrained dbRDA a dummy species was added to bat call samples from all sites, since this improves stability of ordination results in sparse data matrices (Clarke, Somerfield et al. 2006). Ordinations were based on a Bray Curtis similarity matrix calculated from log-transformed call counts per site. An ANOSIM (analysis of similarity) was also performed to compare species composition between samples from managed and old-growth forests.

The results of the Mann-Whitney U tests are displayed with the asymptotic significance level according to the z-distribution (2-tailed). The species saturation curve was calculated with iNEXT Online (https://chao.shinyapps.io/iNEXT/).

The significance level for all tests was fixed at $p = 0.05$. All tests were performed including the data from nights with zero records.

3. Results

3.1. Structural differences between the old-growth and managed forests

I found differences between old-growth and managed forest sites for the following habitat parameters: content of broad-leaved trees (p = 0.022), cover of the herb layer (p = 0.030), content of lying (p < 0.001), upright (p = 0.003) and total deadwood (p = 0.001) as well as the heterogeneity (texture) of the forest (p = 0.009), the distance to the next path (p < 0.001) and settlements (p < 0.001), the content of large trees (p < 0.001) and according to the surroundings of the forest (p = 0.008) (Table 2).

Table 2: Comparison of the means (standard deviation in brackets) and medians of the habitat parameters that revealed significant differences between old-growth and managed forest; OGF = old-growth forest, MF = managed forest.

habitat parameter	mean		median	
	OGF	MF	OGF	MF
content of broad-leaved trees (%)	54.4 (± 27.1 SD)	29.8 (± 37.4 SD)	50.0	5.0
herb layer (%)	14.9 (± 21.3 SD)	31.8 (± 23.4 SD)	8.0	29.0
lying dead wood	2.3 (± 1.3 SD)	0.6 (± 0.6 SD)	2.0	1.0
upright dead wood	2.0 (± 1.4 SD)	0.7 (± 0.7 SD)	2.0	1.0
total dead wood content	2.1 (± 1.3 SD)	0.7 (± 0.7 SD)	2.0	1.0
texture	2.9 (± 0.8 SD)	2.0 (± 0.8 SD)	2.5	2.0
distance to the next path (m)	379.8 (± 296.0 SD)	32.7 (± 73.9 SD)	257.0	37.0
distance to the next settlement (m)	3908.7 (± 948.1 SD)	1915.4 (± 1015.0 SD)	3608.0	1551.0
content of large trees	2.7 (± 0.9 SD)	0.8 (± 1.0 SD)	3.0	1.0
surrounding of the forest	3.7 (± 0.7 SD)	2.8 (± 0.9 SD)	4.0	3.0

In the old-growth forest a higher content of dead wood and large trees as well as a higher number of deciduous trees was found. In addition, the surroundings of the sampling points in old-growth forests were more often dominated by deciduous forest than in managed forests. Managed forests on the other hand showed a denser herb layer. They were also closer to paths and human settlements.

3.2. Bat call activity in old-growth and managed forests

In the 23 nights 1370 bat passes were recorded (44.2 calls per night, ± 98.2 SD). These could be assigned to nine bat species and two species pairs that I could not resolve to species level based on call information only. Thus, at least eleven bat species are occurring in the study area. The true species number is likely higher, because in some cases only OTUs could be recognized, which contain more than one species (Table 3).

Five of the recorded species are classified as vulnerable, one as near threatened and two are of least concern (Spitzenberger 2005). All recorded bat species are listed in Annex IV of the Habitat Directive of the European Union and *Barbastella barbastellus*, *Myotis bechsteinii* and *Rhinolophus hipposideros* are also listed in Annex II (Anonymous 1992). Some of the recorded OTUs contain additional species which are also of conservation concern in Austria (Spitzenberger 2005).

In total 83.8 % (n = 820) of the calls in old-growth forest and 87.5 % (n = 343) in managed forest could be determined to species level. On the other hand 11.5 % (n = 112) and 8.7 % (n = 34), respectively, were only given a group status (OTU comprising two or more bat species). Furthermore 4.6 % (n = 45) and 3.6 % (n = 14) of the calls, respectively, belonged to the genus *Myotis.* One call sequence in each forest type could not be determined and was therefore called "Chiroptera indet." (0.1 % in old-growth forest and 0.3 % in managed forest).

The minimum species number and the number of recorded sequences per night were highly correlated (Spearman's Rho = 0.88, p = 0.001): a higher number of call sequences resulted also in a higher number of recorded species.

The bat species with highest call activity in the old-growth forest was *Pipistrellus pipistrellus* (n = 744; 76.1 %). Other OTUs with high call activity were Mkm (n = 111; 11.4 %) and Mbart (n = 46; 4.7 %). In managed forests the results were similar: *P. pipistrellus* (n = 291; 74.2 %), Mkm (n = 31; 7.9 %) and Mbart (n = 22; 5.6 %). Together these three OTUs accounted for the vast majority (87.7 %) of recorded sequences.

Myotis nattereri, as well as the OTUs Pmid (*Pipistrellus nathusii* or *P. kuhlii*) and Ptief (*Hypsugo savii*, *Pipistrellus kuhlii* or *P. nathusii*) were only detected in the old-growth forest (0.7 % of all recorded sequences there), while *Nyctalus noctula*, Nycmi (*Nyctalus leisleri, Eptesicus serotinus* or *Vespertilio murinus*) and Nyctaloid (*Nyctalus* ssp., *Eptesicus* ssp. or *Vespertilio* sp.) were only recorded in the managed forest (1.3 % of all recorded sequences there) (Table 3). However, all these species (or OTUs) were very rarely observed.

Table 3: Recorded species in old-growth and managed forests and the total number of recorded call sequences per night (mean per night in brackets). HD (Anonymous 1992): II = listed in Annex II; IV = listed in Annex IV; RL: conservation status in Austria (Spitzenberger 2005): VU = vulnerable, NT = near threatened, LC = least concern, NE = not evaluated.

Latin Name	**HD**	**RL**	**Old-Growth Forest**	**Managed forests**
Rhinolophus hipposideros	II & IV	VU	1 (1.0)	2 (1.0)
Myotis bechsteinii	II & IV	VU	4 (2.0)	2 (1.0)
Myotis daubentonii	IV	LC	13 (1.4)	1 (1.0)
Myotis nattereri	IV	VU	2 (2.0)	0 (0.0)
Mbart (*Myotis brandtii* or *M. mystacinus*)	IV	VU/NT	46 (4.6)	22 (2.8)
Nyctalus noctula	IV	NE	0 (0.0)	1 (1.0)
Pipistrellus pipistrellus	IV	NT	744 (67.6)	291 (48.5)
Eptesicus nilsonii	IV	LC	0 (0.0)	2 (2.0)
Eptesicus serotinus	IV	VU	2 (1.0)	2 (2.0)
Barbastella barbastellus	II & IV	VU	2 (2.0)	20 (10.0)
Pmid (*Pipistrellus nathusii* or *P. kuhlii*)	IV	NE/VU	4 (4.0)	0 (0.0)
Mkm (*M. daubentonii*, Mbart or *M. bechsteinii*)			111 (8.5)	31 (3.4)
Nycmi (*Nyctalus leisleri, Eptesicus serotinus* or *Vespertilio murinus*)			0 (0.0)	1 (1.0)
Ptief (*Hypsugo savii*, *Pipistrellus kuhlii* or *P. nathusii*)			1 (1.0)	0 (0.0)
Myotis ssp.			47 (3.6)	14 (1.8)
Nyctaloid (*Nyctalus, Eptesicus* or *Vespertilio*)			0 (0.0)	2 (1.0)
Chiroptera indet.			1 (1.0)	1 (1.0)
sum			**978**	**392**
minimum number of species			**9**	**9**

The mean number of call sequences per night was 51.5 (± 120.9 SD) in old-growth forest and 20.6 (± 139.7 SD) (Figure 1) in managed forest (Mann-Whitney U-test: $p = 0.29$). The medians of call sequences per night were 7.0 (old-growth forest) and 3.0 (managed forest), respectively. Four nights in old-growth forest and six nights in managed forests had no records of bat calls at all. In old-growth forest 71.4 % (n = 978) of the total call sequences were recorded while only 28.6 % (n = 392) of the sequences were recorded in managed forests.

