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Decaying wood and saproxylic Coleoptera in two old spruce forests: a comparison based on two sampling methods

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The saproxylic beetle fauna was compared in two old spruce dominated forests in northern Finland. The volume of decaying wood in the forests was 32 m^3 and 8 m^3 per hectare. The beetles were sampled by carefully peeling the bark off all the dead trees within twenty circular sample plots of 100 m^2, and by window flight trapping. The pooled sample comprised 7184 individuals of 207 saproxylic species. According to both sampling methods, common generalist species were equally abundant in both forests, whereas specialists living either on decaying spruce or birch were more abundant in the forest with a larger supply of decaying wood. The set of dominant species was, however, almost completely different with the two methods. Bark peeling yielded mostly sub-corticulous species. Window flight trapping yielded, in addition, many species living inside decaying trees, on microfungi on dead trees or on polyporous fungi. The amount of decaying wood around the traps did not affect the number of species or specimens caught. The problems involved in the sampling methods are discussed.

1. Introduction

Several hundreds of species of Coleoptera live on decaying wood and on wood decomposing fungi in Finland (e.g. Saalas 1917, 1923, Palm 1951, 1959). Speight (1989) defined saproxylic invertebrates as species that depend, during some part of their life-cycle, on the dead or dying wood of moribund or dead trees, on wood inhabiting fungi, or upon the presence of other saproxylics. Saproxylic beetles are one of the largest taxa contributing to biodiversity in forests. Most of these species are small and cryptic, and difficult to sample (see Rauh & Schmitt 1991). Standardized sampling methods with known performance need to be sought for and developed to make comparisons of the level of biodiversity possible between different kinds of forests.

Potential methods described include peeling bark off dead trees ("trunk sampling", Väisänen et al. 1993), different kinds of window flight traps and silhouette traps (Younan & Hain 1982, Chénier & Philogène 1989, Kaila 1993) and eklectors (traps that capture insects emerging from or walking on the trunks of dead trees; Rauh & Schmitt 1991). Few studies have dealt with the relation between the amount and quality of decaying wood in a forest and the saproxylic fauna.

The aim of the present study is

1) to compare the tree-living beetle faunas in two forests with a different supply of decaying wood,
2) to compare the results obtained with two sampling methods, the peeling of bark on sample plots and window flight trapping, and
3) to discuss the problems involved in the sampling methods.

2. Material and methods

2.1. Study area and forests

The study area is located in western Finnish Lapland in Kolari commune, at about 67°30′N, 24°E. Phytogeographically the area belongs to the northern boreal zone (Ahti et al. 1968). Two study forests about 1 km from each other were chosen. Both forests were old spruce (*Picea abies*) dominated stands surrounded by pine (*Pinus sylvestris*) dominated mires, 160 m above sea level, with flat topography. The forest site type was the *Hylocomium-Myrtillus*-type (Kalela 1961). The principal difference between the forests was in the amount and continuity of decaying wood.

The first forest, Lahosaajo, is a stand which has never been cut and has not burned for several centuries (a "second generation" stand Sirén 1955, Norokorpi 1979). This can be concluded by the lack of charcoal beneath the thick humus layer, small density and regeneration by gaps in the tree stand, and by the continuous succession of fallen trunks in different stages of decay. Birch (*Betula pubescens*) is regenerating by sprouting from the base, thus forming groups of many trunks. The second forest, Kämppäsaajo, has regenerated after a forest fire ca. 150 years ago. Old, heavily decayed barkless trunks were missing. The forest has been silviculturally treated for about twenty years which has included cutting the birches in 1971, thinning in 1975 and removal of wind-thrown trees in 1985. These treatments have reduced the supply of decaying wood in the forest.

2.2. Sampling of saproxylic Coleoptera

Twenty circular sample plots were established in both study forests. The plots were placed systematically on a 25 m × 25 m grid in the middle of the forest stands. Each sample plot was a circle of 100 m^2 with a radius of 5.64 m.

Bark was carefully removed with a knife from all the dead trees within the sample plots. To make it possible to peel the underside, trunks lying pressed to the ground were cut with a chainsaw and rolled over. All Coleoptera adults, pupae and larvae found were collected and preserved in alcohol. The bark pieces detached were put into large plastic bags and sifted. Soft parts of trunks and stumps were sifted as well. The sifted material was examined later in small lots on white paper. The field work was performed in May, June and September 1990 at Lahosaajo, and in June, July and September 1991 at Kämppäsaajo. The treatment of the sample plots took about 250 working hours at Lahosaajo and 60 at Kämppäsaajo. The volume and bark area of decaying trees studied was 6.3 m^3 and 86 m^2 in Lahosaajo, and 1.6 m^3 and 29 m^2 in Kämppäsaajo (Table 1).

