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Renaturation of hybrid poplar stands with the example of xylobiontic fauna in the "Regelsbrunner Au" (Nationalpark Donau-Auen in Lower Austria)

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Renaturation of hybrid poplar stands with the example of xylobiontic fauna in the "Regelsbrunner Au" (Nationalpark Donau-Auen in Lower Austria)

durchgeführt am

Department of Conservation Biology, Vegetation and Ecology
Faculty of Lifesciences
University of Vienna

Wien, im Mai 2009

Foreword

15 years and some experience of life lie now between the beginning and completion of this thesis. Thanks to the support of friends, encouraging colleagues and my very patient advisor Univ.-Prof. Dr. Wolfgang Waitzbauer, I succeeded in finishing this project.
In the meantime much has changed around my former sampling sites in the "Regelsbrunner Au". This 411 ha area originally belonging to the WWF has 1996 become part of the "Nationalpark Donau-Auen", and now stretches along 38 km of the Danube. Today the formerly well-maintained forest tracks are overgrown and the sample sites can scarcely be identified. As a result of the termination of forestry operations ("Außer-Nutzen-Stellen") and various projects for renaturation, a once monotonous commercial forest has become near-natural floodplain forest. Today standing and fallen deadwood is abundant, thanks in no small way to the lively activities of beavers.

Figure 1: Regelsbrunner Au December 2008 [1]

[1] All un-referenced pictures are private material

ABSTRACT

Ancient trees are precious – there is little else on earth that plays host to such a rich community of life within a single living organism.

(Sir David Attenborough 2002)

Der WWF hat 1989 ein 411 ha großes Areal der Regelsbrunner Au erworben, um diesen monotonisierten Hybridpappelforst durch sofortiges Außer-Nutzen-Stellen und gezielter Renaturierungsmaßnahmen in einen naturnahen Auwald rückzuführen.
Auf Grund der kurzen Umtriebszeiten fehlte Totholz weitgehend, somit dem Wald Lebensraum und Nahrungsquelle für eine Vielzahl von spezialisierten Organismengruppen.
Ziel dieser Arbeit ist es, eine erste Bestandsaufnahme der xylobionten Fauna in Abhängigkeit zur Renaturierungsmaßnahme: Löcherhieb mit (LmA) und ohne Abtransport (LoA) der Stämme und Dickungspflege (Di) zu erheben.

In 1989 the WWF acquired a 411 ha area in the "Regelsbrunner Au" in Lower Austria to revert the commercial monocrop of hybrid poplar (*Populus canadensis*) to a natural floodplain forest. This was achieved by immediate cessation of the forestry management of large, contiguous areas and the deployment of specific schemes for renaturation.
Due to short production turnovers, dead wood, and therefore the forest habitat and food source for many specialized organism groups, was scarce.
The aim of this study is a first survey of the xylobiontic fauna using three different methods of renaturation: group selection with (LmA) and without (LoA) removal of trees, and juvenile spacing (Di).

1 Introduction

Figure 2: Sample sites (BEV Luftbild vom 17.08.2006 Bruck an der Leitha, Streifennummer 4, Bildnummer 4095)

The issue of deadwood has received increasing attention during recent decades. Furthermore, ever more research is being done on the mutual interaction between deadwood and dependent species (FUNKE 1979, KÖHLER 1991, KLAUSNITZER 1994). According to „Hemerobie Österreichischer Waldökosysteme" (GRABHERR, KOCH, KIRCHMEIR, REITER; 1998), 3% of the forest area can be categorized as natural, 22% as semi-natural. Criteria for this categorisation have included "quantity of deadwood", "diversity of tree species" and "intensity of human utilisation", amongst others.

47% of Austria is forested. 85% of this area is in one or another way used economically (commercial, protective, recreation). The amount of deadwood and old growth has significantly decreased with the intensification of forestry. The propagation of highly-productive monocrop and thinning methods introduced subsequently have resulted in short turnover times. Deadwood in all stages of decay contributes significantly to the diversity of species within the forest habitat and can also be used as an indicator for its naturalness (cf. RECKENDORF, HEILER, HEIN, KECKEIS, LAZOWSKI, W. & P. ZULKA, 1998).

Many organisms are closely bound to dead or dying wood and, because of this high degree of specialisation, tend to rarer species. Approximately a quarter of all Austrian and German beetle species are either directly or indirectly dependent on deadwood. In Germany 60% of this group are categorized as vulnerable, a significantly higher proportion than in other insect groups (SCHIEGG, 1998). According to the MOBI-e report (April 2006), two thirds of extinct beetle species belonged to forest species dependent on deadwood and old growth.

The aim of this study is a first survey of the sub-bark and surface fauna of fallen deadwood in the area of the "Regelsbrunner Au", a floodplain forest along the Danube in Lower Austria. The emphasis is on the comparison of 3 different methods of renaturation: group selection with (LmA) and without (LoA) removal of trees, as well as juvenile spacing (Di).

2 Study Sites

The area of the "Regelsbrunner Au", with its long meandering streams and extended stretches of gravel, is today part of the "Nationalpark Donau-Auen", established in 1996. The park ranges along the river Danube for 38 km downstream from Vienna to the confluence with the March at the Slovakian border. Its width extends to a maximum of 4 km. The influence of the continental Pannonian climate is predominant, resulting in hot and dry summers and cold winters with little snow.

In 1989 411 ha of the "Regelsbrunner Au" were purchased by the WWF (World Wide Fund for nature), who in 1991 subsequently set up a scheme to re-nature the commercial monocrop of hybrid poplar (*Populus canadensis*) to a semi-natural floodplain forest.
This was achieved by immediate cessation of the forestry management of large, contiguous areas and the deployment of specific schemes for renaturation.

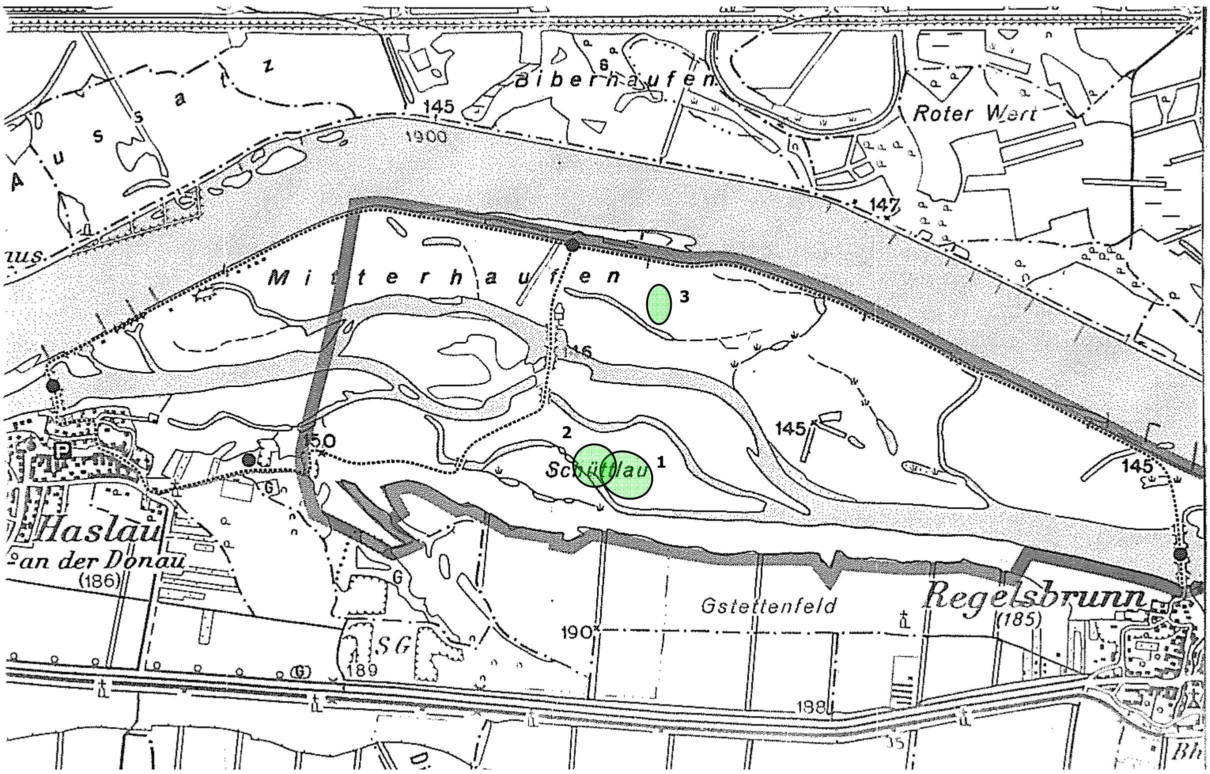

Figure 3: Sample sites (Site 1: group selection without removal (LoA), Site 2: juvenile spacing (Di), Site 3: group selection with removal (LmA); from: Gebietskarte der Regelsbrunner Au, NÖ; 1:13000; Herausgeber: WWF)

At the time of investigation (1993/94) 60% of the area was populated by *Populus canadensis* with no significant old growth (70% max. 30 years old). A further 10% consisted of *Robinia pseudoacacia*, *Ailanthus altissima* and *Populus balsamifera*. This composition originated from the preceding decades of commercial forestry use. After short turnover periods of only 30-40 years, large areas (~2 hectares) had been cleared completely. The ground was then leveled up with bulldozers

(EICHELMANN 1992). All mature, healthy trees were therefore felled and removed, leaving a total lack of deadwood and diversity of age distribution.