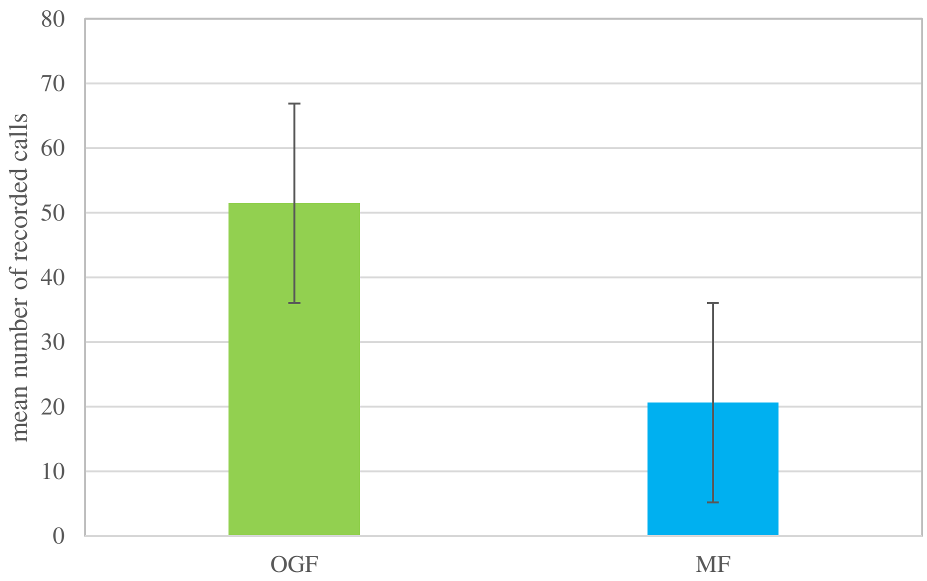

Figure 1: Number of mean recorded call sequences per night in old-growth (OGF) and managed forests (MF) including standard error.

A difference in the expected species number was not found between the two forest types (Figure 2), but in old-growth forests more records were needed to attain the same species number as in managed forests.

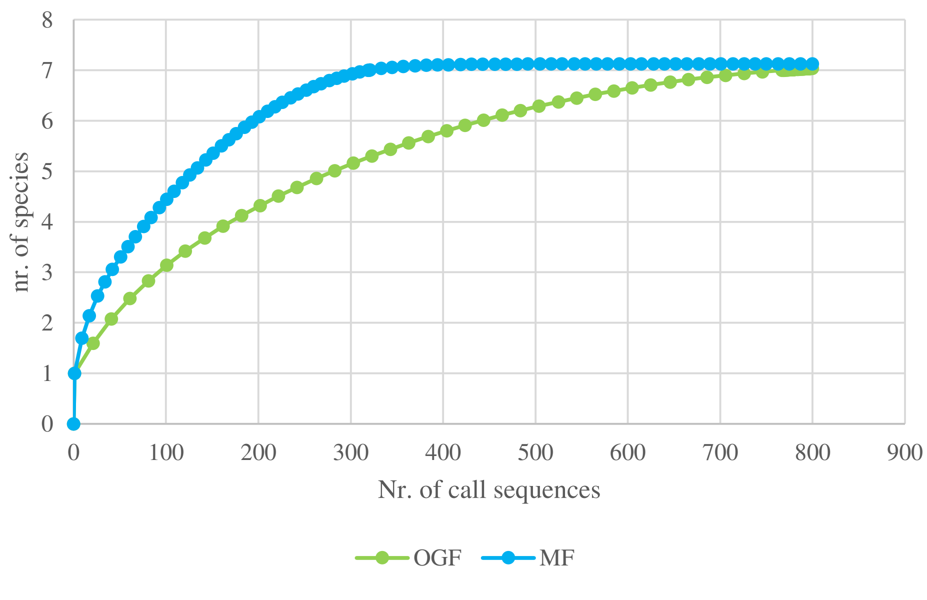

Figure 2: Species saturation curve of bats recorded through acoustic surveys in the two forest management types; OGF = old-growth forest, MF = managed forests.

No significant difference in the species composition between the two different forest management types could be detected (Figure 3; ANOSIM: $R = 0.047$, $p = 0.139$): Sampling sites located in each forest type did not form distinct data clouds.

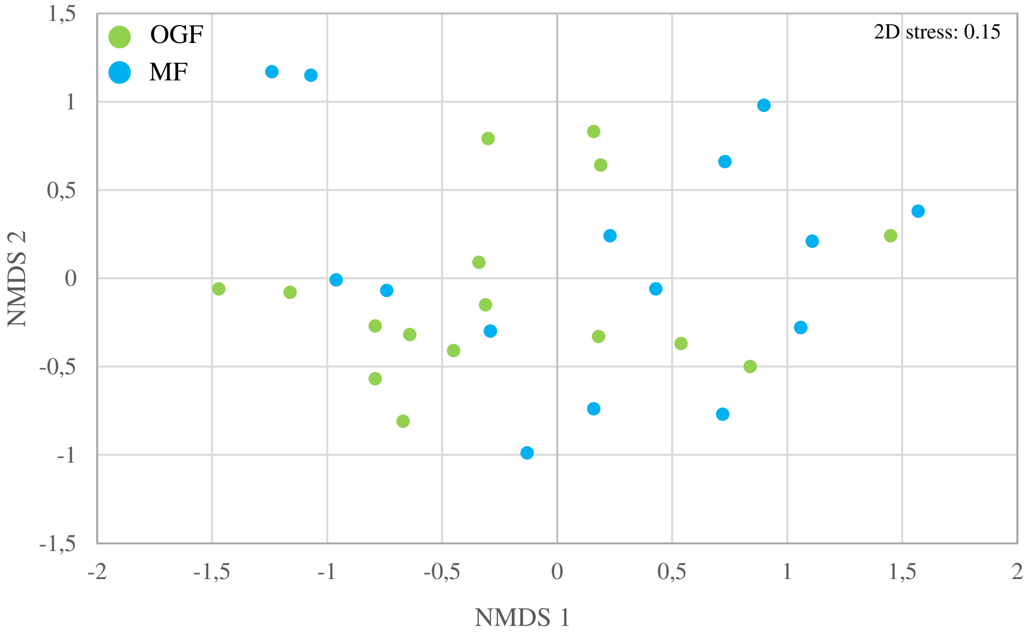

Figure 3: Unconstrained NMDS ordination plot of all recorded call sequences (stress: 0.15), based on Bray-Curtis similarities. Symbols refer to bat assemblages of individual study sites; OGF = old-growth forest, MF = managed forests.

A distance-based redundancy analysis with 13 candidate variables (Table 4) describing topographic site conditions and forest structure revealed that only three of them had a significant or near-significant influence on the species composition of the bat communities.

