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Summary

Carabid beetle assemblages of the national park "Thayatal" in Lower Austria were investigated at nine sites, displaying various geology and forest communities by using pitfall traps from March until October 2005 and in an additional investigation during 2006. The immediate reaction to disturbances and the well known ecological preferences of ground beetles make them generally suitable for ecological studies. Each sampling site was characterised by analysing the composition of flight dynamic types, body size, and ecological valences among the carabid assemblages.

In total 35 carabid species were identified. The number of species varied between the sites from 21 to 1. *Abax parallelepipedus* appeared at seven sites and was the most individual rich species followed by *Aptinus bombarda*, *Abax ovalis*, *Pterostichus melanarius* and *Limodromus assimilis*. *Aptinus bombarda*, which is a stenoecious species of old forest systems of South-eastern Central Europe was limited to hornbeam forest habitats where it adopted eudominant position and made up more than 50% of all individuals. With 21 and 12 species, one floodplain forest sampling sites (FPF2) and onw water meadow site (WM1) proved that such dynamic and ecotone like habitats provide best conditions for high diversity, where highest values of the Shannon index (>2) and lowest values of the Evenness (<0.5) were recorded. The forest affinity index (FAI) reached the highest value (0.94) at the hornbeam forest site HBF1. Flight ability, body size and ecological valence of carabids were adopted and used to characterise the single forest habitats. Again, the dynamic habitats noticeable differ from all other sites. Smaller and macropterous species were mainly registered at floodplain forests and water meadows, while stenoecious species appear at every site with highest rate (50%) at WM2. To point out similarity, a non-metric multidimensional scaling ordination (NMS) was applied which formed two clusters. The first was formed by dynamic sampling sites (floodplain forests and water meadows), and the second cluster by stable sites (hornbeam forests). Only one single sampling site (HBF3) didn't fit in any cluster and was silhouetted against all other sites. As a final result of this study it was proved that next to the habitat type the grade of disturbance may be an important driving force for the structure of the investigated carabid assemblages. Summarizing, the forest communities of the national park "Thayatal" were found to be species poor, but host carabid assemblages, which are typical for Central European forests.

Keywords: Carabid beetles, forest communities, similarity, national park "Thayatal"

1. Introduction

The national park "Thayatal"

The national park "Thayatal" is located in lower Austria (15 km north to the city Retz) close to the Czech Republic and is separated from the much larger Czech national park "Podyi" by the river Thaya. It was founded in the year 2000 and represents the smallest Austrian national park (1330 ha). During and after the Second World War the forests were managed and even clear-cut, but now according to the status of IUCN category 2, forestry and managing is only allowed for protection and recreation. With 90% coverage forest is the dominant landscape form. Despite its small size the national park offers a high amount of various habitat types like huge hornbeam forests, oak forests, floodplain forests, water meadows, and grasslands, which serve as a base for high biodiversity. National parks should guarantee a high rate of biodiversity and protect it for the next future generations. To document this biodiversity and habitat quality a two year study was conducted, in which various invertebrate groups (snails, carabid beetles and xylobiontic beetles) were investigated. This study reports the results for the carabid communities of the western part of the national park "Thayatal". According to the before mentioned high heterogeneity of the study area this study serves as a pilot study in assessing biodiversity as a whole. Sampling sites were chosen following WRBKA (2006) in order to link the botanical and faunal results and to cover most of the representative forest ecosystems in the national park.

Ground beetles as indicators

During the last decades carabid beetles were used in several studies to document various ecological topics (BUTTERFIELD et al. 1995, ASSMANN 1996, NIEMELÄ et al. 2006). Their morphological structures are easily identifiable and listen up in various identification keys (TRAUTNER & GEIGENMÜLLER 1987, HURKA 1996, FREUDE et al. 2004), and their autecology is more or less well documented (KOCH 1989, MARGGI 1992, HURKA 1996). According to their epigeic inhabiting life form, they can be assed easily with pitfall traps (LUFF 1975, DESENDER & MAELFAIT 1986). Most carabid beetles prey on insect larvae, snails and earthworms and so they form the top of the food-pyramid of small soil invertebrates. Furthermore, ground beetles as a group are sensitive indicators of temperature and moisture gradients and different habitat types support distinct, identifiable communities (THIELE 1997). Because of their high activity abundance and species richness carabids count as important indicators for comparative synecological studies (MÜLLER-MOTZFELD 1989). Their high mobility gives them the opportunity to

react more quickly and more sensitively on disturbances than vegetation (BUCK et al. 1992, TRAUTNER & ASSMANN 1998). Therefore carabid beetles may also be used for characterisation and classification of naturalness in various forest communities. According to the mentioned parameters, this group was chosen to document various forest communities in the national park “Thayatal”.
The aims of this study were (1) to achieve a status quo assessment of carabid fauna in different forest communities of the national park “Thayatal”, (2) to characterise the different habitats according to their carabid coenosis, (3) to point out their similarities and differences and (4) to register endangered carabid species to underline the importance of the national park “Thayatal” as a hideaway for remarkable species.

2. Materials and methods

2.1. Sampling sites

Description of vegetation communities follows WRBKA (2006).

Hornbeam forest 1 (HBF1) – „Untere Bärenmühle”
(N 48° 51‘ 1.9" E 15° 52‘ 40.2")

This sampling site is dominated by the hornbeam *Carpinus betulus* while some lindens (*tilia* sp.) are existent. Forest coverage is close, so that most parts of the ground are completely shaded. Mica slate forms the geological substrate. Dead wood contingent is low and leaf litter coating sparely distinct. The sampling location is approximately 200 m away from the river Thaya and shows a moist climate. Vegetation community is described as *Galio sylvatici-Carpinetum*.

Hornbeam forest 2 (HBF2) – „Merkersdorf“
(N 48° 50‘ 27" E 15° 53‘ 20.4")

This sampling site lies in the middle of a hornbeam forest next to a trail and is located on a hillside with an inclination of approximately 40°. Close forest coverage and a north exposure lead to cool, humid and shady climatic conditions. Orthogneiss built up the geological background, while mosses and brakes grace the ground. Mentionable is a high amount of dead wood and a rubble field, which is located right next to the investigated area. *Galio sylvatici-Carpinetum* is the described vegetation community.

