The carabid fauna of a large Danish spruce forest
(Coleoptera, Carabidae)

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In a two year study the carabid fauna of a large Danish plantation of spruce (*Picea abies*) was investigated. The study comprised six different spruce stands and standard entomological traps were used, viz. emergence traps, trays and buckets. Vertical series of buckets were also employed. A total of 2688 carabid individuals in 15 species were caught and identified, dominant species in all stands being *Calathus micropterus* (81%) and *Pterostichus oblongopunctatus* (8%). Most individuals and species were caught in trays, few in emergence traps. In the vertical series only *Dromius*-species were caught within the canopy, *D. agilis* showing seven times higher catches than *D. quadrimaculatus,* while *D. spilotus* only occurred rarely/incidentally. The semiquantitative data are compared to those of other coniferous forests of adjacent countries and to those of other Danish forest types. It is concluded that the epigaeic carabid community of spruce plantations in Central and West Jutland has a unique dominance structure, although it consists of species all native and common to other forest types in the eastern part of Denmark. The arboreal carabids are generally more specific concerning forest type with several additional species belonging to the fauna of coniferous forests becoming more common and generally distributed. None of these species were caught among 147 *Dromius*-individuals in Gludsted Plantation.

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Introduction

The carabid fauna of most areas and habitats in Denmark is rather well known owing to its status as a very popular object to many serious amateur collectors. Recently, the distribution of all Danish carabid species has been reviewed by Bangsholt (1983), and a recent key to the Fennoscandian carabids (Lindroth, 1985 & 1986) has greatly facilitated the correct identification of the species.

Thus, for most major habitats it is possible to construct a theoretical species list of carabids based on information on vegetation, geographic location and/or soil conditions.

During the last decade a large number of detailed and systematic investigations of the carabid fauna of agroecosystems in the northwestern regions of Europe have appeared due to growing awareness of the significance of polyphagous predators, such as carabids, to various pests. In most other habitats quantitative data from systematic sampling of populations are still rare or non-existing.

Spruce forest (*Picea abies* L.) is the dominant forest type in Denmark and is widely distributed, although concentrated in Central, West and North Jutland on poor diluvial soils. To our knowledge, quantitative data on carabids have not yet been produced from this habitat. Quantitative data on forest carabids are available from spruce forests in Sweden (Nilsson, 1987), in Fin-

land (Niemelä et al., 1989) and in Germany (Thiede, 1977), and from deciduous forests in Denmark, i.e. beech (Jørum, 1976) and oak (Jørum, 1988).

In 1980-1981 a general arthropod sampling program was established in relation to an outbreak of the nun moth (*Lymantria monacha* L., Lepidoptera) in Gludsted Plantation (Jensen & Bejer, 1985). Although trapping was not designed for collecting carabids, a large number of carabids (N = 2688 individuals) were caught, and the data are presented below.

Study area and methods

All investigations were carried out in Gludsted Plantation in Central Jutland. This plantation is in itself large (5000 ha) and is furthermore situated adjacent to several other large heath plain plantations on poor diluvial soils. Norway spruce (*Picea abies* L.) is by far the dominant tree species.

Trapping was carried out in six large and pure stands of mature Norway spruce (approx. 90 years old). Canopies were dense and therefore the vegetation of the forest floor was poor, primarily consisting of scattered patches of wavy hair grass (*Deschampsia flexuosa*) and mosses. All stands were located within an irregular area of approximately 2.5×2.5 km^2 in the central part of the plantation.

A number of standard-traps were run in each stand (cf. Jensen, 1988). Standard traps were white buckets (height: 17 cm, diameter: 22 cm), yellow trays (height: 4 cm, area: 25×35 cm) and emergence traps (height: 10 cm, area: 50×50 cm). The traps were placed on the forest floor. Additionally, four vertical series of white buckets were established with buckets hanging from branches at various height in the canopies (stand nos. 29 and 77 (one series each) and 94 (two series)). Average levels of buckets in vertical series were 6.6 m. (I), 10.6 m. (II) and 13.2 m. (III). Trays, buckets and the collection unit of emergence traps were half filled with a 1% formaldehyde solution with detergent. During the winter a number of arthropods were collected under bark flakes on trunks of mature spruce. This search was not systematic in any way, being directed towards the collection of eggclusters of the nun moth.