Ten window flight traps were operated on the sample plots through the growing season at the same time as the treatment of the plots. The trapping period was 18 May – 19 September 1990 at Lahosaajo and 21 May – 3 October 1991 at Kämppäsaajo. The traps were made of two perpendicular intercepting 40 × 60 cm panes of soft PVC plastic, reinforced with galvanized iron wire at the corners ("baffle" or "vane" traps, Hines & Heikkenen 1977). The panes were attached below a plastic roof, and a plastic funnel leading into a 1 l container was attached below the panes. The traps were hung on a string between tree trunks, with the lower edge 1 m above the ground. A solution of water, salt (NaCl) and detergent was used in the container. The traps were emptied every third week.

The window flight trapping was repeated in 1992 with six traps in both forests. The trapping period was 19 May – 5 October.

2.3. Measurement of decaying wood and living trees

Lying dead trees, or the parts of them, within the sample plots were measured in one or two metre pieces. Tree species, the circumference at the middle of each piece (minimum diameter 5 cm) and the percentage of bark left were recorded. The tree species, length, circumference and bark percentage of stumps were also recorded. The tree species and diameter at breast height on the living trees (minimum diameter 5 cm) and dead standing trees were also noted.

The amount of decaying wood around the window flight traps was also measured on ten larger circular sample plots of 500 m^2 each, with a radius of 12.62 m.

Table 1. Volume (m^3/ha) of the living trees, volume and bark area (m^2/ha) of the decaying trees, and volume (m^3) and bark area (m^2) per the sample plots in the study forests.

	Lahosaajo	Kämppäsaajo
Living trees		
Total volume	104	87
Spruce	59	80
Birch	45	2
Pine	–	5
Decaying trees		
Total volume	32	8
Spruce	28	4
Birch	4	4
Pine	–	.
Total bark area	430	145
Spruce	348	40
Birch	82	104
Pine	–	1
Sample plots		
Total volume	6.3	1.6
Total bark area	86	29

2.4. Data treatment

The volume of the lying trunks was calculated in pieces by multiplying the length of each piece by the cross sectional area in the middle. The bark area was calculated using the circumference in the middle and the bark percentage. The volume and bark area of the stumps was calculated similarly. The volume of living trees and dead standing trees was determined using volume equations based on the diameter at breast height.

All the beetles caught, including larvae and pupae, were identified to species (except most *Atomaria* spp. and some larvae). Only saproxylic species were included. The nomenclature and systematic arrangement follow Silfverberg (1992).

Data between the forests (e.g. number of species in the window flight traps) were compared using the Mann-Whitney *U*-test. The relation between the amount of decaying wood on the sample plots and the number of beetle species and specimens caught was studied using Spearman's rank correlation coefficient.

3. Results

3.1. Amount of decaying wood

The volume of the living trees was about 100 m^3/ha in both forests (Table 1). In Kämppäsaajo there were a few pines, and the proportion of birch was considerably lower than in Lahosaajo because of the cutting of the birches in the 1970s. The volume of the decaying wood was fourfold in Lahosaajo (32 vs. 8 m^3/ha); lying spruce trunks accounted for most of the volume. The volume of decaying birch was equal in both forests (4 m^3/ha); in Kämppäsaajo the volume was made up mostly of birch stumps.

The distribution of decaying wood was very uneven in both forests. On the 500 m^2 sample plots, the volume ranged from 0.5 to 6.5 m^3 (corresponding to 10 and 130 m^3/ha, respectively) in Lahosaajo and from 0.1 to 0.5 m^3 (2 and 10 m^3/ha) in Kämppäsaajo.

3.2. Saproxylic Coleoptera

The pooled sample comprised 7184 individuals of 207 saproxylic species (a complete species list is available from the author upon request). The number of species found by peeling the bark on sample plots was about two-fold and the number of individuals eight-fold in Lahosaajo as compared to Kämppäsaajo (Table 2). When the sample plots were used as replicates, the species richness did not differ significantly between the forests. This means that, on an average, there were equally many species per plot in both forests, but the species composition varied more between plots in Lahosaajo. However, it is very doubtful whether the sample plots can be regarded as standardized replicated samples of the fauna in a forest.

The twenty-five most abundant species on the sample plots (both forests pooled) were tentatively grouped into five ecological groups according to their principal substrate (Table 3). The grouping was based on the literature (e.g. Saalas 1917, 1923, Palm 1951, 1959) and on own experience. The generalist species on decaying wood were equally common in both forests, but specialists on dead spruce and dead birch were far more abundant in Lahosaajo. The only exception was *Denticollis linearis*, which can live on soft birch stumps. No species specialized on microfungi (including Myxomycetes, etc.) on dead trees or polyporous fungi on birch were found abundantly by peeling the bark.