Hornbeam forest 3 (HBF3) – „Umlaufberg Profil“
(N 48° 50‘ 36.3" E 15° 50‘ 40.3")

The third investigated hornbeam forest differs to the two before mentioned hornbeam sampling sites. This forest community is situated at a hang with an inclination of 30°. The dominant tree species is again *Carpinus betulus* but in higher levels it is detached by the oak *Quercus petraea.* Geological conditions are similar to HBF2; it is formed by Orthogneiss. But the most important difference are the soil surface conditions. A high wild boar occurrence influences the vegetation to a high extent. Most parts of the surface are devastated in periodic intervals so that only a very spare vegetation remains and dead wood is nearly destroyed. This sampling site is lighter, warmer and displays a more open character. Vegetation community is described as *Galio sylvatici-Carpinetum*.

Oak-forest 1 (OF1) – “Umlaufberg Kuppe”
(N 48° 50‘ 36.4" E 15° 53‘ 32.8")

With Orthogneiss the same geological background like HBF2 and HBF3 is given, but all other parameters are different. The dominant and only representative of makropyhtae is the oak *Quercus petraea*. Traps were installed at a hillside in south direction with an inclination of about 30°. Additionally to that fact, forest coverage at the investigated area is pretty low; it comes to a very dry and warm climate. Soil is all over covered by grasses while leaf litter and deadwood misses nearly completely. Vegetation community is described as *Sorbo torminalis-Quercetum*.

Oak-forest 2 (OF2) – “Umlaufberg Fuß”
(N 48° 50‘ 37“ E 15° 54‘ 03“)

The second oak-forest is again a bias with north exposition and an inclination of 10°. Dominant tree species is *Quercus petraea*, with huge birch tree population nearby. With a distance of only about 100 m from the river Thaya, site OF2 is a pretty humid location. Treetops are tight so that the soil surface, which is covered by a dense leaf litter layer, is nearly shaded all time. Deadwood is present and geological underground is formed by quartzite and pegmatite. Vegetation community is described as *Sorbo torminalis-Quercetum*.

Floodplain forest 1 (FPF1) – "Kajabach-Au"
(N 48° 49' 44.5" E 15° 53' 31.2")

Totally different from the first five sampling sites, all parameters changed at this sampling site. The vegetation community is described as *Stellario nemorum-Alnetum* and silt, sand and potter's clay forms the geological underground. The sampling site is located in a broad chasm, directly at the riverside of the brook Kaja. Trees are more densely at the slopes on both sites of the brook, but directly next to the brook typical floodplain vegetation with fewer trees is found.

Floodplain forest 2 (FPF2) – "Thaya-Au"
(N 48° 50' 3.3" E 15° 53' 43.5")

Next to this sampling site the brook Kaja flows into the river Thaya. *Aceri-Tilietum festucetosum altissimae* is the described vegetation community, and mica slate forms the geological underground. The river Thaya often overflows the waterside and washes a high amount of driftwood ashore. Temperature stays cool and soil surface is shaded. As huge grasslands form the right end of the investigated area, it displays the character of a forest edge.

Water meadow 1 (WM1) – "*Langer Grund*"
(N 48° 51' 46.2" E 15° 50' 35.5")

At this sampling site the described vegetation community is a *Stellario nemorum-Alnetum*, intermixed with locally adjacent humid grasslands and coniferous forests. Therefore the studied area is more an ecotone than a closed ecosystem. Sand, silt and potter's clay are typical for watersides and form the geological background. This is the second sampling site where wild boars occurred in high frequencies. Soil surface is therefore troubled and muddy, and dead wood is missing.

Water meadow 2 (WM2) – "Turmfelsen"
(N 48° 52' 26.8" E 15° 50' 33.2")

Extraordinary at this studied area is a high stone wall, 50 m above the river Thaya which offers unique microhabitat conditions. The vegetation community is a *Galio odorati-Fagetum*, the geological underground is Orthogneiss. A lot of dead wood and rocks cover the soil surface. Moss and brakes show high humid conditions. A second noteworthy fact is the high age of some trees in this area, due to the fact that no greater forest managing on this steep slope was performed in the past.

2.2. Sampling design

Carabid beetles were collected with unbaited pitfall traps consisting of plastic cups (diameter of 6.5 cm, depth 9.5 cm), two third filled with ethylene-glycol and detergent. Traps were covered with metal caps to protect them from heavy rain and leaf litter. Because of high wild boar activity at site HBF3 and WM1, three rods were sunk into the ground around the traps to keep the boars off. Three traps per site, following DESENDER & VANDEN BUSSCHE (1998), were installed in the beginning of April 2005 and were emptied in a ten to fourteen days interval (see LUFF 1996) to the end of October in 2005.
The sampling sites WM1 and WM2 were only hardly attainable and therefore investigated in a different way with plastic cups with a diameter of 8.5 cm and depth of 12 cm. Formaldehyde 4% was added to the ethylene glycol mixture to achieve a better conservation of the beetles. This traps were emptied only monthly from the beginning of April until October 2006.
Carabid beetles were identified to species level according to HURKA (1996) and FREUDE et al. (2004).

2.3. Data analysis

In order to assess the structure of the different carabid assemblages of the various forest communities typical morphological parameters were regarded; hind wing morphology and body size. Changes in composition of these two parameters among a carabid coenosis can give insight into the stability of the investigated area (HEYDEMANN 1964, BLAKE et al. 1994, LÖVEI & SUNDERLAND 1996).
The quality of each sampling area, ecological valence and ecological preferences of the single carabid species was documented. Therefore the new ecological index, the forest affinity index (FAI), assesses the relative quality of a habitat compared to another habitat, was proposed by ALLEGRO & SCIAKY (2003) and used in this study. To calculate this index, each species was divided into forest species, generalist species and open habitat species and weighted by a coefficient which varied from +1 (obligate forest species), +0.5 (partial forest species), 0 (indifferent to forest coverage), -0.5 (partial open habitat species), to -1 (obligate open habitat species). The value of the forest affinity index is higher when more forest species are present in the habitat. Forest specialists with higher coefficients appear in later succession stages or undisturbed habitats (see DESENDER et

al. 1999, KOIVULA et al. 2002), so that habitats with high FAI values could be characterised as stable, undisturbed habitats with a high grade of naturalness.

The forest affinity is calculated as follows:

$$\text{FAI} = \sum_{(i=1,n)} (p_i F_i)$$

Where p_i is the sum of species frequencies and F_i is the value of the forest specialisation of species. The F_i coefficients of species were determined according to literature (HURKA 1996, FREUDE et al. 2004) and studies of ALLEGRO & SCIAKY (2003) and MAGURA et al. (2006a).