The survey of the deadwood fauna of the "Regelsbrunner Au" between April 1993 and April 1994 was limited to 3 areas treated with different renaturation methods according to the WWF scheme.

2.1 Description of the renaturation methods and the examined areas (cf. HAJEK 1994)

2.1.1 Site 1: group selection without removal of trees – "Löcherhieb ohne Abtransport" (LoA)

Group selections of 0.1-0.3 ha are cut and the whole trees are left at the site similar to the natural cycle. Thus the crowns of the felled trees protect the new saplings against game bite.

Figure 4: Site 1 (LoA): (XI-Schüttelspitz: Fläche 8)

The site is characterized by *Solitago gigantea* with a coverage of 40%. Followed by *Rubus caesius* with 30% and *Cirsium arvense* with approximately 10%.
Total coverage: 95%

2.1.2 Site 2: juvenile spacing – „Dickungspflege" (Di)

Hybrid poplars within an extended area of young growth are felled if a sapling of a typical floodplain forest species germinates underneath their canopy. Thus a hemerobic young growth can gradually be transformed into a natural one. The chopped wood is left on the site.

Figure 5: Site 2 (Di): (XI-Schüttelspitz: Fläche 6)

Site 2 (Di) is separated only by a forestry track from site 1 (LoA). Both are enclosed by streams. The understorey is dominated by *Allium ursinum* (90%). The remaining 10% are mainly *Urtica dioica*.
Total coverage: 70%

2.1.3 Site 3: group selection with removal of trees – „Löcherhieb mit Abtransport" (LmA)

Procedure as at site 1 with the exception that the logs are removed to be sold. Only the branches and twigs of the crowns are left at the site.

Figure 6: Site 3 (LmA): (III-Mitterhaufen: Fläche 10)

Site 3 is situated nearest to the bank of the Danube. *Urtica dioica* and *Glechoma hederacea* characterize the site with approximately 60%, respectively 30% coverage.
Total coverage: 90%

3 Materials and Methods

3.1 Sampling period and sampling method

Sampling and investigations on the 3 sites took place April – November 1993 at 7-day intervals and later from November 1993 – April 1994 once a month. 2 trunks per site and day (total 168 trunks) were manually examined along a length of 50 cm. Trunks were first examined at the surface with exhaustor and forceps (surface catches), then the bark was stripped off layer by layer and sampled as well (sub-bark catches). Finally the bits and pieces of the bark were re-examined by sieving using a "Reitersieb".
All individuals were preserved in 70% ethanol.
During all catches additional variables, such circumference of the trunk, time of day, temperature and weather conditions, were recorded as well.

3.2 Classification

All material was classified to family level. Further identification of species was done for most of the adult and juvenile Coleoptera and for some Diptera, since these groups serve as indicators for various micro-ecosystems.
The breeding of selected groups of Diptera from larvae to imago helped in the classification of collected larvae and pupae.

3.3 Selection and properties of the trunks

The wood investigated came exclusively from hybrid poplars (*Populus canadensis*) cut in 1991. The selection of single trunks was more or less random, although I tried to ensure the trunk was in thorough contact with the ground over its whole length, or in some cases with only minimal distance to the ground's surface. Upright deadwood undergoes a different decay process (SCHIMITSCHEK 1953) and therefore was not included into this study.
The area of the trunk (mid section or end) that was sampled was either random or simply a result of practical accessibility.
Smaller structures like branches with less than 6 cm diameter were not examined.
The texture of the bark as well as the condition of its outer and inner layers were also recorded.

3.4 Origin of deadwood and phases of decay

"Deadwood" is the collective term for all dead trees of a forest, either standing or supine. The origin can be from commercial use (logging, branches and brush-wood as leftovers in a commercial forest),

as well as natural (wind throw, fire, parasites and diseases, competition for light/water/nutrients, and to a lesser degree ageing).
It can take 100 years or more for a tree to decompose completely, depending on the species, the diameter of the trunk, the microclimate, whether the trunk is upright or supine, and whether the site is exposed or shaded.
In the course of its decay dead wood gradually changes its structural and chemical properties until finally it becomes homologous with the soil.

The surrounding, local and micro-climatic conditions play an important role in the slow process of decomposition, the consistency of the wood itself to a lesser extent. Thus it is impossible to define general rules of how the decomposition of a trunk takes place (BRAUNS 1954).
SCHIMITSCHEK (1954) describes how various stages of decay in the same piece of trunk can be observed at the same time. Different micro-climatic conditions at the top, the bottom and the front of the log alone can lead to different decay conditions.

Because of this micro-climatic heterogeneity, GEISER (1989 a) emphasises that an overly-detailed categorisation of old growth and deadwood biotopes for xylobiontic beetles does not make sense.

Generally, the bark of a tree that dies off remains undamaged, providing significant resistance to penetrating insects.

In this first phase of colonisation mainly Scolytidae, Cerambycidae and Buprestidae (i.e. primary xylobionts) can be observed. Since food is scarce, their larval development frequently takes several years.
As soon the bark's structure is mechanically broken down by mining Rhizophagidae, Anobiidae and Lymexylonidae follow. Fungi and micro-organisms facilitate this process by the degradation of cellulose and lignin.

In the following disintegration phase the bark peels off the trunk. Depending on the condition of the underlying wood, various insects penetrate according to their ecological preferences (availability of mining ducts, semi-decomposed wood, predators of primary xylobionts).
Typical representatives are Pyrochroidae (e.g. *Pyrochroa coccinea*), Elateridae and Formicidae.

During the phase of humification the decay of the wood proceeds until it finally merges with the top soil. Larvae of Diptera, Collembola and Acari as secondary xylobionts, as well as Lumbricidae and Formicidae together with fungi and bacteria, transform duff into humus.

The factors "moisture" and "texture" have to be emphasised because of their high significance for the population of the wood by insects. In particular, moisture contributes a great deal to the development

and survival of the larvae of numerous xylobiontic species (BRAUNS 1954, DERKSEN 1941, SCHIMITSCHEK 1954).
Further factors are insolation, total quantity of wood, degree of decay, fungal infections, conditions of the bark and as limiting parameter for the xylobiontic fauna the isolation of single deadwood trunks.

3.5 Deadwood as micro-habitat

In fallen deadwood the conditions (e.g. gradients of light and humidity) are more uniform. Changes due to weather conditions occur more abruptly. Due to the higher moisture levels the process of decay is accelerated (KÖHLER 1991).

However, not every dead tree has the same importance for deadwood specialists. Thick trunks provide an energetically favourable ratio between effort and benefit. The thicker the trunk the higher the number of different micro-habitats and thus the occurrence of different insect species (HEIß 1991). This means that the diversity of structure increases with the age.

Moreover deadwood has important functions (abstract from WWF 2006)

1) Maintaining forest productivity by providing organic matter, moisture, nutrients and regeneration sites for conifers – some tree species germinate preferentially on logs
2) Providing habitats for creatures that live, feed or nest in cavities in dead and dying timber, and for aquatic creatures that live in the pools created by fallen logs and branches
3) Supplying a food source for specialised feeders such as beetles and for fungi and bacteria
4) Stabilising the forest by helping to preserve slope and surface stability and preventing soil erosion in the event of storms, heavy rainfall and other climatic extremes
5) Storing carbon in the long-term, thus mitigating some of the impacts of climate change

3.6 Data analysis

The calculation of diversity (Margalef Index) and evenness (reverse Simpson Index) were performed by the computer programs PRIMER v6.1.6 (Plymouth Routines In Multivariate Ecological Research) and EstimateS v8.0. The presentation of the dominance follows the logarithmic classification of ENGELMANN (1978).
Rarefaction curves (Software: PAST v1.82 PAlaeontological STatistics; Logarithm KREBS 1998) give an estimate for the completeness of the species inventory of a certain zoenosis.
Cluster analysis (Software: PRIMER v6.1.6) based on present/absence data of surface and sub-bark fauna reveals similarities between sites.
For the calculations no distinction was made between families and species.

3.7 Microclimate

Complementary to each sampling, temperature was measured with a simple thermometer underneath the bark (cf. NICOLAI 1985), on the surface (top and bottom of the trunk), as well as air temperature in the shade. At site 1 (LoA) air temperature in the sun was also measured.

Both insolation and degree of decomposition varied greatly between the different sites hence a heterogeneous arthropod population can be expected.

3.8 Critique of methods

Due to the short preparation time for this investigation, certain sampling methods e.g. stem-eclector (cf. NICOLAI 1985, BÜCHS 1988 and PFARR 1990; BÜCHS additionally developed even a "Borkenemergenz"-eclector) could neither be tested nor deployed.
Furthermore, as a result of the tedious sampling method (1-3 hours per tree) relatively few samples could be retrieved. Hence the scope of the sample size does not meet the requirements of a solid statistical evaluation.
Such snap-shots also represent a more or less random assortment of various parameters (weather conditions, daytime, season, activity of animals, etc.). They should be interpreted with caution, especially when being used to compare different types of habitats.