Table 4: Univariate marginal tests of individual site descriptors in distance-based redundancy analysis (9999 permutations); SS = sums of squares, F = value of test statistic, p = p-value; bold data are significant or near significant.

Variable	SS (trace)	Pseudo-F	p
northernness	1448.9	0.88913	0.4696
easternness	1309.3	0.8012	0.5317
inclination	2783.0	1.7558	0.1255
broad-leaved trees	585.4	0.35301	0.8697
shrub cover	399.9	0.24027	0.9342
herb cover	1060.5	0.64568	0.6479
canopy cover	775.1	0.46917	0.7849
dead wood	5609.1	3.7623	**0.0081**
texture	7218.8	5.0228	**0.0018**
distance to forest edge	301.4	0.18074	0.9622
distance to water body	1613.6	0.99354	0.4097
distance to settlement	3381.5	2.1605	**0.0707**
thick stems	2800.4	1.7674	0.1225

Through a model-building procedure, using adjusted multivariate R^2 as criterion, five variables were included in the model, which together accounted for 33.1 % of the variance in the species composition matrix (Table 5).

Table 5: Results of distance-based linear model, built through sequential selection of variables; SS = sums of squares, p = p-value, df = degrees of freedom; bold data are significant.

Variable	Adjusted R^2	SS	Pseudo-F	p	Cumulative R^2	residual df
texture	0.1149	7218.8	5.0228	**0.001**	0.1434	30
distance to settlement	0.1509	3131.6	2.2713	**0.0525**	0.2056	29
inclination	0.1710	2292.6	1.7031	0.1385	0.2512	28
northern-ness	0.1841	1924	1.4523	0.2115	0.2894	27
dead wood	0.2023	2089.8	1.6133	0.1631	0.3309	26

The resulting constrained ordination diagram (Figure 4) reveals that the bat assemblages in old-growth forest did differ from those in managed forest, with shifts at OGF sites mostly associated with high forest texture, larger distance to nearest settlements and large amounts of dead wood. In contrast, shifts in species composition of bat communities in managed forest were associated with proximity to settlements, less dead wood and higher inclination.

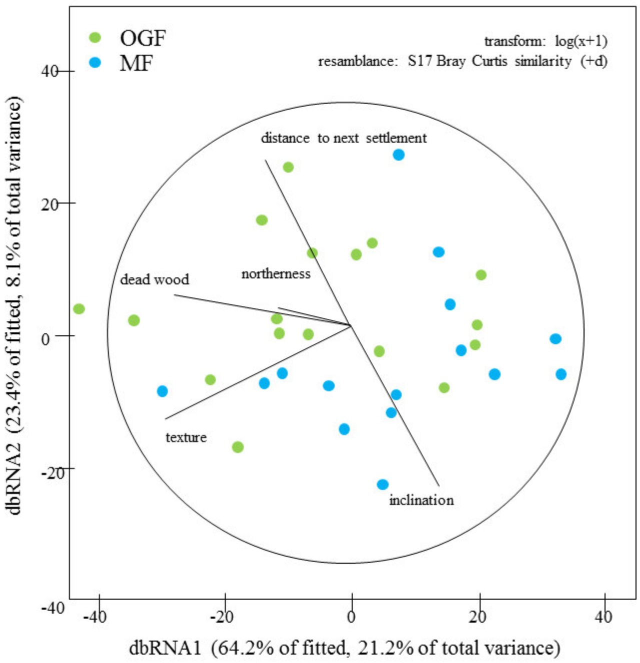

Figure 4: Constrained dbRDA ordination diagram with the five most important habitat factors projected; symbols refer to bat assemblages of individual sites; OGF = old-growth forest, MF = managed forests.

The projection of the five most common species/OTUs on the same ordination shows that *Myotis* species (*Myotis* ssp., Mbart, Mkm) are quite common in old-growth forests, while *Pipistrellus pipistrellus* is occurring in both, the old-growth and managed forests. *Barbastella barbastellus* was more commonly encountered in managed forests (Figure 5).

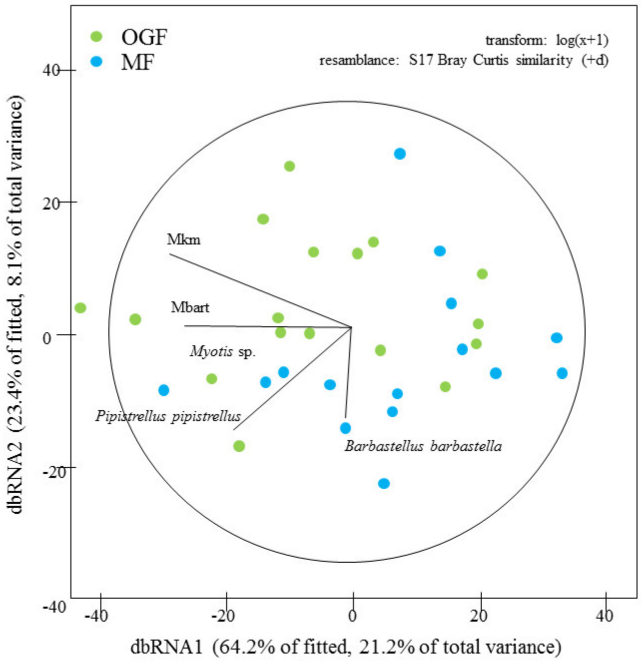

Figure 5: Projection of the five most often recorded bat species (as vectors) on the dbRDA ordination (symbols refer to bat assemblages of sites); OGF = old-growth forest, MF = managed forests.

An aggregation at a higher taxonomic level (all *Myotis* spp. to *Myotis*, all *Pipistrellus* spp. to *Pipistrellus* and all *Eptesicus* spp., *Vespertilio* sp. with *Nyctalus* ssp. to Nyctaloid) allows a rough classification into ecological guilds (compare Reiter, Plank et al. 2014).

I found that *Myotis* species had slightly higher activity in old-growth forest whilst Nyctaloids were more often detected in managed forest. *Pipistrellus* spp. were more common in old-growth forest, but had slightly higher call frequencies in managed forest compared to *Myotis* ssp. Nyctaloids were more abundant in managed forests (Figure 6).

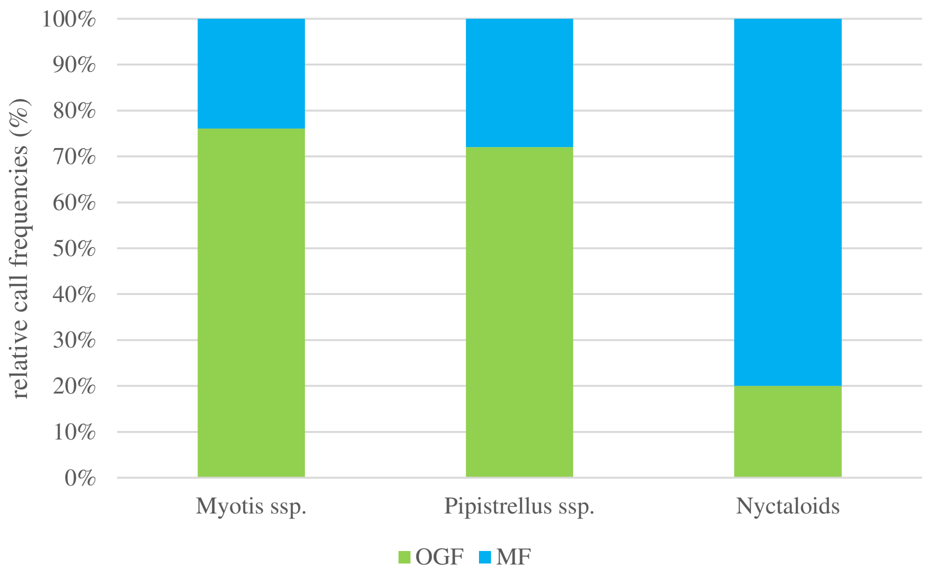

Figure 6: Comparison of the relative call frequencies of the three bat guilds in the two differently managed forest types; OGF = old-growth forest, MF = managed forests.