Diversity was expressed by the Shannon Index (H_S) and the distribution of specimens within a species was expressed by the Evenness (E), (MAGURRAN 1988). Both discussed measures of diversity include numbers of individuals and have to be interpreted carefully with respect to the fact that pitfall trapping only reflects activity abundance but not real abundance values. Indices were nevertheless calculated in order to compare results with those of previous studies. A rarefaction curve was applied to give information about the assessment status of carabid species in the national park "Thayatal", using the program PAST version 1.7.
Finally as a measurement of similarity a non-metric multidimensional scaling ordination (NMS) was performed, using the program PC-ORD version 4.

3. Results

3.1. Assemblage structure

In total 35 species and 567 individuals (Table 1) were recorded. With 118 individuals (20,8% of the total number) *Abax parallelepipedus* represented the most abundant species and appeared at nearly every sampling site (7 out of 9).
Highest species richness, (21 species), was recorded at water meadow site WM1, and lowest with only 1 species at oak forest site OF2. The total species richness and number of forest species was obviously higher in hornbeam forest, floodplain forest and water meadows than in oak forests.

Table 1 Recorded carabid beetles, their habitat preference and their forest specialisation value (F_i). Species represented by less than 8 individuals are listed in the footnote. Abbreviations: F – forest species, O – open-habitat species, G – generalist species

	Habitat pref.	F_i	HBF1	HBF2	HBF3	OF1	OF2	FPF1	FPF2	WM1	WM2
Abax ovalis	F	1	10		6			2		1	33
Abax parallelepipedus	F	1	15	31	10			4	3	5	50
Abax parallelus	F	1			1			7	6	2	5
Aptinus bombarda	F	1	110	1							
Carabus hortensis	F	1	5	2						2	
Carabus scheidleri	F	0.5	9	1					1	6	
Limodromus assimilis	F	1						20	13	12	
Molops piceus	F	1	3		4			2	1		
Nebria brevicollis	G	0.5							2	11	
Notiophilus rufipes	O	-0.5			6	1		1			
Pterostichus burmeisteri	G	1	4				1		3	1	
Pterostichus melanarius	G	0						1	8	52	
Pterostichus niger	G	0.5								20	
Pterostichus oblongopunctatus	F	0.5							17	14	1
Total number of individuals			156	35	27	1	1	37	54	126	89
Total number of species			9	4	9	2	1	9	12	21	6

Abax carinatus F 1, *Agonum lugens* G -0.5, *Amara aulica* O -1, *Amara communis* O -0.5, *Amara nitida* O -1, *Bembidion lampros* G -1, *Bembidion tibiale* G 0, *Carabus convexus* F 0.5, *Carabus coriaceus* G 0.5, *Carabus intricatus* F 1, *Carabus irregularis* F 1, *Cychrus caraboides* F 1, *Harpalus atratus* O -0.5, *Leistus ferrugineus* G 0, *Metophonus puncticollis* O -1, *Notiophilus biguttatus* G 0.5, *Paranchus albipes* G 0, *Patrobus atrorufus* G 0.5, *Poecilus cupreus* O -1, *Pterostichus strenuus* G 0.5, *Trechus quadristriatus* G 0

The identified species consisted of 14 forest species (40%), 7 open habitat species (20%) and 14 generalist species (40%). Individuals of forest species covered more than 70% of all trapped individuals while specimen of open habitat species made up less than 10% (Figure1).

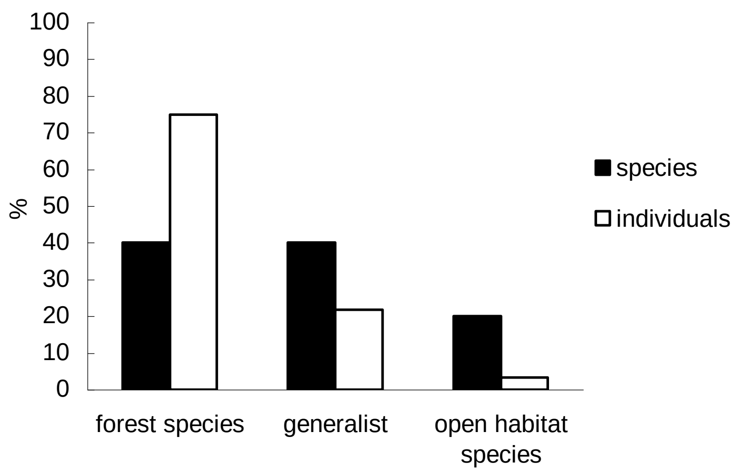

Figure 1 Habitat preference of recorded carabid species.

Forest species clearly dominate at three sampling sites (HBF1, HBF2, WM2), whereas two sites host no forest species at all. Generalist species are missing at two sites but prevailed at the floodplain forest and water meadows (Figure 2). Sampling site WM1 hosts both, most forest species (9) and most generalist species (9).
Finally, open habitat species were only found at four sites (Figure2), but mostly in clear minority. Only sampling site HBF3 show an equally number of open habitat species and forest species (4).

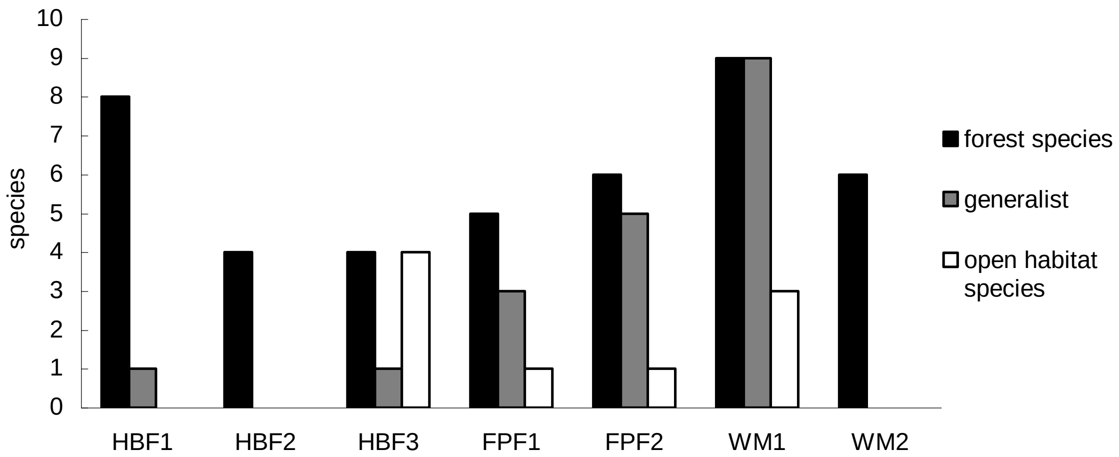

Figure 2 Habitat preference of carabid species at different sampling sites. Only sites with four or more species were analysed.