3.9 Xylobiontic beetles and flies as indicators for the naturalness of a forest

In the course of evolution xylobiontic beetles have specialized to exploit deadwood and thus are dependent on the availability of certain structures, various degrees of decomposition or burrows. Hence they can be indicators for the quality of a woodland, for the diversity of available woody substrate and thus for the degree of "naturalness". Consequently xylobiontic beetles are useful for the evaluation of woodland habitats.

Because of their feeding habits and food source the larvae of diptera also play an important role in the decomposition of wood, and so are examined more closely in the present investigation.

4 Results

Figures 7-9 display the **temperature profile** during the whole investigation period at the three sites.

Site 1: group selection without removal of trees (LoA)

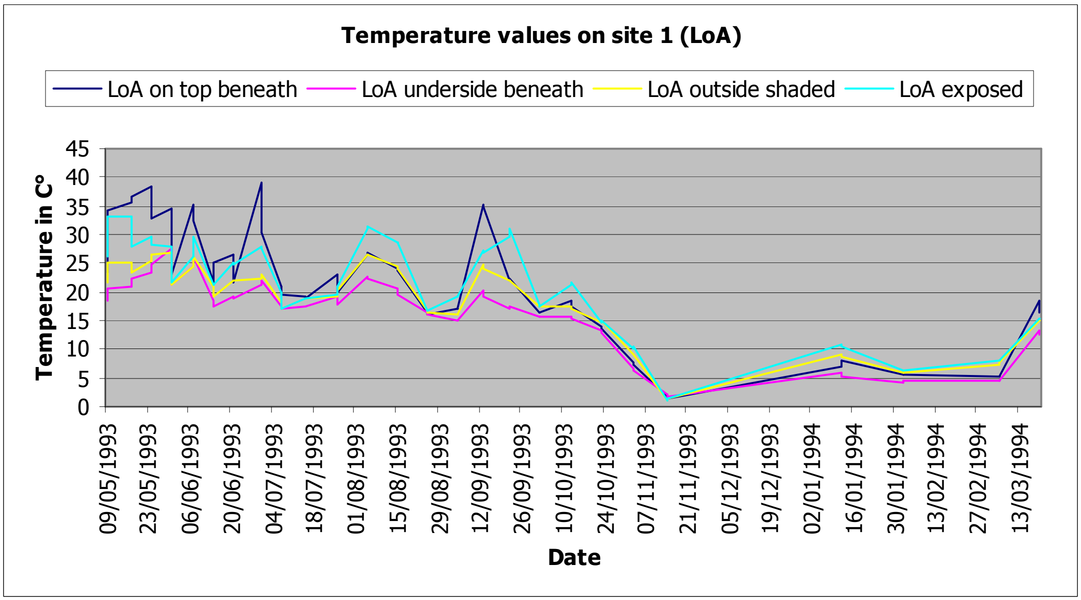

Figure 7: Temperature values of site 1 (LoA)

Site 2: juvenile spacing (Di)

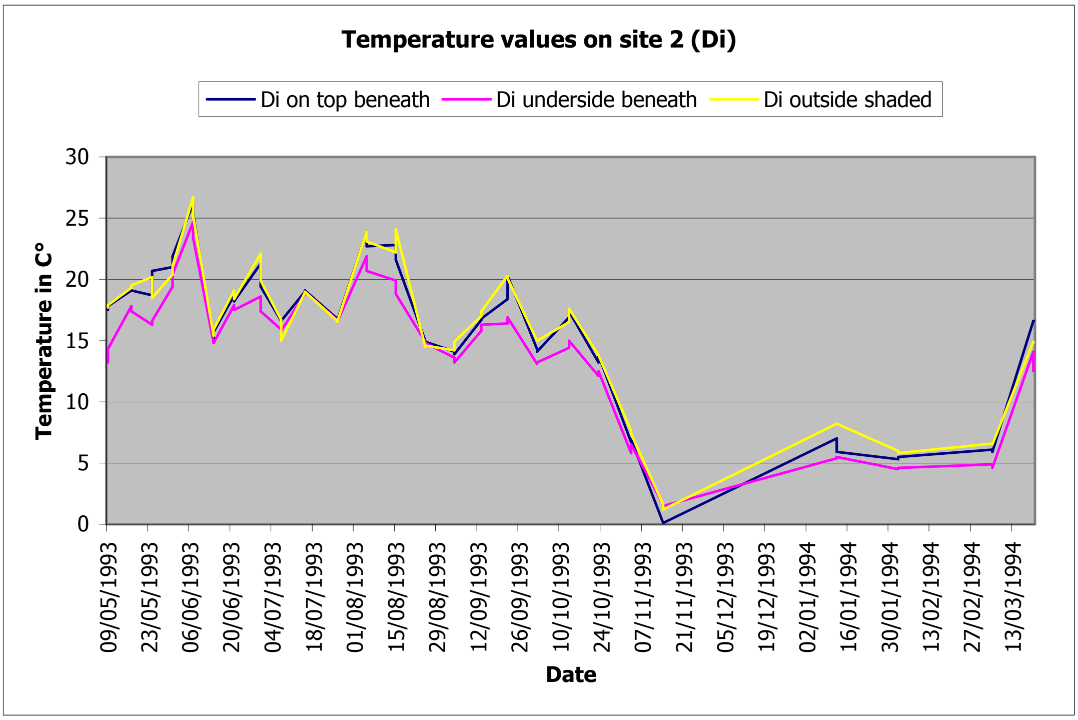

Figure 8: Temperature values of site 2 (Di)

Site 3: group selection with removal of trees (LmA)

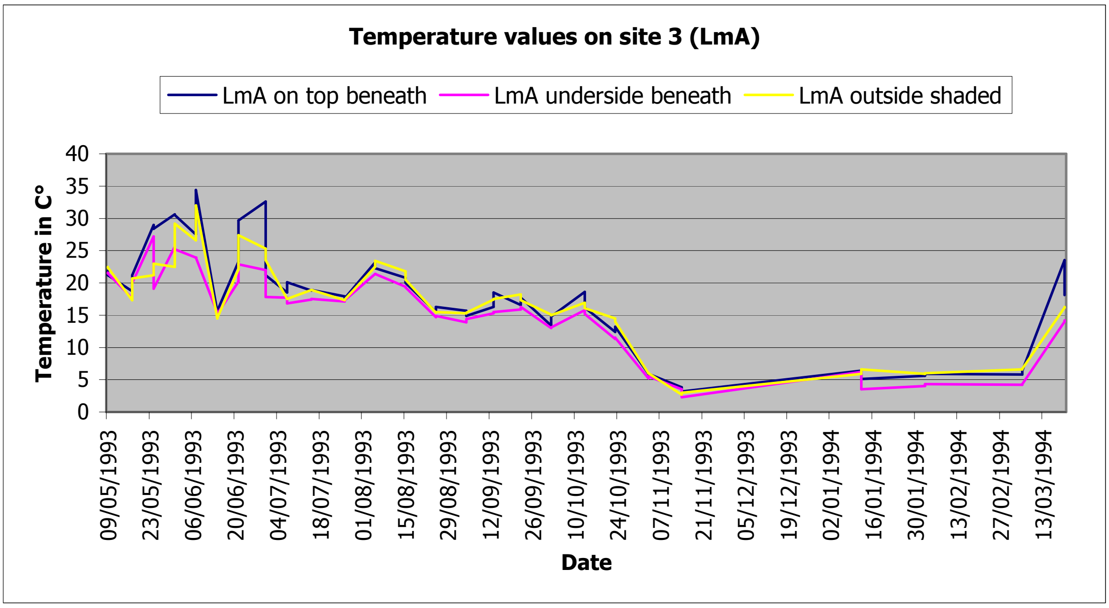

Figure 9: Temperature values of site 3 (LmA)

In 61.5% of all cases at site 1 (LoA) the temperature underneath the bark (taken on the top side of the trunk) was higher than on the bark's surface, and 46% even exceeded the measurements taken in the sun. In 58 % of the cases at site 3 (LmA) and only 30.8% at site 2 (Di) the temperature underneath the bark was higher. The lowest average variation in temperature was found to be 1.6°C at site 2 (Di), the highest being 4.6°C at site 1 (LoA).

These measurements demonstrate that insolation at site 1 (LoA) was highest with the lowest coverage of shading vegetation compared to the other two sites. Besides that there might also be the moderating influence of the proximity of the river Danube at site 3 (LmA).

The **various textures of the trunk surfaces** are illustrated in figure 10 and table 1.