3.3. Comparison of the different forest types

By comparing the different forest types I found that on average spruce dominated stands had a higher call activity in old-growth as well as in managed forest (Figure 7).

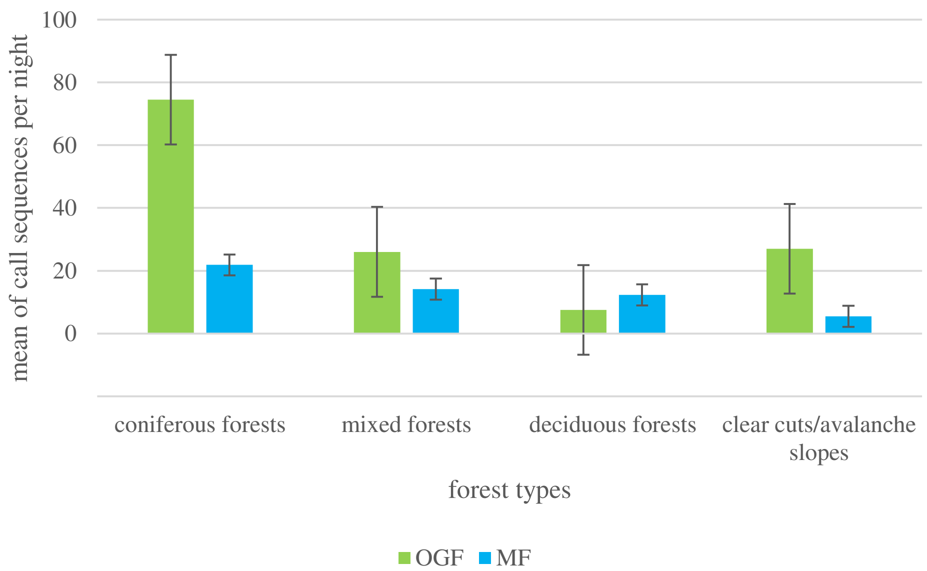

Figure 7: Comparison of the mean bat call sequences per night in four different forest types (standard error included); OGF = old-growth forest, MF = managed forests.

On species level, *Barbastella barbastellus*, *Pipistrellus pipistrellus* and *Myotis* ssp. preferred mixed deciduous forests (Table 7). *Pipistrellus pipistrellus* preferred furthermore coniferous forests, but avoided forests with more than 75 % of deciduous trees. Mkm had a higher observed than expected call activity only in forests with a high content of broad-leaved trees.

Myotis ssp. clearly avoided coniferous forest stands, but preferred forests with at least 25 % of deciduous trees. The observed bat activities on clear cuts and avalanche slopes were in all five common species (or OTUs) higher than expected.

Table 6: Number of calls of the five most common bat species in the four forest types and results of a Chi-squared test for homogeneity of observed vs. expected distribution; expected frequencies were estimated from the distribution of overall bat calls according to the forest types; obs. = observed, exp. = expected.

	coniferous forests		**mixed forests**		**deciduous forests**		**clear cuts/avalanche slopes**		**Chi²**	**p**
	obs.	**exp.**	**obs.**	**exp.**	**obs.**	**exp.**	**obs.**	**exp.**		
Barbastella barbastellus	4	11.13	18	8.9	0	1.6	0	0	16.3	0.000974
Mbart	25	34.4	17	27.2	13	4.9	13	0	102.0	< 0.00001
Mkm	45	3	52	56.7	35	10.2	10	0	84.6	< 0.00001
Pipistrellus pipistrellus	575	4	428	413.2	29	74.0	3	0	51.5	< 0.00001
***Myotis* ssp.**	0	20	19	13.6	12	2.4	3	0	63.1	< 0.00001

A two-way ANOVA showed no significant differences of bat call frequencies between the different forest composition and management types as well as no interaction between them (Table 7).

Table 7: Results of a two-way ANOVA; SS = sums of squares, df = degrees of freedom, MS = mean square, F = F-test, p = p-value.

	SS	**df**	**MS**	**F**	**p**
Management type	3.8379	1	3.8379	1.698	0.204
Forest subtype	1.8381	3	0.6127	0.271	0.846
Management type × Forest subtype	0.9029	3	0.3010	0.133	0.939
Error	61.0279	27	2.2603		

3.4. Habitat and structure parameters

By using a PCA the 14 habitat descriptors were reduced to five factors, which collectively explained 78.4 % of the total variance (Table 8).

Table 8: Factor loadings of the original site descriptors on the five principal components; bold data with a high charge. For better interpretation a varimax rotation with Kaiser normalization was done.

Rotated Component Matrix[a]

	Component				
	1	**2**	**3**	**4**	**5**
eigenvalue	4.372	2.071	2.020	1.313	1.199
% of variance	31.228	14.795	14.429	9.379	8.564
variance in tree height	**0.772**	-0.074	0.248	0.168	0.013
variance in BHD	**0.885**	0.102	0.017	0.165	0.009
texture	**0.747**	0.194	0.185	-0.034	0.074
shrub layer	0.074	**0.851**	0.165	-0.019	0.223
exposition	-0.102	-0.685	0.457	0.260	0.176
content of deciduous trees	0.153	0.648	-0.187	0.560	-0.093
herb layer	-0.045	-0.161	**0.823**	-0.155	0.011
stratification	0.030	0.504	0.618	0.147	-0.299
canopy cover	-0.040	-0.149	-0.571	0.457	-0.519
distance to forest edge/path	0.243	-0.036	-0.054	**0.879**	0.053
distance to water body	-0.123	0.019	-0.063	0.051	**0.944**

Factor 1 describes a gradient from sampling points far away from settlements and forest edges to forests with a high variance in BHD and tree height as well as a lot of upright dead wood and texture. The second factor is related to a high cover of shrub and herb layer, but negatively influenced by canopy cover. Factor 3 has a big positive charge for the exposition and the cover of the herb layer and a negative charge for the percentage of deciduous trees, cover of shrubs and canopy. The fourth factor is formed by a positive charge for the distance to the next waterbody and forest edges and negatively charged by the distance to settlements and the number of plant layers. Factor 5 describes a gradient positively influenced by the distance to the forest edge as well as the exposition and negatively influenced by the distance to the nearest waterbody, the texture and the trees with a BHD of at least 50 cm.

Recorded bat call sequences were weakly related to factor 1 (Figure 8; Pearson correlation: $r = 0.306$, $p = 0.062$; further correlations: factor 2: $r = -0.141$, $p = 0.400$; factor 3: $r = 0.179$, $p = 0.282$; factor 4: $r = -0.057$, $p = 0.732$; factor 5: $r = 0.035$, $p = 0.833$). If tracked down to the primary site descriptors (Table 5), a high variance in BHD as well as tree height, a high forest texture and dead wood content at sites which are far away from settlements and forest edges were related to a higher call activity.