3.1.1. Diversity and Forest affinity

Values of the Shannon Index (H_s) were generally low and in most cases below 2. Only two sites (FPF2 and WM1) reached higher values which reflect the high species richness of these habitats (Table 2). The distribution of specimens within a species was expressed by values of the Evenness (E), which were relatively similar. Nearly all values were above 0.5. Only one hornbeam forest (HBF2) showed a lower value (Table2). In this case *Abax parallelepipedus* reached predominant status.
The values of the forest affinity index based on species frequencies were highest at HBF1 and WM2 and lowest at HBF3 and WM1 (Table 2). In the first case, both sites represent carabid assemblages consisting totally and mainly of forest species, and in the second case, a lot of generalist species and open habitat species kept the values of the forest affinity index low.

Table 2 Values of the Shannon Index (H_S), Evenness (E) and forest affinity index (FAI). Indices were only calculated for sites with four or more species.

	HBF1	HBF2	HBF3	FPF1	FPF2	WM1	WM2
H_S	1.16	0.47	1.81	1.67	2.04	2.25	1.04
E	0.53	0.34	0.82	0.76	0.82	0.74	0.58
FAI	0.94	0.88	0.33	0.61	0.46	0.31	0.92

3.1.2. Rarefaction

According to the rarefaction curve it seemed that still a lot of carabid species could be expected by further sampling (Figure 3). The slope of the curve implies by its low degree in flattening that still more species may be detected. In case of the national park "Thayatal", which offers a lot of different unique microhabitats with their own special carabid conenoses, it isn't surprising that the total species richness has obviously not been assessed yet. The discovery of ten unrecorded species at WM1 in the year 2006 underlines the high heterogeneity of the national park and therefore difficulties in assessing whole carabid diversity in a single sampling season.

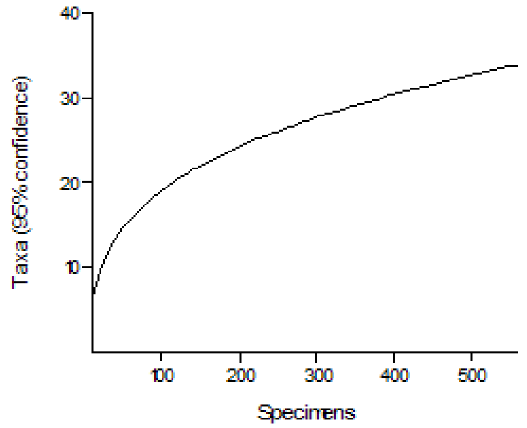

Figure 3 Rarefaction curve

Additionally, the chosen sampling method of pitfall traps offers a lot of lacks which are already well documented in other studies (SOUTHWOOD 1978, SPENCE & NIEMELÄ 1994).

3.2. Wing morphology

Among 35 carabid species 19 were brachypterous (54%), 2 dimorphic (6%) and 14 macropterous (40%). Taking activity abundance into account, nearly 80% of individuals were brachypterous (Figure 3). *Abax parallelepipedus*, *Aptinus bombarda* and *Pterostichus melanarius* formed 68% of all captured brachypterous individuals, while *Limodromus assimilis*, *Pterostichus oblongopunctatus* and *Pterostichus niger* formed 71% of the macropterous individuals.

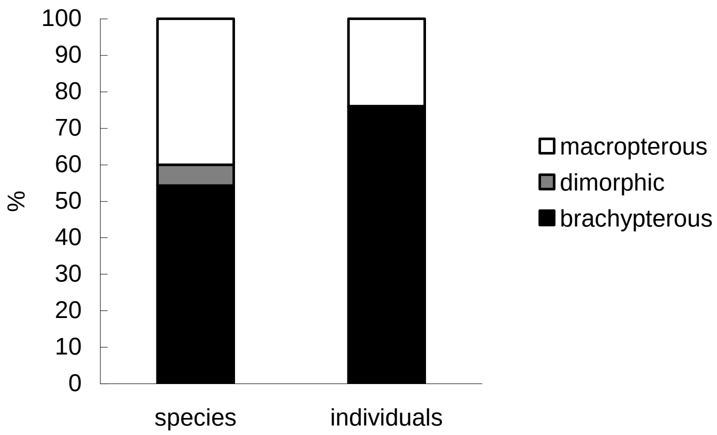

Figure 4 Distribution of wing morphology types across all sampling sites.

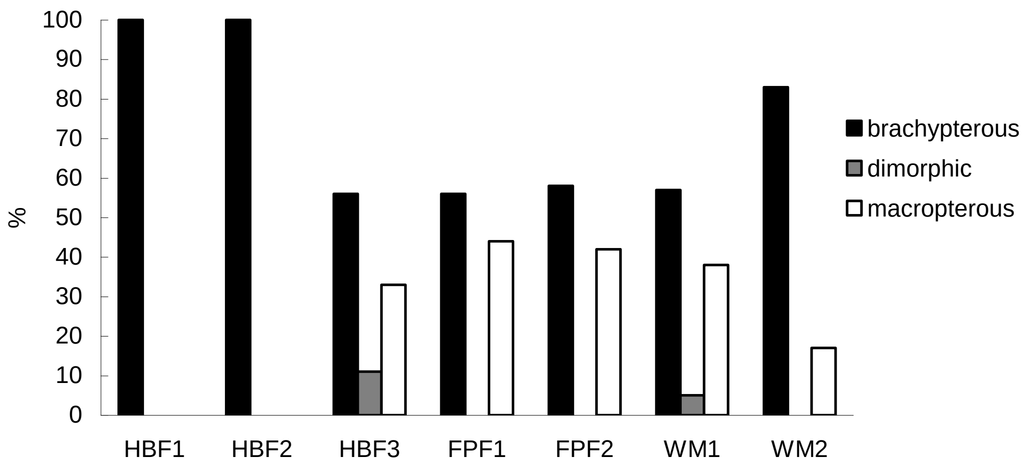

Figure 5 Distribution of wing morphology types at different sampling sites. Only sampling sites with four or more species were analysed.