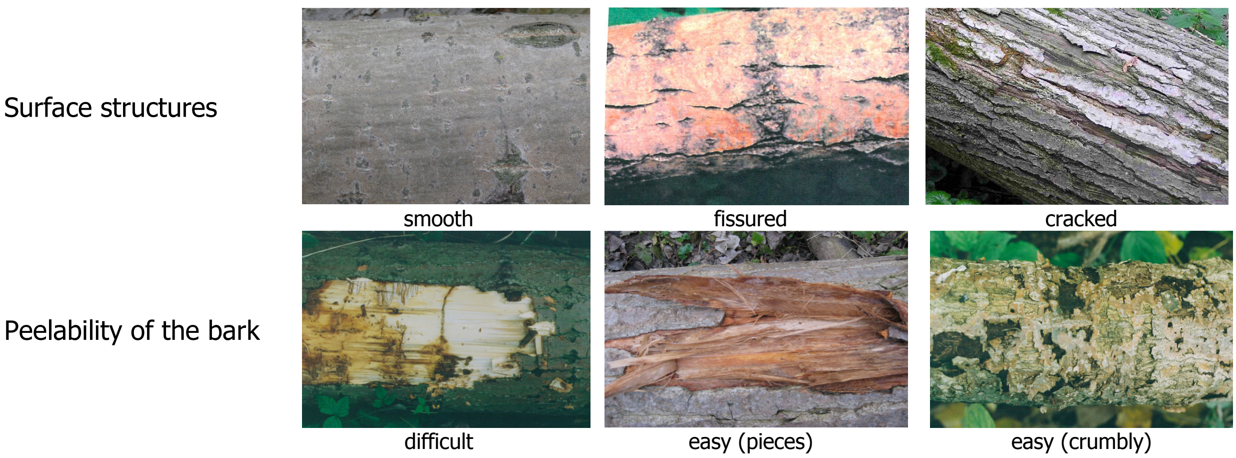

Figure 10: Description of the investigated trees at the three sample sites.

		Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
Mean trunk diameter		25 cm	22 cm	19 cm
Bark	smooth / slightly fissured	61%	41%	41%
	heavily fissured / cracked / heavily cracked	39%	59%	59%
Peelability outer layer (SäS)	difficult	48%	0%	4%
	easy	52%	100%	96%
Peelability inner layer (SiS)	difficult	39%	0%	4%
	easy	61%	100%	96%

Table 1: Description of the investigated trees at the three sample sites (n=56 pro site).
Bark texture categories: b1: smooth and b2: slightly fissured have been summarized as well as b3: heavily fissured, b4: cracked and b5: heavily cracked

According to the categorisation in table 1, 61% of all trunks investigated at site 1 (LoA) belonged to the smooth/slightly-fissured group, and 39% to the heavily-fissured, cracked and heavily-cracked type. At either of the two sites the situation is reversed. The insolation at site 1 (LoA) is highest hence the conditions for a quick decomposition are least likely. 42% of all investigated trunks of category b1 and b2 have been found here.
However, 78% of all organisms (70% Diptera and 4% Coleoptera) were been found underneath almost undamaged bark (bark type b1: smooth, b2: slightly fissured). At site 2 (Di) and site 3 (LmA) were hardly any trunks of type b1. Over 90% of all organisms were here found underneath bark, which was already broken.

The **peelability of the topmost bark layer** was rated 'difficult' for 48% of all trunks at site 1 (LoA), whereas this type was near absent at the other two sites. Here the topmost layer of the bark was found to be easy to peel off, though the surface was sometimes still little affected by decomposition.

The **peeling of the bast layer** down to the sapwood was rated 'easy' at these sites (2 (Di) and 3 (LmA), as well. However, at site 1 (LoA) the inner layers could not be peeled in 39% of all trunks. 21% of the investigated trunks at this site (n=56) are still in a condition of little decay (according to bark type b1 and b2 and the peelability of inner and outer layer). Nevertheless 51% of all individuals at site 1 (among them 63% of the Brachycera) have been found here.

The **total number of individuals** on all three sites was 11269, comprising 18 orders, 94 families and 110 species. The largest proportion was found at site 1 (LoA) with 48.8%, followed by site 2 (Di) with 26.6% and site 3 (LmA) with 24.6%.

Sample Site	Total Number of families/species found on this site	Total Number of Individuals	Diversity (Margalef's Index d)	Evenness (Simpson 1-λ)
LoA surface	72	367 (29.3%)	12.53	0.94
Di surface	52	430 (36.4%)	8.41	0.86
LmA surface	58	455 (36.3%)	9.31	0.87
Σ		**1252**		

Sample Site	Total Number of families/species found on this site	Total Number of Individuals	Diversity (Margalef's Index d)	Evenness (Simpson 1-λ)
LoA sub-bark	75	5129 (51.2%)	8.66	0.81
Di sub-bark	84	2566 (25.6%)	10.57	0.92
LmA sub-bark	104	2322 (23.2%)	13.29	0.95
Σ		**10017**		

Table 2: Diversity and Evenness Indices for the three sample sites on the surface and underneath the bark; in parentheses percent values.

As **indicators for diversity and evenness,** Margalef's and Simpsons 1- λ index were used. Compared to other indices these two have proven robust (assuming a Gaussian distribution) in relation to sample size and distribution of species richness (LANDE 1996; MOUILLOT & LEPRETRE 1999). Strictly speaking, Margalef's diversity index is not a measure of diversity, as it does not include any component of evenness. The index will be independent of the number of individuals in the sample only if the relationship between S (or S - 1) and ln(N) is linear.

The high evenness and low diversity in table 2 indicate heterogeneous distribution of only few species.

In comparison, the **abundance values** in table 3 show that at all three sites the number of individuals/10cm^2 would be very similar if the 18th sample from 13. Sept. 1993 were excluded. At that time 1343 larvae of the subfamily Phaoniinae (Diptera) were found. However, this extremum is included in all following calculations.

Abundance/10 cm^2	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
surface fauna	0.02	0.02	0.03
sub-bark fauna	0.23 (0.15)	0.13 (0.13)	0.14 (0.14)

Table 3: Abundance values by comparison; in parentheses values without data from 13.9.1993.

The species composition matches at all three sites up to 18% for surface species and up to 29% for species found underneath the bark (table 4).

Number of families/species found on all three sites	
surface fauna	21 (18%)
sub-bark fauna	43 (29%)

Table 4: Number of families/species which are caught on all three sites

Listing the number species/families shared between two sites (table 5), then site 2 (Di) and 3 (LmA) have more in common than sites 2 and 1 (LoA).

matching families	Site 2 (Di) surface/sub-bark	Site 1 (LoA) surface/sub-bark
Site 3 (LmA) surface/sub-bark	28% / 41%	28% / 34%
Site 2 (Di) surface/sub-bark	-	24% / 31%

Table 5: Number of matching families/species in percentages on the surface and underneath the bark

The fact that no less than 33% of all families/species on the surface (table 6) have been found exclusively at site 1 (LoA) is due to the sampling method (see chapter critique of methods). Trunks on this site are more easily accessible, causing fewer disturbances, so a higher number of swift or elusive species could be caught.

An explanation for the 24% of sub-bark families/species found exclusively at site 3 (LmA) could be the different microclimate due to the proximity of the Danube. Higher humidity might result in an accelerated decomposition of the bark and thus providing better conditions for specialised taxa.

exclusively on one site	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
surface fauna (n=116)	33%	13%	13%
sub-bark fauna (n=149)	15%	13%	24%

Table 6: Number of families/species caught exclusively on one site

The **Rarefaction curves** in figure 11 show that the sub-bark fauna could obviously not be covered completely. According to the graphs, site 1 (LoA) has the lowest number of species together with the highest total of individuals, whereas at site 3 (LmA) the highest number of species can be observed.

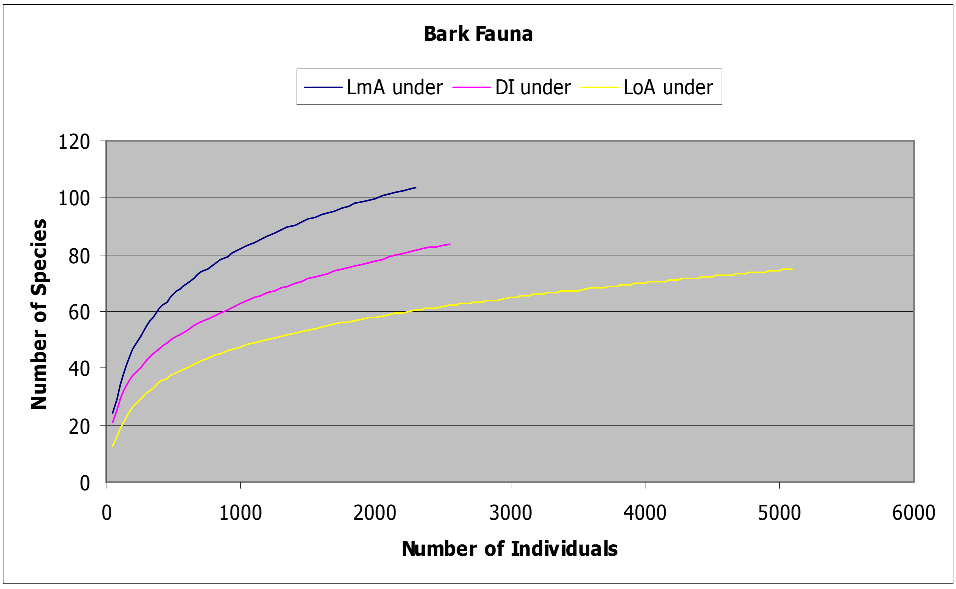

Figure 11: Rarefaction curves (program: PAST v1.82) for the sub-bark fauna of all three sites

Graphs do not plateau even for surface fauna (figure 12), but the distribution is different. In this case, site 1 (LoA) shows the most species together with the lowest number of individuals. Site 3 (LmA) and 2 (Di) are very similar with more individuals but less diversity.