In 1980 the total number of standard traps were: 2 trays and 4 buckets on the ground in each of four stands and two of these stands were supplied with 1 and one stand with 2 vertical series of buckets. This added up to a 1980 total of 8 trays and 28 buckets. Furthermore, in two of these stands there were 6 emergence traps.

In 1981, correspondingly, the total number of standard traps were: 2 trays and 4 buckets in each of four stands and one of these stands was supplied with 1 and another stand with 2 vertical series of buckets. Furthermore, three of these stands had 10 emergence traps each. In 1981 trapping in canopies (vertical series) was for practical reasons stopped by late June, but data from 1980 has shown that most *arboreal* coleopteran activity had peaked before this. Traps were emptied 9 times at rather irregular intervals during both years.

Statistics were not applied as methods, design and irregular emptying of traps are only thought to allow a semiquantitative analysis.

Results

The individual catches of a total of 15 species are presented in Table 1. Bangsholt (1983) considered all species to be abundant and widely distributed in Denmark although *Pterostichus lepidus* and *Dromius agilis* were listed as uncommon.

A total number of 2688 individuals were collected and identified. Dominant species were *Calathus micropterus* (81%) and *Pterostichus oblongopunctatus* (8%), which together with *D. agilis* and *Calathus melanocephalus* made up 97% of all individuals.

The distribution of the species by stand and year is shown in Table 2. In no single stand or year *C. micropterus* made up less than

Table 1. The distribution of carabids (individuals) in catches from Gludsted Plantation by species and by collecting method.

Tabel 1. Fordelingen af løbebiller (individer) i fangster fra Gludsted Plantage på arter og på indsamlingsmetode.

Trap type Level (m)	Trays 0.05	Buckets 0.15	Buckets > 6.6	Emergence 0.1	Search 0.2-1.5	All methods	%
Calathus micropterus	2082	29	1	67	0	2179	81
Pterostichus oblongopunctatus	144	0	0	64	0	208	8
Dromius agilis	9	22	84	0	12	127	5
Calathus melanocephalus	75	1	0	0	0	76	3
Dromius quadrimaculatus	0	0	12	0	6	18	0.7
Carabus problematicus	14	0	0	4	0	18	0.7
Carabus nemoralis	17	0	0	0	0	17	0.6
Carabus violaceus	14	0	0	0	0	14	0.5
Calathus erratus	12	0	0	0	0	12	0.4
Notiophilus biguttatus	0	0	0	6	0	6	0.2
Pterostichus niger	5	0	0	0	0	5	0.2
Calathus fuscipes	4	0	0	0	0	4	0.1
Dromius spilotus	0	0	2	0	0	2	0.1
Pterostichus lepidus	1	0	0	0	0	1	0.1
Leistus ferrugineus	1	0	0	0	0	1	0.1
N, all species	2394	35	99	141	18	2688	100
N (%)	89	1.3	3.7	5.2	0.7	100	-
Number of species	12	3	4	4	2	15	-

Table 2. The distribution of carabids (% of individuals) caught in trays and buckets in Gludsted Plantation by species and by stand/year.

Tabel 2. Fordelingen af løbebiller (% individer) i fangster fra bakker og spande i Gludsted Plantage på arter og på afdeling/år.