With exception of HBF3 the hornbeam forests showed a unique structured composition of wing morphology types. At HBF1 and HBF2 not even one macropterous species was found (Figure 4). Floodplain forests and water meadow sites exhibited higher macropterous species rates. Most abundant macropterous species at these dynamic habitats were *Limodromus assimilis* and *Pterostichus oblongopunctatus*. Dimorphic species (*Notiophilus biguttatus* and *Pterostichus strenuus)* occurred at two sites with only one individual each.

3.3. Body size

Sizing of carabid beetles was performed following HEYDEMANN (1953). Across all sampling sites larger carabid species (category IV, V) and smaller species (category II, III) were equal in their percentage contribution of all found species (Figure 6). The individual distribution (Figure 6) revealed that smaller species of category II formed only a fractional amount.

Smallest species of category I were missing completely at investigated sites. Probably insufficient assessment by the method of pitfall trapping could be a reason for this absence.

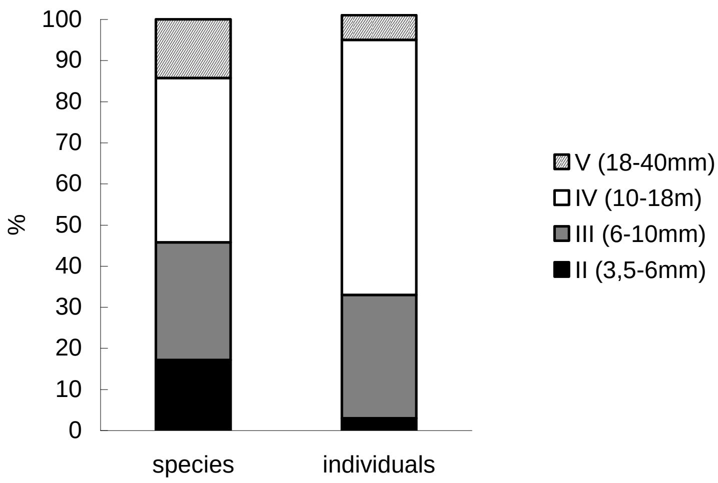

Figure 6 Body sizes across all sampling sites.

At the different sampling sites, the composition of body size categories varied enormously. Large species of category V were most abundant at HBF1 and HBF2, while they were missing completely at HBF3 and FPF1 (Figure 7). Species of category IV were found universally and they form the major amount of total recorded species. Category III species were found at every sampling site except WM2. Finally, smallest recorded species of category II were exclusively found at three sampling sites (Figure 7). WM1 shows the most heterogenic body size composition (4 categories) and WM2 formed the most homogenous one (2 categories).

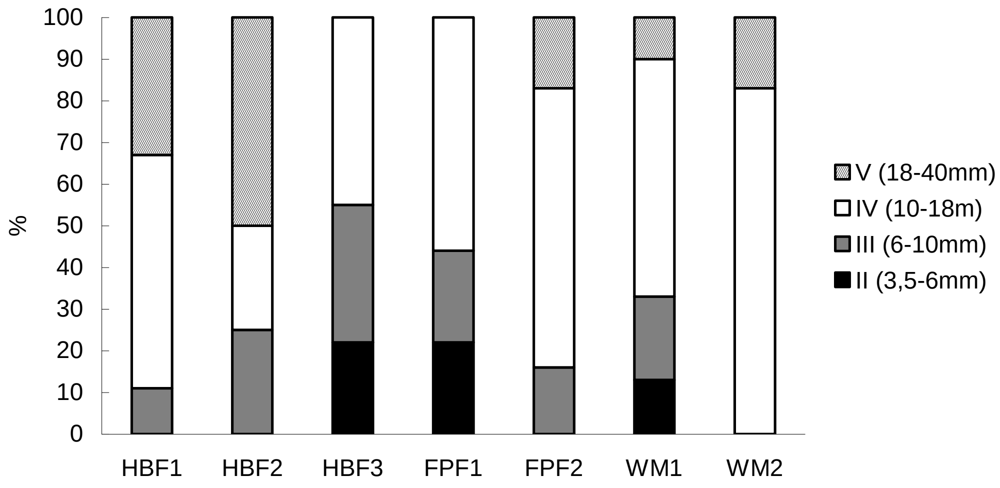

Figure 7 Distribution of body sizes at different sampling sites. Only sampling sites with more than four species were analysed.

3.4. Ecological valence

Euryoecious carabid beetles form both, highest species proportion and highest individual proportion (Figure 8). In total 28 euryoecious species were recorded, with *Abax parallelepipedus*, *Limodromus assimilis* and *Pterostichus melanarius* being most abundant (61% of total caught euryoecious carabids).

Out of seven identified stenoecious species (20% of total recorded species), *Aptinus bombarda*, *Abax ovalis* and *Abax parallelus* were most abundant. *Aptinus bombarda* only appears at two sampling sites (HBF1, HBF2), but forms 55% of total caught stenoecious carabids.

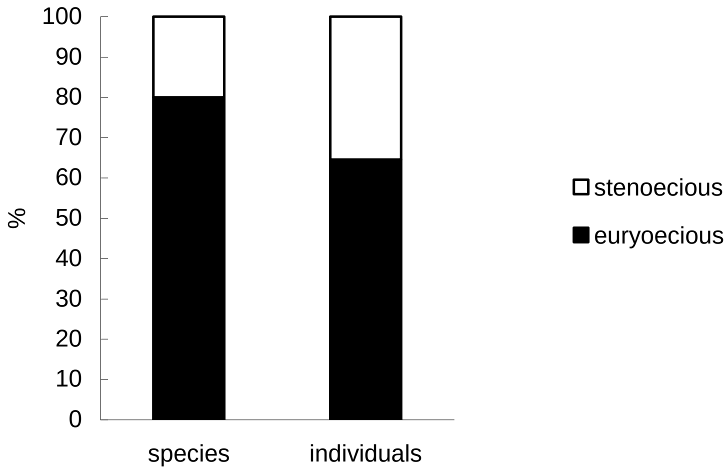

Figure 8 Ecological valence types across all sampling sites.