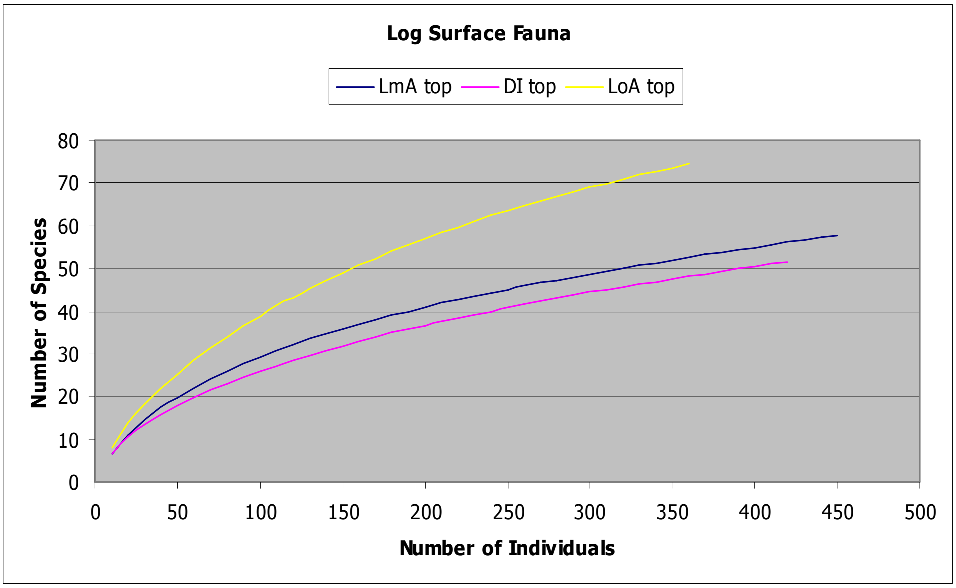

Figure 12: Rarefaction curves (program: PAST v1.82) for the surface fauna of all three sites

The **cluster analysis** in figure 13 shows a clear distinction between surface and sub-bark fauna, and a close similarity between the sites 2 (Di) and 3 (LmA).

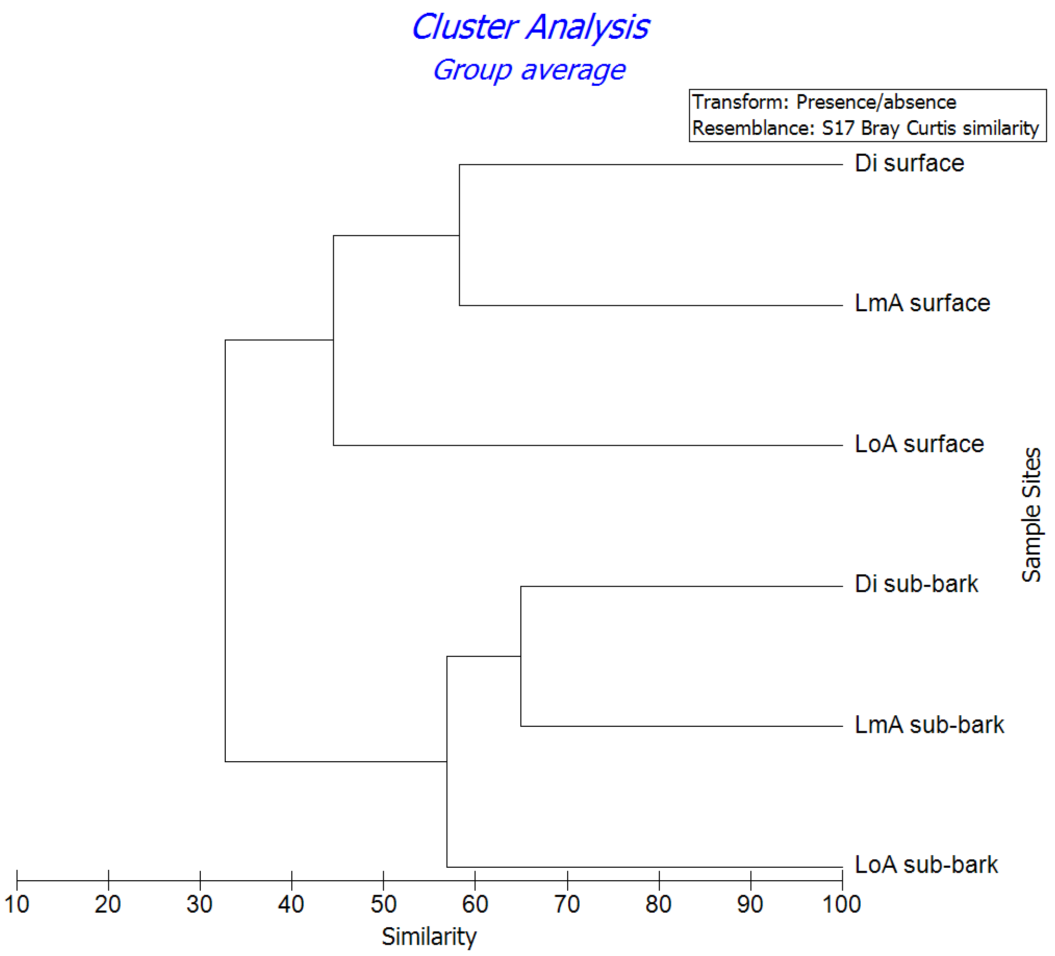

Figure 13: Cluster analysis (program: PRIMER v6.1.6; presence/absence) of the three samples sites

4.1 Biology and ecology of coleoptera and their larvae

When listing the beetles dependent on deadwood its necessary to consider not only the xylophagous species, but also the complex, xylobiontic communities of the various stages of decomposition of wood. This comprises dwellers of decay, classes of fallen logs and xylobiontic fungi as well as their highly specialized predators. Numerous species live in and on wood of various phases of decay, in lignicolous (wood-decaying) fungi and in the leaf litter. Though originally a single-crop silviculture, the foerna still offers a wide range of niches.

Among the observed 44 identified species from 31 different families 59% can be rated as dependent on deadwood, or at least as facultative deadwood dwellers. A species is referred to as 'facultative deadwood beetle' if it is capable to pass its development cycle in deadwood as well as in other habitats (KÖHLER 1991). The remaining 41% originate from other habitats, and ended up in the various investigated structures of deadwood for hibernation, foraging or simply by chance.
Deadwood beetles rely on particular tree species to a lesser extent than on special structures or microclimates.

Good examples of this include ***Cucujus cinnaberinus*** (Cucujidae) and ***Uleiota planata*** (Cucujidae). Following the classification of KÖHLER (1991) both are bark dwellers (corticole). Here it is not the species of tree which is essential, but the properties and quality of the bark habitat with large enough trunks. According to the FFH-Guidelines 2005, Austria has the largest populations of *Cucujus cinnaberinus* within the EC territory (then EC 15) and so bears a great responsibility for the conservation of this species.

The occurrence of various groups of coleoptera can only be interpreted with due reservation, since the sample size is too small after just one vegetation period.

During the period of investigation (1993/94) a total of 1813 individuals (surface and sub-bark catches; imagines and larvae) from 32 different families could be identified. At the sites 2 (Di) and 3 (LmA) the imago to larva ratio was found 60% to 40%, whilst at site 1 (LoA) the opposite was true. 99% of all individuals at the surface were imagines.

Staphylinidae were the dominant family for surface communities (36%; n=769) as well as for sub-bark communities (37%; n=705).

An analysis of the **larvae** (table 7) shows that at all three sites *Pyrochroa coccinea* (Pyrochroidae) as well as *Uleiota planata* (Cucujidae) were dominant. The latter, together with *Cucujus cinnaberinus* (Cucujidae), which as a predominant species only occurs at site 1 (LoA), is listed in the "Rote Liste Österreichs" (1990) as category 4 (potentially vulnerable).

The larvae of various Carabidae species appear at site 2 (Di) and site 3 (LmA) and were also dominant. They were even found at the very dry site 1 (LoA), where they were still subdominant.
The primary xylobiontic families Scolytidae and Cerambycidae only appear in larger numbers at site 1 (LoA).

Larvae beneath the bark		Site 1 (LoA) n=303	Site 2 (Di) n=200	Site 3 (LmA) n=202	dependency on deadwood
Cantharidae	Cantharis sp.	0	r	sd	
Carabidae	Cychrus sp.	0	sd	sr	
Carabidae	Eurynebria sp.	0	0	sd	
Carabidae		sd	d	d	
Cerambycidae		d	0	0	+
Cucujidae	Cucujus cinnaberinus	sd	0	sr	+
Cucujidae	Uleiota planata	d	d	d	+
Cucujidae		sd	r	sd	
Elateridae	Denticollis sp.	0	d	r	(+)
Elateridae		0	0	sd	
Pyrochroidae	Pyrochroa coccinea	d	d	d	+
Scolytidae		sd	0	0	+
Silphidae		0	d	0	
Staphylinidae	Staphylinus sp.	0	sd	sd	
Staphylinidae		d	r	0	

Table 7: Dominant Coleoptera larvae beneath the bark (n=705; e…eudominant, d…dominant, sd…subdominant, r…rezedent, sr…subrezedent, sp…sporadisch; ENGELMANN (1978)

Among the **imagines** (table 8) the Staphylinidae were eudominant at sites 2 and 3.
Carabidae were found mainly at site 3 (LmA), which is situated nearest to the Danube, where they represent 82% of individuals (n=100). 38% of the Carabidae species, e.g. the hygrophilous *Platynus obscurus* (n=22), appeared exclusively there. *Hololepta plana* (Histeridae) occurs as the dominant species (98%; n=51) only at site 1 (LoA), and also belongs to the potentially vulnerable species in Austria. Cerambycidae, Histeridae and Scolytidae appear only at site 1 (LoA) in significant numbers, Chrysomelidae and Silphidae only at site 2 (Di).