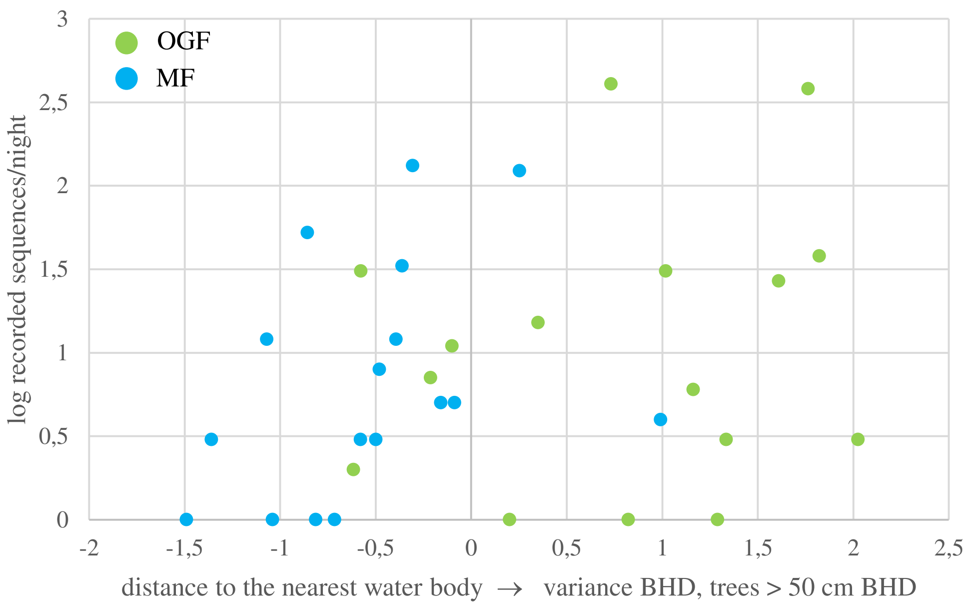

Figure 8: Correlation between the number of recorded bat call sequences (log transformed) and the PCA factor 1; OGF = old-growth forest, MF = managed forests.

4. Discussion

4.1. Bat activity and recorded species

On average, bat activity in the present study (mean = 44.2 calls per night, ± 98.2 SD) was higher than in the study in the Biosphere Reserve Wienerwald (mean = 33.0 calls per night, ± 58.0 SD), while the number of species was lower (Reiter, Plank et al. 2014). This could be due to the fact that the present study was carried out at slightly higher elevations (Grindal, Morissette et al. 1999; Kaňuch and Krištín 2006). It must also be considered that Reiter, Plank et al. (2014) were only recording in the forest interior. In the present study also forest edges and small clear cuts were reviewed. These open habitats are used more frequently for hunting (Rachwald, Boratynski et al. 2001; Zahn, Gelhaus et al. 2008; Zielinski and Gellman 1999).
Baar and Pölz (2001) only found two bat species in the Rothwald (*Pipistrellus pipistrellus* and *Plecotus auritus*), using less acoustic methods but also mist netting. However, they were using a limited access.
In deciduous forests in Germany an average of seven species is expected. At higher elevations up to 1,250 m six species can be found on a regular basis (Meschede and Heller 2000). So the species number of the study area is slightly higher than in an average mountain forest of comparable elevation.

Here an overview over the certain species, according to their total number of occurrence is given:
The common pipistrelle was the most often recorded species in old-growth as well as in managed forests. It was also detected by Baar and Pölz (2001) in the Rothwald. *Pipistrellus pipistrellus* is a generalist and has its habitat preferences in open spaces as well as in forests (Meschede and Heller 2000). They occur in mountain forests on a regularly basis (Meschede and Heller 2000). Thus my findings are in good accordance with other studies.

The OTU Mbart consists of the two species *Myotis brandtii* and *M. mystacinus*, which cannot be distinguished clearly by calls (Reiter, Plank et al. 2014; Skiba 2003). On the one hand it is possible that Brandt's bat is more common because it hunts up to 97 % in forests while the whiskered bat prefers foraging at forest edges, along hedges and in urban areas (Meschede and Heller 2000). It seems that Brandt's bat is more bound to forests, which could be the major niche difference between these two sibling species (Meschede and Heller 2000). *M. brandtii* prefers hunting in forests (Bontadina, Schofield et al. 2002; Meschede and Heller 2000; Russo, Cistrone et al. 2004; Sierro 1999; Spitzenberger 2005; Zahn, Gelhaus et al. 2008). On the other hand *M. mystacinus* is more common in the Alps and therefore it could make up more of this OTU at my study sites (pers. comm. G. Reiter).

Barbastella barbastellus was recorded only twice in the old-growth forest (at one site) and twenty times (at two sites) in the managed forests. Hence, although sometimes claimed to be a “primeval forest bat” (Meschede and Heller 2000) it was more often detected in managed forest. This disagrees with studies from e.g. Russo, Cistrone et al. (2010). Therefore my results show differences to the majority of previous studies, but it was also recently published that this species is very flexible in ecology and behaviour (Ancillotto, Cistrone et al. 2015). The preferred hunting sites of the genus *Barbastella* are forest edges, which are more common in managed forests (Rachwald, Boratynski et al. 2001).

Myotis daubentonii is one of the most common bat species in Europe (Dietz, Nill et al. 2009). Kaňuch, Danko et al. (2008) indicate that Daubenton’s bats are more common in the lowlands, but other studies showed that they can occur at elevations above 1,000 m and it is also one of the three most often detected bats in mountain forests (Meschede and Heller 2000). Forests – especially in the proximity of water bodies – are important habitats for Daubenton's bats, although they can travel seven to eight kilometres between their roosting and foraging areas (Meschede and Heller 2000). All this together explains the relatively high detection rate.

Bechstein’s bat is the most prominent “primeval forest bat” in Central Europe (Meschede and Heller 2000; Spitzenberger 2005). It prefers forest stands which have at least 50 % deciduous trees and a low cover of the shrub layer (Meschede and Heller 2000). Although some studies found that *Myotis bechsteinii* favours warmer areas (Baar and Pölz 2001; Dietz 2012; Reiter, Bruckner et al. 2013) some authors stated that it can also occur at elevations above 1,350 m (Baar and Pölz 2001; Kaňuch, Danko et al. 2008; Meschede and Heller 2000). Bechstein’s bat is connected with old-growth forests with natural tree species composition (Kaňuch, Danko et al. 2008; Spitzenberger 2005). Bechstein’s bats are extremely tree-dependent (Holmes 1996) and forests are essential for the survival of these bats (Meschede and Heller 2000). This rare species was detected twice as often in old-growth than in the managed forests (though based on only a few records), in line with its assignment as “primeval forest bat” (Meschede and Heller 2000; Spitzenberger 2005). Findings of this rare species in the about 15 kilometres distant “Ötschertropfsteinhöhle” (pers. comm. G. Reiter) could support my results. The reason why it was not even more often recorded in the old-growth forest could be 1) because they emit rather quiet echolocation calls (Meschede and Heller 2000), 2) because they often use passive hearing of their prey instead of active echolocation calling (Dietz 2012), 3) because they often hunt in the canopy layer (Plank, Fiedler et al. 2012), 4) because they prefer warmer regions in lower elevations, especially with oak trees (Reiter, Bruckner et al. 2013) and 5) because it could have partially be lumped into the OTU Mkm and the genus *Myotis* ssp.