Year	1980	1980	1980	1980	1981	1981	1981	1981	All years & stands	
Stand no.	77	94	29	55	77	94	136	140	N	%
Calathus micropterus	92	76	78	87	77	66	93	78	2112	84
Pterostichus oblongopunctatus	4	3	2	2	20	0	0	7	114	6
Dromius agilis	2	16	10	2	0.5	18	5	0	115	5
Calathus melanocephalus	1	0.6	7	7	0.5	5	2	2	76	3
Dromius quadrimaculatus	0.4	1.4	2	0	0	5	0	0	12	0.5
Carabus problematicus	0.1	1.4	0	0	0	0	0	5	14	0.6
Carabus nemoralis	0.2	0	0.4	0.4	2	5	0	3	17	0.7
Carabus violaceus	0	1.4	0.8	0	0	2	0	4	14	0.6
Calathus erratus	0.4	0.3	0.8	1	0.2	0	0	0	12	0.5
Pterostichus niger	0	0.3	0	0	0.5	0	0	1	5	0.2
Calathus fuscipes	0.1	0	0	0.6	0	0	0	0	4	0.2
Dromius spilotus	0	0.3	0.4	0	0	0	0	0	2	0.1
Pterostichus lepidus	0	0	0	0.2	0	0	0	0	1	0.1
Leistus ferrugineus	0	0	0	0	0.2	0	0	0	1	0.1
All species/no. of indv.	809	352	254	491	391	44	45	153	2529	100

Table 3. The distribution of carabids (individuals) caught in vertical series of buckets in Gludsted Plantation by species and by level. Number of traps and trap-days are equal at all levels.

Tabel 3. Fordelingen af løbebiller (individer) i de lodrette serier af fangspande i Gludsted Plantage på arter og på højde (meter). Antallet af fælder og fældedage er ens på alle niveauer.

Level	Ground (0.15 m)	Canopy I (6.6 m)	Canopy II (10.6 m)	Canopy III (13.2 m)	All levels
Dromius agilis	5	20	38	26	89
D. quadrimaculatus	0	4	6	2	12
D. spilotus	0	1	0	1	2
Calathus micropterus	1	1	0	0	2
All species	6	26	44	29	105

two thirds of all individuals (range: 66-93%), and in no single stand or year the four dominant species made up less than 87% (range: 87-99%). Apparently, Table 2 shows fewer individuals in 1981 than in 1980. However, trapping ended earlier in 1981, and the 1980-data have shown, that autumn catches (August 18th to October 29th) alone might constitute more than half the total catches. Besides, stands and trapping were not throughout identical in 1980 and 1981, and for these reasons years should not be compared.

All carabid species and their numbers from all stands and both years are shown in Table 1 by sampling method. Trays on the forest floor contributed about 90% of all individuals. Emergence traps only contributed 4% (N = 141) of all individuals, but emergence trap catches at least confirmed that *C. micropterus* and *P. oblongopunctatus* were two very dominant species (93% of all indv. from emergence traps).

Trays contributed the largest number of species (S = 12), the three non-occurring species being rare in the total catch, and therefore easily missing by chance.

Table 3 lists the total catches from the vertical series of buckets. These are directly comparable due to equal trap numbers and trap days. A specific arboreal carabid fauna was clearly demonstrated with no apparent decline in catches in the upper canopy. *D. agilis* seemed to be the more abundant of the three arboreal *Dromius*-species, as its numbers were always higher both in trays and buckets on the ground, in the buckets in the canopy, in searches of hibernating individuals under bark flakes (column 4 of Table 1) and in each of all stands (all applied methods pooled) and in both years (Table 2). Neither of the three *Dromius*-species were caught by supplementary sweep-net catches from low green branches at the borders of stands.

Discussion

It is not clear in which way the trapped species and individuals have entered the traps, but possible ways are climbing of trap, climbing adjacent vegetation (mainly grass leaves) and falling/dropping from canopies above. Almost all species collected in Gludsted Plantation have wings always/normally reduced or have in other ways restricted flying abilities (Lindroth, 1985 & 1986). Important exceptions are the arboreal carabids of the genus *Dromius,* which were all found to have fully developed wings in our material and were the only species showing (frequent) signs of trying to escape the trapping liquid by flying.