Imagines beneath the bark		Site 1 (LoA) n=191	Site 2 (Di) n=302	Site 3 (LmA) n=275	dependency on deadwood
Carabidae	Agonum sp.	0	sr	sd	
Carabidae	Carabus granulatus	0	sr	sd	+
Carabidae	Platynus assimilis	sr	r	sd	+
Carabidae	Platynus obscurus	0	0	sd	+
Chrysomelidae	Phyllotreta undulata	r	sd	sr	+
Cucujidae	Uleiota planata	sd	sr	r	+
Histeridae	Hololepta plana	d	sr	r	+
Silvanidae	Silvanus unidentatus	d	sr	sd	+
Staphylinidae	Staphylinus sp.	0	d	0	
Staphylinidae		d	e	e	

Table 8: Dominant Coleoptera Imagines beneath the bark (n=768; e…eudominant, d…dominant, sd…subdominant, r…rezedent, sr…subrezedent, sp…sporadisch; ENGELMANN (1978))

4.2 Biology and ecology of diptera and their larvae

In spite of their large numbers and their significant part in the overall deadwood fauna (PFARR, 1990), the Diptera are often neglected in studies on deadwood. Evidently the reason for this is their tricky classification (BÜCHS 1988).

Most of the collected Diptera families are facultative deadwood dwellers. For the sake of a more robust classification some larvae and pupae were observed until the adult stage and subsequently classified.

Nevertheless the results have to be interpreted with caution because of the small sampling size due to the short investigation period and the general problem of manual sampling.

Diptera represent 59% of the total verified material with 6655 individuals (imagines, larvae and pupae). The ratio between sub-bark Brachycera and Nematocera was 78% to 22%.
The predominant proportion of the catches were larvae (95%; n=6349), while the remaining 4% were Lonchaeidae pupae (n=274). As a result of the sampling method, adult individuals were extremely underrepresented, with 1% of the total sample.

It is striking that the fraction of Brachycera underneath the bark at site 1 (LoA) was significantly higher than at the other two sites (77%, in comparison to 14% on Di and 9% on LmA). On the other hand, for the Nematocera the ratio is 54% on Di, 24% on LmA and 22% on LoA.

Among the **Brachycera** (n=5195; imagines + larvae + pupae; surface + underneath of the bark), the most prevalent families were Muscidae (38%), Lonchaeidae (29%) and Stratiomyidae (27%). These are categorized for all three sites as dominant or eudominant.
At sites 2 (Di) and 3 (LmA) larvae of Lonchaeidae were predominant, whereas at site 1 (LoA) they were in 3rd place behind Muscidae and Stratiomyidae.
Beneath the bark, individuals were most numerous at site 1 (LoA) for all families except the Erinnidae.

Brachycera	**Site 1 (LoA)** n=3943	**Site 2 (Di)** n=702	**Site 3 (LmA)** n=540	**dependency on deadwood**
Erinnidae	sp	r	sd	+
Sphaeroceridae	r	sd	sd	+
Muscidae	e	d	d	+
Stratiomyidae	d	d	d	(+)
Lonchaeidae	d	e	e	+

Table 9: Dominant Brachcera families (imagines, larvae, pupae) beneath the bark (n=5185; e…eudominant, d…dominant, sd…subdominant, r…rezedent, sr…subrezedent, sp…sporadisch; ENGELMANN (1978)

Comparing all three sites, among the **Nematocera** (n=1460; imagines + larvae + pupae; surface + underneath of the bark) the Limoniidae were most numerous with 67%, followed by the Scatopsidae

(19%). The former predominate at site 1 (98%) and site 2 (74%). At site 3 they were the second most numerous group with 22% behind Scatopsidae (60%). Their high abundance can be explained by the large quantities of foerna and moist detritus, where the larval development takes place.

In contrast to the Brachycera the Nematocera were most numerous at site 2 (Di). This indicates a higher humidity caused by shading, and probably a higher water table in this area. They represent 94% (n=118) of individuals at this site, but are not found at all at site 1 (LoA), where insolation was significantly higher and trunks less well rotted.

Nematocera	**Site 1 (LoA)** n=325	**Site 2 (Di)** n=771	**Site 3 (LmA)** n=343	**dependency on deadwood**
Cecidomyiidae	0	r	sd	+
Sciophilidae	sr	r	sd	(+)
Mycetophilidae	0	d	r	+
Scatopsidae	sr	sd	e	+
Limoniidae	e	e	d	+

Table 10: Dominant Nematocera families (imagines, larvae) beneath the bark (n=1439; e…eudominant, d…dominant, sd…subdominant, r…rezedent, sr…subrezedent, sp…sporadisch; ENGELMANN (1978))

Just like in Coleoptera, it is not the species of tree that is crucial for the population with diptera, but the availability of certain structures and the contents of moisture (HAMILTON 1978). For many of them, especially for the larvae, deadwood has a vital role as foraging grounds, for egg deposition or as medium for development.

5 Discussion

This survey has tried to compile a preliminary inventory for the xylobiontic fauna of a floodplain forest. It compares three different methods of renaturation of a formally commercial woodland: group selection with and without removal of trees, and juvenile spacing. The presented results have to be considered as snapshots which only indicate certain trends.

The existing studies on this subject particularly emphasise the significance sufficient quantities of deadwood in various degrees of decomposition to protect the biodiversity of a forest, as well as the responsibility to preserve the last refuges for deadwood specialists (e.g. RÜEGG 1994, ZABRANSKY 2006).
For that reason a follow-up survey on the same sites would produce interesting results. Sampling further deadwood structures such as driftwood and standing deadwood would be a useful exercise, although manual sampling should be reduced in favour of stem- or "Borkenemergenz"-eclectoren as described by BÜCHS.

A deadwood structure (host tree) has to be considered as a multi-functional unit which can satisfy various ecological requirements. It offers the living conditions for a more or less broad spectrum of plant and animal species which forms an entire specific community in itself (BÜCHS 1988).

In the course of the 'individual succession' of a tree, not only does the composition of the bark-dwelling community constantly change, but there is also an increase in the overall number of species. Thus old trees feature communities of high diversity with specific requirements.

At all the three sites hybrid poplars were felled at the rather young age of 30 years. At the time of investigation 1993/94 they had been lying about as deadwood for roughly 1½ years, a very short period for detecting related effects of succession on the trunks.

Regarding the diversity, the rarefaction curves (figure 11 and 12) reveal that the species both on the bark's surface as well as underneath have not been recorded completely, while levelling out cannot be observed.
One possible reason is the heterogeneity and structural diversity of floodplain forests, which generally are counted to the most species-rich habitats in Central Europe (GERKEN 1988, LAZOWSKI 1997).

Unsurprisingly, the cluster analysis (figure 13) based on present-absence data, shows an early separation between surface and sub-bark fauna. However, in both cases there is a considerable similarity between sites 2 (Di) and 3 (LmA) although they are not directly linked topographically, in contrast to sites 1 (LoA) and 2 (Di), which are separated only by a small forest track. The former pair share similarly high degrees of shading and moisture content of the wood, as well as the much higher proportion of Stylommatophora (Di: 41%, LmA: 52%; n=359) and Myriapoda (Di: 33%, LmA 55%; n=930). Greater shade and moisture provide better initial conditions for healthy succession.

5.1 Discussion of results

5.1.1 Site 1: group selection without removal of trees (LoA)

Dryness (cf. table 1 LoA) as a result of higher direct insolation due to a thinned standing stock without young growth has slowed the outward decomposition of trunks, and so the development of different degrees of decay. The less well-shaded vegetation allowed easier access to animals on the surface but as a result of the problem with manual sampling a lower final density of individuals was observed further illustrated by the rarefaction curve (figure 12). Nevertheless, 32% of all species/families are found only at this site. JANK (1995) described in his study on this site as having the highest share of xerophile Carabidae species.
Slightly decomposed wood presents substantial physical resistance. Scolytidae as well as Cerambycidae were found only subdominatly as colonists of these initial stages. It is interesting that the ratio of larvae to imagines for Coleoptera at this site (60:40) is the reverse of those of the other sites.

For the sub-bark fauna the picture is completely different. Only few species were found, even at highest density of individuals. The low values of diversity and evenness can be explained by the enormous proportion of Brachycera, which make up 39% of all individuals seeking a suitable, warm and humid microclimate underneath the bark, as well as at the beginning of succession.

5.1.2 Site 2: juvenile spacing (Di)

Although this site is separated from site 1 (LoA) only by a small forestry track, it is more similar to site 3 (LmA) in regards to shading and decomposition of the trunks. But in contrast to site 3, young trees from autochthonous floodplain species have already germinated, as a result of felling single trees of hybrid poplar. This gives an impression of a near-natural undergrowth, but with the exception of *Allium ursinum,* spring-flowering plants are widely missing.
Humidity and shading, together with even temperatures on the trunk surface and underneath the bark, seem to be the reason for the increased number of Nematocera. These, especially Mycetophilidae, are only categorized as dominant on this site.