The northern bat (*Eptesicus nilsonii*) is one of the most common mountain forest bat species in Europe (Kaňuch, Danko et al. 2008; Meschede and Heller 2000), therefore it is remarkable that it was only detected once. Contrary to that, *Eptesicus serotinus* was recorded twice. Serotine bats are quite common in the lowlands and occurs often in rural areas (Baagoe 1986; Baar and Pölz 2001; Kaňuch, Danko et al. 2008). Overall, the number of recorded call sequences was very low, but some calls of both species might have been classified into the OTU Nyctaloid.

From the OTUs Pmid and Ptief, *Pipistrellus nathusii* is the most likely species to occur in the study area. Pmid was recorded only four times in old-growth forest and Ptief was detected just once there. *P. nathusii* uses natural tree roosts (splitting bark and tree holes) as well as buildings and raised stands for roosting (Meschede and Heller 2000). Nathusius' pipistrelle can be found regularly in mountain forests (Aellen 1983 in Meschede and Heller 2000). It inhabits forests with waterbodies nearby (Meschede and Heller 2000; Vaughan, Jones et al. 1997). Also richly structured forests and forest edges serve as habitats (Arnold et al. 2002 in Hüttmeir and Reiter 2014). *P. nathusii* was only expected in autumn, because Nathusius' pipistrelle is a migrating species, which is only expected to occur in late summer or autumn (pers. comm. G. Reiter).

Rhinolophus hipposideros forages mainly in forests (Reiter, Pölzer et al. 2013). However, Dietz, Nill et al. (2009) observed that they fly even through denser vegetation. Especially submontane and montane forests are important hunting areas. A high structural complexity of their habitats seems also to be important for these bats (Meschede and Heller 2000).
Of the lesser horseshoe bat only one sequence in old-growth forest and two sequences in managed forests were recorded. In former times it was detected in the surroundings of the Wilderness Dürrenstein by Baar and Pölz (2001). Baar and Pölz (2001) found two nursery roosts near the Wilderness Area and Bürger, Hüttmeir et al. (2015) found nursery roosts as well as summer and winter roosting sites in the Natura 2000 site "Ötscher-Dürrenstein". Forests seem to play an important role for foraging (Reiter 2004). Therefore the potential suitability of the Dürrenstein area for this bat species might be higher than indicated by the low detection rate in this study. The distance travelled between roosts and foraging areas is usually low (less than five kilometres) (Dietz, Nill et al. 2009). Reasons why it could not be detected more often could be the same as descripted in Hüttmeir and Reiter (2014) – the calls are very high-frequent and are therefore easily absorbed in the air.

Myotis nattereri is a cold resistant and montane bat species, which can occur up to 1,000 m above sea level (Meschede and Heller 2000). It roosts in forests as well as around buildings (Bontadina, Schofield et al. 2002; Meschede and Heller 2000; Russo, Cistrone et al. 2004;

Zahn, Gelhaus et al. 2008). Kaňuch, Danko et al. (2008) stated that it is a true forest bat, because they hunt primarily in forests. This species is associated with coniferous forests (which can be due to the presence of nesting boxes) and can also roost in this forest type (Meschede and Heller 2000). Forests which are suitable for Natterer's bats are often humid and are well structured (Meschede and Heller 2000). Natterer's bat was recorded just twice in the Rothwald. Reiter, Plank et al. (2014) detected it with higher call activity in the core zones of a lowland forest reserve.

Nyctalus noctula is a forest bat of the lowlands (Baar and Pölz 2001; Kaňuch, Danko et al. 2008; Müller, Brandl et al. 2013; Vaughan, Jones et al. 1997). It is quite rare and can therefore easily be overlooked by using just one method (Flaquer, Torre et al. 2007). This could be the reasons why it was just detected once.
The possible occurrence of *N. leisleri* could not be proven in this study. In Austria this species hunts mainly outside the Alps (Spitzenberger 2001). So it is not likely that it is included in the OTU Nycloid or Nycmi, although it was caught in the area before (Bürger, Hüttmeir et al. 2015).
Vespertilio murinus belongs also to the Nyctaloids and was not clearly identified by the acoustic monitoring. Thus, this species might be hidden in the OTU Nyctaloid (two sequences in managed forest) or Nycmi (once detected in managed forest). It is also cold resistant. Its main foraging grounds are areas over water bodies (Meschede and Heller 2000), which weren't reviewed in this study.

Myotis emarginatus is one of the bats that have their main distributional range in the warmer regions of Austria (Spitzenberger and Bauer 1987). This might explain why I did not detect it in this study. It prefers forests with beech, oak and hornbeam (Spitzenberger and Bauer 1987) – the latter ones aren't very common in the study area due to elevation. Geoffroy's bat also needs forest with a high texture. However, in 2001 Baar and Pölz observed this species in the surroundings of the Rothwald and it is possible that recordings of this species are included in the OTU *Myotis* ssp.

The absence of *Myotis myotis* might be explained by their roosting behaviour. Greater mouse-eared bats use big attics with large openings for roosting (Baar and Pölz 2001; Dietz, Nill et al. 2009), which only occur far away from the Rothwald.

The absence of *Plecotus* spp. is probably due to their calls characterized by very high frequency yet low intensity (Skiba 2003). *P. austriacus* and *P. auritus* are native in the study area (Baar and Pölz 2001; Bürger, Hüttmeir et al. 2015). Therefore it is also possible that just one study method is not enough to detect this bat genus (Flaquer, Torre et al. 2007).

According to Hüttmeir and Reiter (2014) *Myotis* species were more common in the core zones and *Pipistrellus* ssp. were more often recorded in the managed forests in a low-elevation study area in the Wienerwald. The results of *Myotis* ssp. could be proven in this study. Nyctaloids (*Eptesicus* ssp., *Nyctalus* ssp. and *Vespertilio* sp.) are more associated with not very cluttered space (Rachwald, Boratynski et al. 2001) as well as the dominance of coniferous trees (Kaňuch, Danko et al. 2008). Both factors are more common in managed forests and explains the higher occurrence in managed forests.

In the genus *Myotis* many bat species with very specific habitat requirements are included (pers. comm. G. Reiter). Many of them are strongly associated with forests or even old-growth forests. Jung, Thompson et al. (1999) showed that *Myotis* ssp. are up to 5.3 times more often found in old-growth stands than in other stand types. Hence, at the level of individual recorded bat taxa my observations of calling activities between old-growth and managed forest completely agree with expectations derived from other pertinent studies in Central Europe.

4.2. Comparison of old-growth and managed forests

In the old-growth forest a higher rate of *Myotis* species compared to the managed forests was registered, which is due to their more specific habitat requirements. Baar and Pölz (2001) found no difference between the Rothwald and the surrounding forests. However, they weren't using quantitative methods.

The species number was the same in both forest management types. Differences could, however, be found in species composition. In line with Reiter, Plank et al. (2014), *Myotis* species were much more often detected in old-growth forest. Though a clearer result compared to the study in the Biosphere reserve Wienerwald was found.

Many other studies (Conley 2011; Crampton and Barclay 1996; Hayes and Loeb 2007; Thomas 1988; Zielinski and Gellman 1999) have found higher bat activities in old-growth forests. Jung, Kaiser et al. (2012) have stated also that certain habitat parameters (e.g. height of trees, standard deviation of canopy structure) associated with old-growth forests were related to increased bat activity, which was also approved in this study.

One of the reasons why in some aspects no clearer results were achieved is that the managed forests weren't chosen by the intensity of their use. Through the random sampling design of this study recordings were done in any type of managed forest.