The average number of individuals/m^2 was 4.3 in Lahosaajo and 1.7 in Kämppäsaajo. The correlations between the volume of decaying wood on the sample plots and the number of species and individuals found was significant in both forests (number of plots = 20; Lahosaajo, spe-

Table 2. Number of saproxylic beetle species and individuals caught by peeling bark on sample plots and with window flight trapping in the study forests. *U* = Mann-Whitney test statistic.

	Laho-saajo	Kämppä-saajo	*U*	*P*
Sample plots, 1990–91				
Species	57	34	3.6	NS
Individuals	1861	244	6.0	<0.05
Individuals/m^2	4.3	1.7		
Window flight traps				
1990–91				
Species	152	110	14.1	<0.001
Individuals	2097	1113	8.7	<0.01
1992				
Species	116	106	5.0	<0.05
Individuals	1013	856	2.3	NS
Species, pooled	178	151		
Individuals, total	4971	2213		

Table 3. Twenty-five most abundant saproxylic beetle species caught by bark peeling in the study forests grouped according to their principal substrate.

	Laho-saajo	Kämppä-saajo
Generalists on decaying wood		
Atrecus pilicornis	72	16
Ischnoglossa prolixa	20	45
Leptusa pulchella	20	49
Olisthaerus megacephalus	18	8
Harminius undulatus	11	8
Acrulia inflata	2	17
Total spec./ind.	5/143	5/143
Specialists on dead spruce		
Rhagium inquisitor	408	1
Pytho depressus	135	–
Coryphium angustatus	99	2
Orchesia fasciata	83	–
Olisthaerus substriatus	79	–
Polygraphus punctifrons	50	–
Hylurgops glabratus	44	–
Cryphalus hispidus	40	–
Hylastes brunneus	29	–
Dryocoetes autographus	24	3
Dinaraea arcana	38	5
Ernobius explanatus	26	–
Dendrophagus crenatus	20	3
Zilora ferruginea	23	–
Cis punctulatus	9	9
Total spec./ind.	15/1107	6/23
Specialists on dead birch		
Hylecoetus dermestoides	500	–
Rhagium mordax	50	–
Systenocerus caprea	19	–
Denticollis linearis	–	16
Total spec./ind.	4/569	1/16
On fungi on dead trees	–	–
On polyporous fungi on birch	–	–

cies: $r_s = 0.628$, $P < 0.01$; individuals: $r_s = 0.393$, $P < 0.05$; Kämppäsaajo, species: $r_s = 0.548$, $P < 0.01$; individuals: $r_s = 0.625$, $P < 0.01$). This shows the trivial but important relation: more decaying wood within a forest means generally more saproxylic species.

The set of ten window flight traps yielded in both forests about three times as many species, and the set of six traps over twice as many species as the bark peeling (Table 2). The number of species caught by window flight trapping was only slightly higher in Lahosaajo. The species richness differed, however, significantly between the forests in testing when the traps were used as replicates.

The thirty-five most abundant species (both forests and years pooled) in the traps were grouped into five groups as above (Table 4). The conclusions are similar to those by bark peeling: the common generalist species were equally abundant in both forests, but there is a striking difference in the abundance of specialists on decaying spruce and birch. However, the set of dominant species is almost completely different with the two methods. The dominant species caught by bark peeling are all sub-corticulous (e.g. *Rhagium inquisitor*, *Pytho depressus*), whereas window flight traps abundantly caught several species that live inside the decaying trunks (e.g. *Ampedus tristis*, *A. nigrinus*, *Xylita laevigata*). In the trap samples, a number of species living on microfungi on dead trees or polyporous fungi were very abundant (e.g. *Cryptophagus lapponicus*, *Cis boleti*). Both these groups were slightly more abundant in Lahosaajo, probably because of the greater amount of suitable substrate. Bark beetles (Scolytidae) were well represented in the trap samples and the faunas in the two forests were very similar. The scolytids are dependent on moribund parts of living trees and newly dead trees, not decaying wood.

There was no clear correlation between the volume of decaying wood around the window flight traps and the number of species and individuals caught (number of traps = 10; Lahosaajo, species: $r_s = 0.398$, ns; individuals: $r_s = 0.176$, ns; Kämppäsaajo, species: $r_s = -0.384$, ns; individuals: $r_s = -0.401$, ns). This means that the location of the trap does not greatly affect the number of species caught.

Table 4. Thirty-five most abundant saproxylic beetle species (Scolytidae excluded) caught by window flight trapping in the study forests grouped according to their principal substrate.