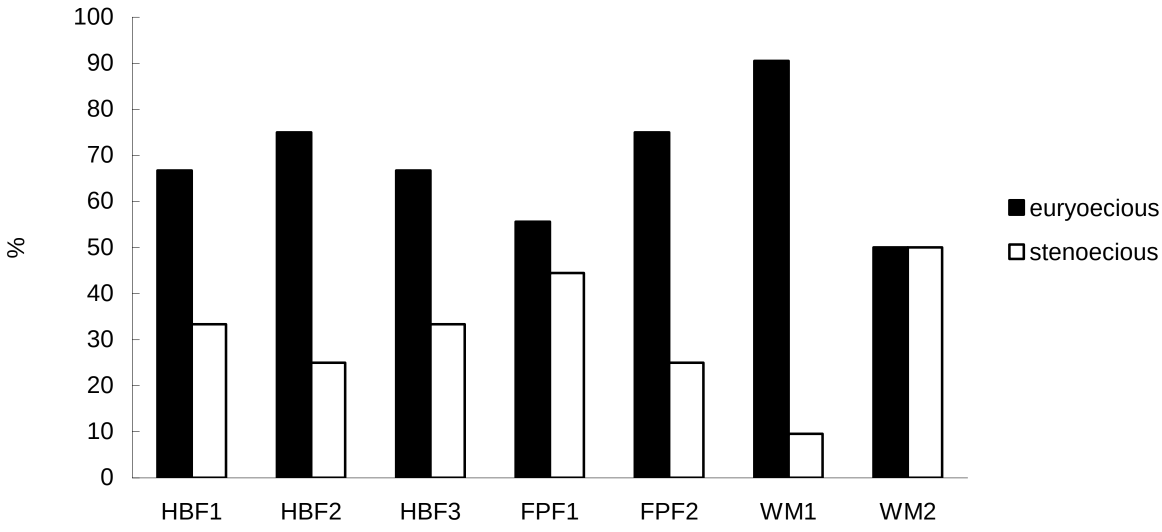

Figure 9 Ecological valence types at different sampling sites. Only sampling sites with four or more species were analysed.

Across all investigated sites euryoecious species made up the majority (Figure 9), except WM2. At this site stenoecious species reached 50%, which is the highest proportion of stenoecious species. At WM1 stenoecious species reached 10%, the lowest proportion among all sampling sites. The most remarkable recorded stenoecious species was *Carabus irregularis*, which was exclusively found at WM2 and only recorded with one individual**.**

3.5. Similarity

Ordination of genus presence/absence data (NMS) separated the sampling sites into two clusters and one isolated site (Figure 10). The first cluster describes carabid assemblages of sites FPF1, FPF2 and WM1. The second cluster consists of the hornbeam forests HBF1, HBF2 and WM2. Solely HBF3 is clearly separated.

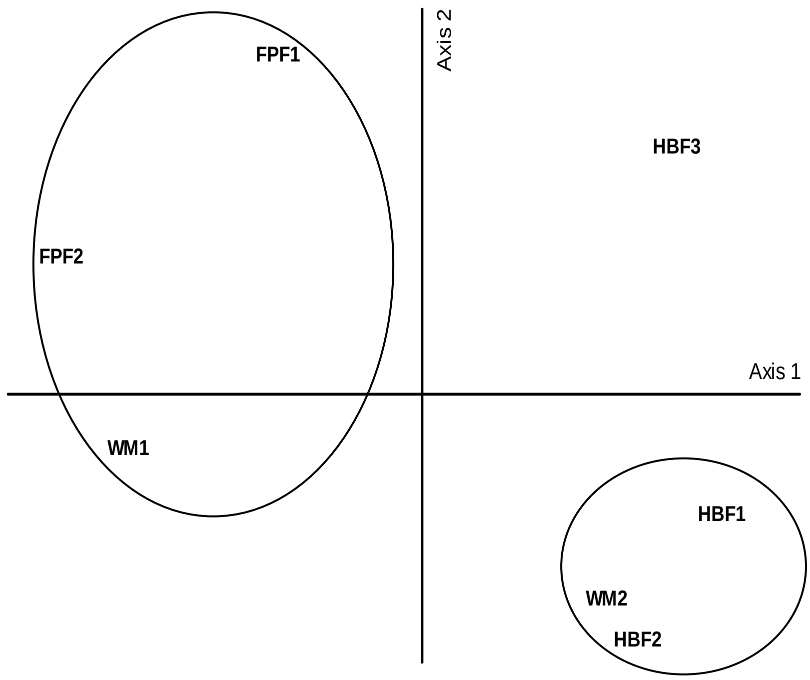

Figure 10 Non-metric multidimensional scaling ordination. Only sampling sites with four or more species were taken into account.

3.6. Characterisation of carabid assemblages

Hornbeam forest 1 (HBF1)

This sampling site shows the highest rate of forest species and a high activity abundance of the stenoecious *Aptinus bombarda*, which appears only at one other site (HBF2). Furthermore HBF1 is characterised by the highest number of representatives of the large and robust species of the genus *Carabus* (*C. hortensis*, *C. intricatus*, *C. scheidleri*). This forest type hosts on one hand specialists like *Cychrus caraboides*, which prefers shady and humid habitats, and on the other hand *Carabus intricatus*, which prefers dry and warm habitats. Mesophile species like *Pterostichus burmeisteri* and *Carbus hortensis* are also present. With *Molops piceus*, a typical inhabitant of hornbeam forest and *Abax ovalis* the whole carabid coenosis describes this sampling site as a closed and stable old forest type.

Hornbeam forest 2 (HBF2)

A similar climatic situation and the same vegetation community offer a similar carabid coenosis like HBF1. All recorded species are again brachypterous and obligate forest species. Only inclination and a higher ground surface fragmentation influences the coenosis in that way that less large and ecological pretentious species, like *Abax ovalis* and *Cychrus caraboides* are missing. Cooler soil surface conditions at the rubble field and surrounding area may be the reason for the missing of *Carabus intricatus*. This is the second sampling site where *Aptinus bombarda* was recorded, but with only one individual. This species was only a kind of “guest species” from adjacent more typical hornbeam forests like HBF1. Finally, the euryoecious forest species *Abax parallelepipedus* reaches a predominant status (88% of all captured individuals).

Hornbeam forest 3 (HBF3)

This last representative of this forest type stays in clear contrast to the sampling sites described before. It hosts the most open habitat preferring species of all investigated sites and the proportion of macropterous species is higher. Species of the genera *Harpalus* and *Amara* are present and were only found at one other site (WM1). With *Metophonus puncticollis* and *Notiophilus rufipes*, which show highest activity abundance, this sampling site can be described as a xero-thermophile habitat. Remarkable is also the lack of all larger carabid species and a higher ratio of very small species (body size below 6 mm).

Oak forest 1 and Oak forest 2 (OF1, OF2)

The carabid coenoses of these two sampling sites are poor in species and probably not well assessed yet. At site OF1 *Carabus intricatus* and *Notiophilus rufipes* were the only recorded species. Both are characteristic representatives of xero-thermophile habitats, which perfectly fit to the sampling site conditions. Nevertheless two species, represented by only one individual each, a serious characterisation is not possible. The same is true for site OF2, where only one individual of the generalist species *Pterostichus burmeisteri* was recorded.