5.1.3 Site 3: group selection with removal of trees (LmA)

In contrast to the previous sites, this area has preserved its original woodland character. This is supported by the subdominant occurrence of the two woodland Carabides *Carabus granulatus* and *Platynus obscurus* (cf. table 8). High trees, lots of undergrowth and the proximity to the banks of the Danube offer good conditions for hygrophilous species. *Platynus assimilis* was present only

subdominant as imago, larvae have not been found. SPÄH (1977) describes this species as typical for floodplain forests, since its ecological niche is in the leaf litter, detritus and rotten bark.
In addition it should be mentioned that 80% of all Lumbricidae (n=207) were found on one third of the sampled trunks underneath the bark. This shows the deadwood was already in an advanced stage of decay (succession phase 'V' after SZUJECKI 1987). This might also be the reason why, in contrast to site 1 (LoA), the highest number of different species were found underneath the bark.
In spite of these differences, *Uleiota planata* (Cucujidae) and *Pyrochroa coccinea* (Pyrochroidae) occur as dominant species for all three sites and the Staphylinidae were the most frequent Coleoptera family found underneath the bark, representing 37% of individuals.

5.2 Biology and Ecology of Coleoptera and their Larvae

This thesis can only be regarded as an incomplete inventory. Among other things it presents evidence for the species composition of xylobiontic Coleoptera, as they have important functions within the ecosystem and document the significance of deadwood for species preservation. Thus 25% of all Austrian beetle species are either directly or indirectly dependent on wood of various degree of decomposition.
Most beetle species mentioned in the European Flora-Fauna-Habitat Guideline are tied to deadwood and have become very rare in Austria. One example is *Cucujus cinnaberinus* (Cucujidae), which is protected according to FFH guidelines and occurs primarily underneath the rotten bark of dead poplar. The species is numerous in the Regelsbrunner Au. For these reasons the "Nationalpark Donau-Auen" represents the most important refuge in Austria. During the sampling however, only a total of 12 larvae (11 at site 1) and 1 imago (Di) were found. The long individual development of 2 years compared to the rather short period of available deadwood (1½ years) could be a reasonable explanation for the limited occurrence of this xylobiont. According to BUSSLER (2002) the naturalness of the tree stand is not a crucial factor since, as in this case, even a hybrid poplar monocrop with little deadwood can be populated. BUSSLER found young larvae exclusively on trunks which had died off only a couple of months prior, on which the base was still connected to the cambium, thus keeping the substrate moist. Both criteria apply to trunks at site 1 (LoA; cf. table 1), which feature the highest share in the category 'difficult peelable bark', whilst at the same time maintaining moist and warm conditions underneath the bark.

A further key species is *Pyrochroa coccinea* (Pyrochroidae), which has an individual development of 2-3 years, but which were only found as larvae (LoA: 32%, Di: 40%, LmA: 28%), never as imagines. It feeds on the larvae of bark-beetles, amongst other things, which appear only at site 1 (LoA) subdominatly.
Silvanus unidentatus (Silvanidae), as a typical corticole species appeared to be dominant at site 1 (LoA) and subdominant at site 3 (LmA), but larvae are only found subrecedent at site 1 (LoA).

Also worth mentioning, since it is considered potentially vulnerable in Austria (GEPP, ZORN 1990) is *Hololepta plana* (Histeridae). Adult individuals were only found at site 1 (LoA) as a main species (98%; n=50).

5.3 Biology and Ecology of Diptera and their Larvae

Research on deadwood fauna has hitherto often dealt only with beetles (RUEGG 1995). The Diptera, especially flies, have so far been only marginally investigated and are still insufficiently studied, even though they represent a substantial proportion of the total deadwood fauna (PFARR 1990). For many of them, tree trunks are of vital importance. They are needed as landing and resting spots, foraging grounds and for egg deposition, as well as a medium for the development of larvae.
SAVELY (1939) demonstrated that the trunk parts examined provide habitats for various insects simultaneously, and hence predatory Diptera species are of particular importance for the control of forest pests. Raptorial species of the genus Lonchaea are able to control the abundance of Scolytidae inside the bark (BRAUNS 1991). Lonchaeidae , including the species *Lonchaea palposa* and *Lonchaea peregrina* occur as dominant species at site 1 (LoA) and eudominantly on the sites 2 (Di) and 3 (LmA). Scolytidae are found only at site 1.

90% of Muscidae larvae were found at site 1 (LoA) and belong to the Subfamily Phaoniidae, which is also predatory.

6 Summary and protective measures

Deadwood plays a central and stabilising role in forest ecosystems. The short turnover times in commercial forests and the removal of deadwood lead to the reduction of an important basic resource for already vulnerable xylobiontic species. The termination of forestry ("Außer-Nutzen-Stellen") operations for large forest areas in the "Nationalpark Donau-Auen" and related renaturation actions by the WWF are a first step towards a near-natural floodplain forest.

Comparing the three investigated sites in respect to the different methods of renaturation it can be said that site 1 (group selection without removal) is the driest location. Here trunk decay proceeds slowly, and as such only few succession stages have developed so far. The fauna are dominated largely by Coleoptera and Diptera, which prefer freshly cut trees with little decomposed bark and plenty of sap.
Site 2 (juvenile spacing) and site 3 (group selection with removal) have already regained some of their natural-forest character after just a year and a half, which is apparent by the increased occurrence of hygrophilous Carabidae (e.g. *Platynus assimilis*).

Due to the sampling method (manual sampling), the low number of samples and the short investigation period, the number of individuals or of certain species alone can be no indicator for the preference of a certain renaturation action. The environmental conditions (age of the trunks, microclimate, soil type, food supply) are all too similar at the different sites. Contrary to expectations it is not possible at that time to identify unambiguous differences regarding the effectiveness of the different renaturation actions related to the abundance of certain deadwood dwelling species. Hence it is not possible to give any reliable recommendation in favour of one method. However, bearing in mind the advice of several researchers (RÜEGG 1995, ZABRANSKY 1998) to leave more trunks with sufficient dimensions (diameter > 20cm, length > 2m; ERDMANN & WILKE 1997) in the forest, 'group selection without removal' should be continued.

The increasing importance of old- and deadwood for nature conservation are a significant contribution to the protection of forest ecosystems. The challenge is to try to understand the highly diverse requirements of these groups of organisms, to create and implement useful concepts for the protection of deadwood.

The necessary range of structures and niches for high biodiversity are only available when deadwood across the full spectrum of decomposition occurs together. The protection of biotopes is however crucial for the sustainable safeguarding of communities, which in the long-term only makes sense if the protected areas are large enough and migration from one to another can occur (WINTER 1988). It is thus essential that these areas are preserved, but in the future we should think about linking different areas (ROLSTAD et al. 2004). Furthermore, there is the need for continuous supply of material to raise the amount of deadwood gradually to a natural level in order to provide the xylobiontic fauna with a variety of stages of decay.

In the end, the precondition for the preservation of natural-forests is to abandon forestry use (cf. GEISER 1994, ZABRANSKY 1998).
According to the MOBI-e report 2006, which compared the surveys of 1971-1980 and 2000-2002 quantity and volume of dry wood in Austrian deciduous and coniferous forests has more than doubled. A Europe-wide recommendation of the WWF (2004) assumes an average of 20-30 m^2/ha until 2030. This positive trend could be used to continue to gradually raise the percentage of deadwood in Austrian forests (compare also SAUBERER et al. 'Nachhaltiges Waldbiomassenmanagement im Biosphärenpark Wienerwald').

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APPENDIX

Table 11: Total number of Coleoptera recorded at all sites

Surface catches					
Family	Species	Author, Year	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
Imagines					
Anaspididae	Anaspis frontalis	(L., 1758)	0	1	0
Byrrhidae	Simplocaria semistriata	(FABRICIUS, 1794)	0	1	0
Cantharidae			0	1	0
Carabidae	Platynus assimilis	(PAYKULL, 1790)	0	1	2
Carabidae	Trechus secalis	(PAYKULL, 1790)	0	0	1
Carabidae	Agonum sp.		1	0	5
Carabidae	Bembidion sp.		1	0	0
Carabidae	Elaphrus cupreus	DUFTSCHMID, 1812	2	1	3
Carabidae			2	1	0
Carabidae	Asaphidion flavipes	(L., 1761)	3	0	1
Cerambycidae	Phymatodes testaceus	(L., 1758)	3	0	0
Ceridae	Thanasimus sp.		2	0	0
Cerylonidae	Cerylon histeroides	(FABRICIUS, 1792)	0	1	1
Chrysomelidae	Phyllotreta undulata	KUTSCHERA, 1866	0	2	0
Chrysomelidae	Oulema melanopus	(L., 1758)	1	0	0
Chrysomelidae			1	0	0
Colydiidae	Bitoma crenata	(FABRICIUS, 1775)	1	0	0
Cucujidae			15	0	0
Cucujidae	Uleiota planata	(L., 1761)	19	2	1
Curculionidae	Sitona lineatus	(L., 1758)	6	0	0
Curculionidae			18	10	10
Elateridae			0	0	1
Elateridae	Synaptus filiformes	(FABRICIUS, 1781)	1	1	0
Endomychidae	Endomychus coccineus	(L., 1758)	0	2	2
Erotylidae	Triplex russica	(L., 1758)	2	6	17
Histeridae	Hololepta plana	(SULZER, 1776)	2	0	0
Monotomidae			3	0	0
Nitidulidae	Pria dulcamarae	(SCOPOLI, 1763)	0	1	0
Oedemeridae			1	0	0
Phalacridae	Stilbus testaceus	(PANZER, 1797)	2	4	1
Ptiliidae	Pteryx suturalis	(HEER, 1841)	0	1	0
Silvanidae	Silvanus unidentatus	(OLIVIER, 1790)	44	0	7
Staphylinidae	Othius punctulatus	(GOEZE, 1777)	0	0	1
Staphylinidae			55	42	24
Larvae					
Histeridae	Platysoma sp.		2	0	0