Other reasons could be 1) the low degree of habitat specialisation of many bats as well as 2) the mix of roosting and foraging grounds, 3) the low sample size and 4) the high mobility of the bat species. Even species (e.g. *Rhinolophus hipposideros*, *Barbastella barbastellus*) which travel only relatively shortly distances between their roosts and foraging habitats, can surmount several kilometers every night (Dietz, Nill et al. 2009).

In this study coniferous forests were used more frequently by bats than forests with a higher content of deciduous trees. This was the case in the old-growth forests as well as in the managed forests. Especially in old-growth spruce forest large amounts of insects can occur, making them attractive foraging areas (Erickson and West 1996; Meschede and Heller 2000; Ressl 2004; Summerville and Crist 2003). Butterflies can have high abundances in coniferous forest stands too, at least some time of the year (Hammond and Miller 1998; Ober and Hayes 2010).

Furthermore, some studies (Celuch and Kropil 2008; Grindal and Brigham 1999; Rachwald, Boratynski et al. 2001; Zahn, Gelhaus et al. 2008) have shown that forest edges are habitats with high bat activities. These structures are more common in managed forests (due to forest roads etc.). Also clear cuts as a result of forestry practices create forest edges. Thus, these factors might explain the intense use of the coniferous forests in the present study.

On the other hand coniferous forest stands provide fewer snags for roosting, because woodpeckers prefer deciduous wood for pecking (Carlson 2000; Meschede and Heller 2000). Nevertheless, the coniferous forest stands in the old-growth forest also contained a high number of large diameter trees, which make the habitat more interesting for bats (Meschede and Heller 2000). A higher bat activity in forests with more thick trees was proven in this study.

The lack of significant differences in bat activity between the two forest management types could be due to the random selection of the managed forests. In the study area not all forests are very intensively used, also because of the higher elevation. If the managed forests would be chosen by the intensity of the impact by humans, maybe a clearer result would be given. The same problem was faced by Reiter, Plank et al. (2014).

4.3. Influence of habitat and structure parameter on the activity of bats

The positive influence of increasing forest structure on bats was confirmed in this study. Old-growth and managed forest differed markedly in terms of most structural descriptors such as variance in BHD, tree height, texture as well as content of upright dead wood. Already Meschede and Heller (2000) stated that the structure of forests is depending on the tree species composition, the variation in tree age and the intensity of forestry. Forest structure enhances the overall diversity and therefore also the species richness of bats. Hence, a complex forest structure supports a high insect density and is as important as the availability of roosts for bats (Meschede and Heller 2000). Forests which are intensively used by bats have many old trees and a high level of forest structure (Zahn, Gelhaus et al. 2008). Spatial complexity with a high insect availability influences the activity of bats in forests (Grindal and Brigham 1999).

A high amount of trees with a diameter of at least 50 cm is another important factor for bats. This is particularly fundamental because large diameter trees are the basis for roosts (Hayes and Loeb 2007). The amount of thick tree stamps was significantly higher in the old-growth forest.

Preserving big trees in forests might be even more important than leaving dead wood there (Meschede and Heller 2000; Weggler and Aschwanden 1999).

Structure is the most important factor influencing bat activity. Especially upright dead wood and large diameter trees are essential issues for bat roosting as well as the diversity and amount of prey. In managed forests bat activity can be increased if structure, mainly the number of trees with a large breast height diameter and upright dead wood, is increased.

4.4. Criticising of the used methods

More significant results could be achieved by a higher sampling size. Also a higher replication rate could bring a good insight of seasonal changes. This wasn't possible, due to time, weather, availability of batcorders and access to the forest areas during rut.

The use of other methods, especially mist netting, would help with species discrimination. However, species that are difficult to record via bat detectors, because of their weak calls or very high-frequent calls, are very difficult to capture with mist nets, too. Batcorders placed in higher strata might have helped gathering more data, but I didn't expect substantial differences in the overall species composition (compare Plank, Fiedler et al. 2012).

4.5. Conclusions

The Rothwald and the other areas of the Wilderness Dürrenstein provide important habitats for bats. Especially *Myotis* species had at least slightly higher activity rates in the old-growth forests. The old-growth forests harboured at least three species, which are listed in Annex II of the European habitat directive (Anonymous 1992) as well as five bat species which are considered as vulnerable in Austria (Spitzenberger 2005).

Therefore it can be said that natural forests play an important role for bats. Endangered species (e.g. *Myotis bechsteinii*, *M. nattereri*) had higher activities in the old-growth forest Rothwald, though based on a low detection rate. A more complex structure, the higher content of upright dead wood and availability of more large trees affect bats positively. Moreover, not intensively used managed forests can provide important habitats for bats. Optimising management procedures in managed forests can boost the protection of bats in forests.

The results suggest that the promotion of bats in forests can be achieved 1) by leaving more upright dead wood in forests, 2) by leaving more thick trees in forests and 3) by enhancing the forest structure. All of these measures will not only support bats in forests, but also enhancing the whole forest biodiversity.

5. Literature

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6. Appendix

6.1. Abstract

Forests are important habitats for bats and bats play important roles in forest ecosystems. Especially in old-growth forests bat activity is often higher than in less structured ecosystems, due to a higher resource supply (food and roosts) and a higher number of available niches.

The present study was carried out in and up to 10 km around the Wilderness Area Dürrenstein, the only "Area of the Wild" (Category I, IUCN) in Austria. The goal was to compare bat activity and the composition of bat communities between old-growth and managed forests.

An automated acoustic sampling of bat calls with batcorders (ecoObs, Nuremberg, Germany) was carried out. Nineteen sampling points were located in the old-growth forest and compared with 19 points, matching in their elevation above sea level, in surrounding managed forests. This way, a total of 1370 bat passes were recorded which could be assigned to at least nine different bat species in each forest management type.

We observed differences in bat activities between the two forest management types for a few commonly recorded species or species groups [*Barbastella barbastellus*, *Myotis brandtii*/*M. mystacinus*, Mkm (*Myotis daubentonii*, *Myotis brandtii*/*M. mystacinus* or *M. bechsteinii*) and *Pipistrellus pipistrellus*]. No significant difference in overall call activity and the species number could be detected. However, bat species composition varied between the two forest management types. Furthermore, bat activity was positively related to the structural complexity of the forests around the recording sites.

Our results confirm the importance of upright dead wood and large trees in forests. Thus, these structural characteristics should be primary goals if bats are conservation targets in forests. Moreover, not only bats would benefit from these management measures.

6.2. Zusammenfassung

Wälder spielen eine wichtige Rolle als Lebensraum für viele Fledermausarten. Fledermäuse sind aber auch ein wichtiger Teil von Waldökosystemen. Vor allem alte Waldbestände weisen oftmals aufgrund eines erhöhten Nahrungs- und Quartierangebotes, sowie einem höheren Angebot an ökologischen Nischen eine gegenüber Wirtschaftswäldern erhöhte Fledermausaktivität auf.

Die vorliegende Studie wurde im und zehn Kilometer um das Wildnisgebiet Dürrenstein durchgeführt, dem einzigen „Strengen Naturreservat" bzw. „Wildnisgebiet" (Kategorie Ia bzw. Ib, IUCN) in Österreich. Das Ziel der Arbeit war es, die Fledermausaktivität in Wäldern inner- und außerhalb dieses wertvollen Naturschutzgebietes zu vergleichen.