Floodplain forest 1 (FPF1)

As this habitat type completely differs from the before described ones, the carabid assemblage differs as well. Typical representatives of floodplain forests can be found exclusively at this site. *Bembidion tibiale, Paranchus albipes* appear and the floodplain forest specialist *Limodromus assimilis* shows highest individual numbers. All species prefer shady and cool habitats near watersides and are restricted to the investigated floodplain forests and water meadows. Both first mentioned species are even restricted to this sampling site. The whole carabid coenosis is typical for floodplain forests and describes the habitat conditions in a suitable way.

Floodplain forest 2 (FPF2)

This sampling site already shows the character of a water meadow, a forest edge and a floodplain forest. As a result of this habitat aggregation, the second highest species richness is recorded. The stenoecious *Agonum lugens*, which was only found at this sampling site, and the typical floodplain forest specialist, *Limodromus assimilis* indicate a floodplain forest character. *Carabus coriaceus*, which was only registered at this site and *Poecilus cupreus* are likely to be invader species from adjacent grassland and forest edges than indicator species for this forest type. Finally the highest activity abundance of the generalist forest species *Pterostichus oblongopunctatus* was recorded.

Water meadow 1 (WM1)

A suitable characterisation of this sampling site is difficult according to the fact, that various habitat types are situated in close proximity. The high diversity is underlined by 10 species exclusively found at this sampling site. The hygrophile *Patrobus atrorufus*, *Bembidion lampros* and *Pterostichus strenuus* indicate a humid water meadow character. Furthermore, the exclusively record of *Abax carinatus*, underlines this assumption.
Carabus convexus was only found at this site and indicates a kind of forest edge character, while finally representatives of the genus *Amara and Poecilus cupreus* certificate this sampling site as an open habitat. All together, the carabid coenosis of this site describes it more as an ecotone like habitat.

Water meadow 2 (WM2)

With six recorded species this sampling site can not be described as a typical water meadow. According to the unique habitat conditions, caused by the stone wall and high surface fragmentation, the assessed carabid coenosis is different.
Most remarkable is the record of *Carabus irregularis*, a stenoecious forest species which indicates primary forest habitats. This species was only found at this sampling site represented by one individual. The highest abundance of representatives of the genus *Abax* was recorded, in which *Abax ovalis* and *Abax parallelus* underline the high grade of

naturalness. The forest specialist *Cychrus caraboides* appears again and perfectly fits in this moist and shady habitat. Altogether ends in the second highest FAI value (Table 2) and a hideaway for forest specialists.

3.7. Appearance of endangered and remarkable species

Due to the fact that there is actual no red list of Carabid beetles for Austria, data from red lists of Bavaria (LORENZ 2000) were used. In total 11 endangered species were found and are listed in Table 3.

Table 3 Endangerment status of specific carabid beetles of the national park "Thayatal".

Grade of endangerment	Species
Grade 2, strongly endangered	*Agonum lugens, Aptinus bombarda*
Grade 3, endangered	*Abax carinatus, Amara nitida, Carabus intricatus, Carabus irregularis*
Pre-warn list	*Carabus convexus, Carabus scheidleri, Harpalus atratus, Notiophilus rufipes*
Insufficient data	*Molops piceus austriacus*

4. Discussion

This study is the first assessment of carabid assemblages in the national park “Thayatal“. In total 35 species were identified. Compared to some studies of ground beetles in Central Europe (WAITZBAUER 2001, WARNAFFE & LEBRUN 2004, SROKA & FINCH 2006) the recorded number of species seems low, but MAGURA et al. (2003) and FINCH (2005) reported comparable species numbers from forest habitats in Central Europe. Furthermore there are some more aspects to consider**:** firstly, forest habitats are known to display lower carabid species richness than grasslands (MAGURA et al. 2001). Secondly, with the applied method of pitfall trapping some species may have not been assessed, especially those which occur in lower densities or don’t show high activity (GREENSLADE 1964). The problem with the sampling method and assessing the whole diversity of a habitat has been discussed (e.g. SOUTHWOOD 1978, MÜLLER 1984) as well as the question how many traps should be installed (RÜMER & MÜHLENBERG 1988, HÄNGGI 1989, HANDKE 1996, ZULKA 1996). Additionally most of the installed traps were filled with ethylene-glycol, which is a weaker attractant to carabids than for example formalin (BUCHBERGER & GERSTMEIER 1993).

Due the high heterogeneity of the national park “Thayatal” and the resulting manifoldness of different habitats, it was not possible to asses the carabid diversity of every microhabitat. Furthermore heterogeneity may have led to habitat fragmentation effects which minimize the number of carabid species. Habitat fragmentation and its effects on carabid assemblages can be induced by many factors like forest managing, farming, urbanisation or street building (EWERS & DIDHAM 2005, KOIVULA & VERMEULEN 2005, NIEMELÄ et al. 2006, SADLER et al. 2006).

According to all these aspects and the rarefaction curve (Figure 3), more carabid species may be expected. .By investigating more forest habitats and in the first instance the open habitats of the national park more unrecorded species can be expected. Nevertheless, a first characterisation of the habitat qualities and their specifics can already be made by analysing the obtained data.

First of all, the results of this study confirm anew the actuality, that floodplain forests and water meadows form some of the most species rich habitats (see HANDKE 1996, LUDEWIG 1996, ANTVOGEL & BONN 2001, DRAPELA 2004, KRAUSGRUBER 2006). Highest species number (Table 1) and highest value of the Shannon index (Table 2), at sampling site FPF2 and WM 1, clarify this conclusion. A high niche richness, which can be occupied by various carabid species (see “*intermediate disturbance hypothesis”*, CONNELL 1978) may be responsible for this high grade of diversity.