Sub-Bark catches					
Family	Species	Author, Year	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
Imagines					
Carabidae	Agonum sp.		0	1	9
Carabidae	Bembidion sp.		0	0	2
Carabidae	Carabus granulatus	L., 1758	0	1	9
Carabidae	Clivina fossor	(L., 1758)	0	0	1
Carabidae	Demetrias atricapillus	(L., 1758)	0	0	1
Carabidae	Dromius quadrimaculatus	(L., 1758)	1	0	0
Carabidae	Elaphrus cupreus	DUFTSCHMID, 1812	0	1	4
Carabidae	Patrobus atrorufus	(STRÖM, 1768)	0	0	1
Carabidae	Platynus assimilis	(PAYKULL, 1790)	1	8	20
Carabidae	Platynus dorsalis	(PONTOPPIDAN, 1763)	0	0	4
Carabidae	Platynus obscurus	(HERBST, 1784)	0	0	22
Carabidae	Pterostichus oblongopunctatus	(FABRICIUS, 1787)	0	0	5
Carabidae	Pterostichus sp.		1	4	2
Carabidae	Stomis pumicatus	(PANZER, 1796)	0	0	1
Carabidae	Trechus sp.		0	0	1
Cerambycidae	Phymatodes testaceus	(L., 1758)	1	0	1
Cerylonidae	Cerylon histeroides	(FABRICIUS, 1792)	1	1	0
Chrysomelidae	Chaetocnema hortensis	(FOURCROY, 1785)	0	0	1
Chrysomelidae	Gastrophysa polygoni	(L., 1758)	0	1	0
Chrysomelidae	Oulema melanopus	(L., 1758)	3	4	0
Chrysomelidae	Phyllotreta ochripes	(CURTIS, 1837)	0	0	1
Chrysomelidae	Phyllotreta undulata	KUTSCHERA, 1866	3	14	1
Chrysomelidae			0	1	1
Cleridae			0	1	0
Colydiidae	Bitoma crenata	(FABRICIUS, 1775)	1	0	1
Cucujidae	Cucujus cinnaberinus	(SCOPOLI, 1763)	0	1	0
Cucujidae	Uleiota planata	(L., 1761)	9	3	4
Curculionidae	Dorytomus longimanus	(FORSTER, 1771)	0	0	1
Curculionidae	Phyllobius oblongus	(L., 1758)	1	0	0
Curculionidae			5	1	4
Elateridae	Denticollis sp.		1	0	1
Endomychidae	Endomychus coccineus	(L., 1758)	0	2	0
Erotylidae	Triplax russica	(L., 1758)	0	0	4
Erotylidae			0	1	0
Histeridae	Hololepta plana	(SULZER, 1776)	43	2	4
Histeridae			0	0	1
Melandryidae			0	0	2
Mordellidae			0	1	0
Nitidulidae	Soronia grisea	SCOPOLI, 1763	0	1	0
Phalacridae	Olibrus aeneus	(FABRICIUS, 1792)	4	1	2
Phalacridae	Stilbus testaceus	(PANZER, 1797)	0	1	1
Phalacridae			0	0	1
Pselaphidae			0	0	1
Ptiliidae			0	1	0
Rhizophagidae	Rhizophagus depressus	(FABRICIUS, 1792)	1	0	0
Scolytidae	Ipinae sp.		5	0	0
Scolytidae			3	0	0
Silphidae	Phosphuga atrata	(L., 1758)	0	2	4
Silphidae			0	0	1
Silvanidae	Silvanus unidentatus	(OLIVIER, 1790)	46	2	9

Family	Species	Author, Year	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
Staphylinidae	Othius punctulatus	(GOEZE, 1777)	2	0	0
Staphylinidae	Staphylinus sp.		0	55	0
Staphylinidae	Tachyporus hypnorum	(FABRICIUS, 1775)	0	0	3
Staphylinidae	Tachyporus obtusus	(L., 1767)	0	1	0
Staphylinidae	Tachyporus sp.		0	1	2
Staphylinidae			59	189	142
Larvae					
Buprestidae			3	0	0
Cantharidae	Cantharis sp.		0	2	9
Cantharidae			0	0	2
Carabidae	Cychrus sp.		0	12	1
Carabidae	Eurynebria sp.		0	0	7
Carabidae			19	28	39
Cerambycidae			50	0	0
Cerylonidae	Cerylon histeroides	(FABRICIUS, 1792)	1	0	0
Cleridae	Tillus sp.		1	0	0
Colydiidae	Bitoma crenata	(FABRICIUS, 1775)	0	0	2
Cucujidae	Cucujus cinnaberinus	(SCOPOLI, 1763)	11	0	1
Cucujidae	Cucujus sp.		9	0	0
Cucujidae	Uleiota planata	(L., 1761)	54	22	49
Cucujidae			17	3	11
Curculionidae			8	5	1
Elateridae	Denticollis sp.		0	47	5
Elateridae	Leptoschema sp.		0	0	4
Elateridae			0	0	15
Histeridae	Hololepta plana	(SULZER, 1776)	8	3	1
Histeridae	Platysoma sp.		4	0	0
Pyrochroidae	Pyrochroa coccinea	(L., 1761)	38	47	33
Scolytidae			20	0	0
Silphidae	Phosphuga atrata	(L., 1758)	0	0	1
Silphidae			0	20	0
Silvanidae	Silvanus unidentatus	(OLIVIER, 1790)	3	0	0
Staphylinidae	Staphylinus sp.		4	7	18
Staphylinidae			53	4	3

Table 12: Total number of Diptera recorded at all sites

Surface catches					
Family	Species	Author, Year	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
Brachycera					
Imagines					
Dolichopodidae			1	0	0
Lonchaeidae	Lonchaea palposa	ZETERSTEDT, 1847	0	1	0
Lonchaeidae	Lonchaea peregrina	BECKER, 1895	0	1	0
Lonchaeidae			1	0	0
Muscidae			0	0	1
Stratiomyidae			0	2	1
Trypetidae			0	0	1
Nematocera					
Imagines					
Cecidomyiidae			0	1	7
Limoniidae	Limonia sp.		1	2	1
Limoniidae			3	0	0
Sciaridae			0	0	6

Sub-Bark catches					
Family	Species	Author, Year	Site 1 (LoA)	Site 2 (Di)	Site 3 (LmA)
Brachycera					
Larvae					
Erinnidae	Erinna sp.		1	17	3
Erinnidae			1	0	18
Helomyzidae			5	3	0
Lonchaeidae	Lonchaea peregrina	BECKER, 1895	0	0	12
Lonchaeidae			725	283	204
Muscidae	Phaoniinae sp.		1732	129	54
Muscidae			8	3	20
Piophilidae			62	9	8
Sphaeroceridae			72	64	21
Stratiomyidae	Tylomyia marginata		47	10	10
Stratiomyidae			1172	72	99
Syrphidae			47	0	0
Pupae					
Lonchaeidae	Lonchaea palposa	ZETTERSTEDT, 1847	13	60	54
Lonchaeidae	Lonchaea peregrina	BECKER, 1895	57	50	36
Lonchaeidae			0	2	1
Stratiomyidae			1	0	0
Nematocera					
Imagines					
Limoniidae	Limonia sp.		0	1	0
Larvae					
Cecidomyiidae			0	9	16
Limoniidae			320	567	77
Mycetophilidae			0	111	7
Scatopsidae			2	61	206
Sciaridae			0	7	0
Sciophilidae			3	15	33
Tipulidae	Tipula sp.		0	0	4

Table 13: Distribution of Taxa at all three sites

Surface catches	**Site 1 (LoA)**	**Site 2 (Di)**	**Site 3 (LmA)**
Collembola	0	0	1
Lepidoptera	1	1	0
Lumbricidae	0	0	2
Pseudoskorpiones	2	0	0
Dermaptera	0	4	1
Hymenoptera	9	5	0
Myriapoda	2	8	6
Opiliones	1	11	14
Diptera	7	7	17
Heteroptera	16	25	12
Coleoptera	188	78	77
Araneae	81	129	135
Stylommatophora	60	162	190

Sub-Bark catches	**site 1 (LoA)**	**site 2 (Di)**	**site 3 (LmA)**
Lepidoptera	0	0	0
Opiliones	0	0	2
Dermaptera	1	5	0
Heteroptera	6	2	2
Pseudoskorpiones	9	1	9
Araneae	6	21	18
Hymenoptera	12	72	38
Lumbricidae	9	33	165
Collembola	190	1	30
Stylommatophora	27	146	186
Myriapoda	108	310	512
Coleoptera	493	502	477
Diptera	4268	1473	883

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