Dazu wurden automatische Rufaufzeichnungsgeräte (batcorder, ecoObs, Nürnberg, Deutschland) an 19 Standorten im Wildnisgebiet Dürrenstein und an 19 Punkten gleicher Höhenlage in einem Wirtschaftswald für eine Nacht (und vereinzelt in zwei Nächten)

aufgestellt. Insgesamt wurden 1.370 Rufsequenzen von Fledermäusen aufgezeichnet, welche in jedem Waldtyp mindestens neun verschiedenen Fledermausarten zugeordnet werden konnten.

Die Ergebnisse zeigten, dass sich die Fledermausaktivität zwischen den beiden Bewirtschaftungstypen für einige Fledermausarten [*Barbastella barbastellus*, *Myotis brandtii*/*M. mystacinus*, Mkm (*Myotis daubentonii*, *Myotis brandtii*/*M. mystacinus* oder *M. bechsteinii*) und *Pipistrellus pipistrellus*] signifikant unterschied. Die Anzahl der Fledermausarten war in den beiden Waldbewirtschaftungstypen gleich hoch, allerdings unterschied sich die Artenzusammensetzung. Die Rufaktivität der Fledermäuse war positiv mit der Komplexität der Waldstruktur (Varianz BHD, Anteil Totholz, Anteil an Laubbäumen, etc.) korreliert.

Die Ergebnisse bestätigen, dass stehendes Totholz sowie Starkhölzer wichtige Strukturen für Fledermäuse bieten. Daher sollte die Förderung dieser Strukturen bei der Bewirtschaftung von Wäldern stärker berücksichtigt werden.

6.3. Checklists

Batcorder sampling site

Site Nr ____________________
X_Coordinate ____________________
Y_Coordinate ____________________
Elevation ____________________

Notes [ ]

forest surroundings
- [ ] coniferous forest
- [ ] deciduous forest
- [ ] mixed forest, mostly coniferous trees
- [ ] mixed forest, mostly deciduous trees

forest subtypes
- [ ] centre
- [ ] forest edge
- [ ] clearing
- [ ] path
- [ ] other: ____________

Date ____________________
Recording time (start) ____________________
Recording time (end) ____________________

Wind
- [ ] no wind
- [ ] light wind
- [ ] strong wind

Rain
- [ ] none
- [ ] drizzle
- [ ] rain

Figure 9: Checklist for the batcorder sampling site.

forest parameter at batcorder sites

sampling site	date	editor	elevation
coordinates		photos	
forest type		notes litter (%): total cover (%):	
exposition			
inclination (°)			
content of deciduous trees (%)			
shrub cover (Deckung %)			
herb cover (Deckung %)			
canopy cover (Deckung %)			
stratifikation			
texture			
distance to forest edge/clearing (m)			
distance to forest path (m)			
distance to water body (m)			
distance to settlement (m)			
upright dead wood lying dead wood			
trees > 50 cm BHD			

Figure 10: Checklist for the habitat parameters.

tree species	height	BHD

Figure 11: Checklist for the tree inventory.

6.4. Coordinates of sampling points

Table 9: List of all coordinates in the old-growth forest (OGF) and in the managed forest (MF).

Sampling point	X	Y
OGF01	15.03959	47.77725
OGF 02	15.04329	47.77701
OGF 03	15.09135	47.7773
OGF 04	15.08082	47.76871
OGF 05	15.10296	47.78636
OGF 06	15.08706	47.78254
OGF 07	15.09331	47.78253
OGF 08	15.07863	47.76948
OGF 09	15.07036	47.76440
OGF 10	15.08336	47.78261
OGF 11	15.08736	47.77535
OGF 12	15.09113	47.78193
OGF 13	15.09758	47.78012
OGF 14	15.10267	47.77902
OGF 15	15.08343	47.77110
OGF 16	15.07837	47.77351
OGF 17	15.06309	47.76283
OGF 18	15.10334	47.78107
OGF 20	15.07891	47.76866
MF01	15.04329	47.77701
MF02	14.94081	47.86970
MF03	15.03301	47.70807
MF04	14.98114	47.76613
MF05	15.02266	47.78800
MF06	15.15106	47.70008
MF07	15.00272	47.80394
MF08	15.19868	47.72130
MF09	14.97501	47.77331
MF10	15.12197	47.72079
MF11	15.15453	47.70012
MF12	14.98962	47.79959
MF13	15.01591	47.79194
MF14	15.02485	47.69692
MF15	15.17340	47.74799
MF16	15.16556	47.73149
MF17	14.89616	47.72336
MF18	15.03114	47.83576
MF20	15.07165	47.80516

6.5. List of figures

6.6. List of tables

6.7. Acknowledgment

This thesis would not have been possible unless the help of the following people and institutions:

- Univ.-Prof. Mag. Dr. Konrad Fiedler, who always helped me during my work, especially with the statistics of this study.
- Mag. Dr. Guido Reiter assisted me with his huge and detailed knowledge about bats.
- Barbara Tögel, who read through the thesis and gave well advises to the spelling and grammar.
- Dr. Harald Letsch and Dr. Gerhard Antoine who supported my work with the special hardware.
- The team of the KFFÖ (Austrian Coordination Center for Bat Conservation and Research) and Dr. Andreas Zahn for helping out with additional batcorders.
- Special thanks goes to ecoObs, who supported me with the special software as well as the faculty of the University of Vienna and the management of the Wilderness Dürrenstein for financial support.
- Last but not least I want to thank my parents and my husband Fritz for the support during my whole master studies.

6.8. Curriculum Vitae

Personal Details

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Education

2012-2016	Master programme "Conservation Biology and Biodiversity Management" at the University of Vienna Master thesis: Comparison of Bat Activity and Bat Communities in Montane Old-Growth and Managed Forests
2015-2015	Master programme "Ecology" (branch of study: community and landscape ecology) at the University of Vienna Master thesis: Development of hybrid poplar plantations (*Populus ×canadensis* MOENCH) in the National park Donau-Auen
2011-2014	University of natural resources and life sciences, Vienna
2009-2012	Bachelor programme "Biology" (branch of study: ecology)

Related Work Experience

summer semester 2015	tutor in the courses "Access for biologists" and "Landscape and vegetation ecology – Monitoring in protected areas" at the University of Vienna
June 2014 - until now	internship at the National park Donau-Auen
summer semester 2014	tutor at the courses "Landscape and vegetation ecology – Monitoring in protected areas" and "Protected area management" at the University of Vienna
since September 2013	occasional freelancing the KFFÖ
summer semester 2013	tutor in the course "Knowledge of central European communities" at the University of Vienna
since May 2012	internship at the wilderness area Dürrenstein
March 2011 - May 2013	workshop leader at the Environmental Education Austria
August 2011	internship at Birdlife Austria
August 2010	internship at Fulufjället National park, Sweden
August - September 2009	internship at the National park Donau-Auen

Trainings

ERSI User Conference 2015 in Salzburg

Bat registration with detectors (ANL Bayern, October 2013)

Environmental education course – Train the Trainer (ACT WELLL – Austrian Czech Team Widens Evocative Life Long Learning; 2012-2013)

Professional communication at the telephone (Training & Coaching, December 2009 - January 2010)

Personal Skills and Competences

Languages:	German	mother tongue
	English	fluent
	Swedish	B1

IT

Microsoft Office:	very good
ArcGIS:	very good
BioOffice:	very good
Turboveg, Juice, Vegi:	very good
SPSS, Statgraphics, R:	good
Photoshop:	good
AutoCAD:	fundamental knowledge

Other skills

Driving licence (class B)

Experience in field trips leading & private teaching

Merit scholarship for the period 2013/2014 & 2014/2015