	Lahosaajo	Kämppäsaajo
Generalists on decaying wood		
Gabrius expectatus	263	89
Quedius plagiatus	46	118
Atrecus pilicornis	11	78
Cerylon histeroides	50	39
Cerylon ferrugineum	33	49
Stenotrachelus aeneus	67	13
Ischnoglossa prolixa	8	26
Euplectus karsteni	22	2
Total spec./ind.	8/500	8/414
Specialists on decaying spruce		
Ampedus tristis	112	2
Ampedus nigrinus	61	16
Xylita laevigata	34	15
Dendrophagus crenatus	18	6
Orchesia fasciata	22	1
Lacon fasciatus	23	–
Lacon conspersus	21	1
Total spec./ind.	7/291	6/41
Specialists on decaying birch		
Eudectus giraudi	122	36
Euplectus fauveli	25	2
Systenocerus caprea	35	6
Rhizophagus parvulus	19	21
Mycetochara flavipes	22	1
Total spec./ind.	5/223	5/66
On fungi on decaying trees		
Cryptophagus lapponicus	289	231
Enicmus rugosus	160	45
Enicmus fungicola	116	29
Epuraea rufomarginata	52	81
Corticaria orbicollis	35	20
Anisotoma glabra	25	22
Cryptophagus badius	21	10
Anisotoma axilllaris	19	15
Latridius minutus	9	21
Agathidium confusum	8	15
Total spec./ind.	10/734	10/489
On polyporous fungi on birch		
Cis boleti	285	122
Cis hispidus	58	88
Triplax russica	71	3
Scaphisoma agaricinum	36	16
Triplax scutellaris	22	8
Total spec./ind.	5/472	5/231

4. Discussion

4.1. Number of saproxylic beetles

The total number of saproxylic species found (207) is high considering the northern latitude and the sampling effort. Unfortunately, comparable data sets from different kinds of forests and different parts of Finland are still scarce or have not been published. Biström & Väisänen (1988) studied the fauna of decaying logs in Pyhä-Häkki National Park. The total area of bark studied was 91 m^2 (86 m^2 in Lahosaajo) and the number of saproxylic beetles 48 (57 in Lahosaajo).

The number of saproxylic species that would generally be caught in different kinds of forests by using standard sets of window flight traps is not known. The systematic collecting of data sets with different kinds of traps is evidently needed to supplement our knowledge about biodiversity in the forests, and about the relative abundances, distribution and habitat requirements of different species.

Two years of sampling using two methods could not give anywhere near a complete species list. The total number of saproxylic beetles recorded from Lahosaajo on the basis of four years of intensive sampling by several methods is 242, and the final number may be up to 270 species (Siitonen, unpublished data).

4.2. Sampling methods

The idea of estimating the relative abundances of tree-living species within trees or in a forest is old and comes from the field of applied entomology. Saalas (1919) was probably the first author to try to estimate the relative abundances of different bark beetle species in different kinds of forests by peeling dead trees on sample strips. The peeling of bark from dead sample trees, or dead trees on sample plots, has rarely been used in ecological studies as a sampling method. Biström & Väisänen (1988) and Väisänen et al. (1993) used the peeling of sample trunks in studies comparing the sub-cortical beetle fauna in primeval forests of a national park and the surrounding managed forests. Siitonen & Martikainen (1993) compared the saproxylic fauna on decaying aspens in Finland and Russian Karelia by direct searching (including peeling of bark). They standardized the effort by studying a large number of dead and dying trees (about 120) and using an equal amount of time in both countries.

The number of saproxylic species found by bark peeling on sample plots can be related to a surface area, and to the volume and bark area of dead trees. In the present study the number of e.g. individuals per unit area was eightfold (13±11 vs. 105±154 per 100 m^2 plot) in Lahosaajo with a larger supply of decaying wood. Although the method seems to give absolute estimates (individuals/unit area), the relative abundances of different species cannot be directly compared. For instance, species living inside the decaying trunks were clearly under represented compared to subcorticulous species. It is difficult to obtain large enough or sufficient sample units by bark peeling on sample plots because of the great variation between plots (see the standard deviations in number of individuals per plot above). Further problems of the method include its laboriousnes and destructivenes.

Window flight trapping yielded large samples at small cost. Standardized trap sets can be used in any kind of forest. The relative abundances of different species caught cannot be directly compared. For instance, each new generation of scolytids must find newly dead or dying trees as their breeding material, but many elaterids living inside decaying trunks may use the same trunk for decades. The best available option may be the comparison of abundances of ecological groups or guilds including several species with, supposedly, varying susceptibility to trapping, as done in this study. It is quite evident that specialist species living on decaying spruce or birch were more abundant in Lahosaajo.

The amount of decaying wood around the traps did not affect the number of species caught, which indicates that the swarming individuals entering or leaving the trees are distributed over larger areas within the forest. However, the similarities between the catches of different traps and the distribution of individual species among the traps requires much more detailed studies.

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