Generally, the grade of disturbance, which can be caused by many factors like flooding, fire, wild boars and human impact, is a main element for the structure of carabid

assemblages (NIEMELÄ et al. 1993, BELAOUSSOFF et al. 2003, SAINT-GERMAIN et al. 2005, TRAUTNER 2006). This was also proved in this study. In particular, the influence of wild boar activity on carabid coenoses was well documented at sampling site HBF3.
Likewise the distribution of habitat preference types points out that closed forest habitats host other carabid assemblages than dynamic forest habitats or open landscapes (NIEMELÄ et al. 1994, KOIVULA et al. 2002). The forest affinity index is a useful tool to point out the quality of an investigated area (MAGURA et al. 2006a). Forest specialists get higher evaluated by the coefficient and therefore can compensate a higher forest generalist number at other sampling sites. In this study sampling sites WM2 and HBF1 showed high values of the FAI which reflect an exceptional stable character of these habitats. The forest seems to have reached a stage of late succession, where special carabids like representatives of the genus *Carabus* appear (see KOIVULA et al. 2002).
Composition of wing morphology may indicate the habitat's grade of disturbance and the stage of succession. Generally, carabid beetles and their wing morphology can explain the dynamic, stability or age of an investigated habitat (HEYDEMANN 1962, DEN BOER 1970, RIECKEN & SCHRÖDER 2002). In dynamic habitats like floodplain forests or water meadows, with periodic flooding as an important disturbance factor, carabid beetles have to be very flexible (NEUMANN 1971, ZULKA 1994). With the development of functional hind wings carabids can react very quickly on environmental changes (MATALIN 2003). This ability is important for surviving in all highly disturbed habitats. After flooding, habitats gain a mainly unsettled character, so that species which are able to fly are more likely to be the first species or pioneer species of these habitats in an early stage succession. Therefore the here investigated floodplain forest sites (FPF1, FPF2) show the highest amount of macropterous species followed by water meadow site WM1 and the wild boar disturbed HBF3 (Figure 5). The carabid coenoses of these habitats form a similar species composition, which is underlined by ordination (NMS, Figure 10). With a decrease of macropterous species and an increase of brachypterous species, the carabid assemblage indicates a more stable and balanced habitat character (PIHLAJA 2006). Results of this study can confirm this conclusion. According to their carabid assemblage sampling sites HBF1, HBF2 and WM2 can be characterised as more stable habitats and they host not even a single macropterous species. Again the ordination (NMS, Figure 10), which groups all three sampling sites in one cluster, underlines this result.
Similar to wing morphology, the body size distribution in carabid assemblages can be used for interpretation of ecological habitat conditions (HEYDEMANN 1964, BLAKE et al. 1994, NIEMELÄ et al. 2002, MAGURA et al. 2006b). Smaller species are more likely to occur in dynamic or early succession stage habitats, while larger species are characteristic for more stable or older habitats. Again, the results of this study (Figure 7) go conform to this theory and concur perfectly with the results of wing morphology types

(Figure 5). Sites HBF1, HBF2 and WM2 are dominated by larger species (category III-V), while smaller species (category I, II) are completely absent (Figure 7). The same sites mainly host brachypterous carabids. Both parameters describe them as stable habitats.

Contrastingly, highly disturbed habitats, like FPF1, WM1 and HBF3, show high rates of small and macropterous carabids. Both morphological parameters divide sampling sites into two completely different clusters (NMS, Figure 10), which were characterised by their own and unique carabid assemblages.

The distribution of the ecological valence types (Figure 9) does not support this conclusion very well, because there is no oblivious difference among sites. In case of the national park "Thayatal" every investigated area seems to offer suitable conditions for various "specialists". Solely WM2 reaches a high rate (50%) of stenoecious species, which underlines the undisturbed, stable and old character of this sampling site.

Generally, stenoecious species show a smaller ecological optimum and therefore count as important indicators for different habitats of different ecological conditions, age or succession grade (THIELE 1967, WAITZBAUER 2001, KOIVULA et al. 2002, LATTY et al. 2005). Therefore the recorded stenoecious specialists and even some euryoecious species can be used to point out differences and similarities of the different habitat types. Several recorded species are typical for dynamic habitats and there are several species typical for old and stable habitats. Both recorded species of the genus *Bembidion* only appear right next to water edges and humid habitats (KOCH 1989, HURKA 1999, MEITZNER et al. 2006). Therefore these carabids were only recorded at FPF1 and WM1, where such conditions are met. Traps at FPF2 and WM2 were installed several meters away from water edges, which fact may already cause the absence of representatives of this genus. *Abax carinatus*, *Agonum lugen*s, *Limodromus assimilis* and *Patrobus atrorufus*, were also only recorded at dynamic habitats. On the other side, *Aptinus bombarda*, *Molops piceus* and most representatives of the genus *Carabus* indicate old and stable habitat conditions. All these species can be used as indicators to separate the floodplain forests and water meadows from the remaining forest types. This separation was clearly indicated by ordination (NMS) and different composition of morphotypes (wing morphology, body size).

With 11 species mentioned on red lists, nearly one third of all captured species, the national park serves as an important hideaway for some rare carabid species.

Summarising, all assessed carabid assemblages describe forest communities of the national park "Thayatal" as relatively young forests with some relict forms as follows:

On one side, *Carabus irregularis, Abax ovalis* and *Abax parallelus* strongly indicate old or even primary forests (see KÖHLER 1996), but the absence of typical representatives of old and natural forests, like *Carabus violaceus* or *Carabus auronitens* on the other side, displays impacts of historical management in the investigated forests (see ASSMANN 1999, WAITZBAUER 2001).

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7. Appendix

	HBF1	HBF2	HBF3	OF1	OF2	FPF1	FPF2	WM1	WM2
Abax carinatus								x	
Abax ovalis	x		x			x		x	x
Abax parallelepipedus	x	x	x			x	x	x	x
Abax parallelus			x			x	x	x	x
Agonum lugens							x		
Amara aulica								x	
Amara communis			x						
Amara nitida								x	
Aptinus bombarda	x	x							
Bembidion lampros								x	
Bembidion tibiale						x			
Carabus convexus								x	
Carabus coriaceus							x		
Carabus hortensis	x	x						x	
Carabus intricatus	x			x					
Carabus irregularis									x
Carabus scheidleri	x	x					x	x	
Cychrus caraboides	x								x
Harpalus atratus			x						
Leistus ferrugineus								x	
Limodromus assimilis						x	x	x	
Metophonus puncticollis			x						
Molops piceus	x		x			x	x		
Nebria brevicollis							x	x	
Notiophilus biguttatus			x						
Notiophilus rufipes			x	x		x			
Paranchus albipes						x			
Patrobus atrorufus								x	
Poecilus cupreus							x	x	
Pterostichus burmeisteri	x				x		x	x	
Pterostichus melanarius						x	x	x	
Pterostichus niger								x	
Pterostichus oblongopunctatus							x	x	x
Pterostichus strenuus								x	
Trechus quadristriatus								x	