Though trapping methods were far from ideal for carabids, table 1 undoubtedly shows a relevant species list. A total of 15 species in a catch of 2700 indv. is low, but not surprising as this habitat type and particularly the selected stands were rather monotonous and poor compared to other habitats. Jørum (1988) reported 28 species

from a catch of 5500 individuals from mixed and pure oak forest stands, and Jørum (1976) 33 species from a catch of 11500 individuals from a beech forest.

In our samples the dominance of *C. micropterus* and *P. oblongopunctatus* is considered representative of the real carabid populations, as there is accordance between catches from trays, buckets and emergence traps. Thiede (1977) reported rather low catches (111 indv.) in emergence traps from western Germany, but with a surprisingly similar species composition (*C. micropterus* 39%), *P. oblongopunctatus* (23%), *N. biguttatus* (22%) and others (16%)). Most other data on Northwest-European carabids are based on pitfall trapping and hence difficult to compare directly with our data. However striking similarity occurs. Thus, trapping in spruce forests in Sweden (Nilsson, 1987) showed dominance of *Carabus hortensis* (31.5%), followed by *P. oblongopunctatus* (23.5%), *Calathus micropterus* (18.8%) and *Pterostichus niger* (7.9%). Pitfall trapping in fragments of primeval moist spruce forest in southern Finland (Niemelä et al., 1989) showed dominance of *C. micropterus* (34%), *P. oblongopunctatus* (17%), *N. biguttatus* (12%), *Carabus hortensis* plus *C. glabratus* (15%), *Cychrus caraboides* (7%) and *Amara brunnea* (5%). Pitfall trapping in an oak forest only 35 km. north of Gludsted Plantation (Jørum, 1988) showed dominance of *P. oblongopunctatus* (35%), *P. niger* (16%), *C. micropterus* (9%), *Carabus problematicus, Abax parallelepipedus,* and more unevenly distributed *Nebria brevicollis* and *Calathus rotundicollis.* From Germany Thiele (1977) reported *C. micropterus* and *P. oblongopunctatus* as often occurring together and associated with forests on dry soils with low acidity-values, which is in accordance with site conditions in Gludsted Plantation.

The main difference between these and our data is the very low catches of *Carabus* spp. in Gludsted Plantation: it is possible that catches from trays – to a larger degree than pitfall traps – underestimate *Carabus*-activity, as the large individuals of *Carabus* spp. might be able to escape trays due to their low rims and accordingly shallow trapping liquid. On the other hand Jørum (1976) believed *Carabus* spp. to be overestimated by pitfall trapping. It is remarkable that only 4 individuals of *Carabus* spp. were caught in emergence traps in Gludsted Plantation, but too little is known about how species of this genus react to emergence traps and about their ability to escape from capture, but Thiede (op.cit.) similarly caught only one indv. (*C. problematicus*). In two consequtive years Niemelä et al. (op. cit.) caught similar and relatively low numbers of *Carabus* spp. (15%) even though they used pitfall traps. Further, their supplementary handpicking and sieving data showed a species composition very similar to that derived from their pitfall trapping except from a total lack of *Carabus* spp. Thus, the low *Carabus*-activity in our data is not unprecedented, and we believe that it to some degree reflects real low densities. Bangsholt (op. cit.) demonstrated a marked difference in occurrence of a number of *Carabus*-species between eastern (abundant) and western (scattered) parts of Denmark.

Finally, other species were possibly underestimated in the catches. Emergence trap data (Thiede, op.cit.; this paper) and the pitfall data of Niemelä et al. (op.cit.) indicates that *Notiophilus biguttatus* might be common in spruce forests, just as Jørum (op.cit.) thought it underestimated by pitfall trapping in a beech wood. This might be due to its smaller size (not being able to climb rims), but the relatively high catches in emergence traps and the relatively low catches in pitfall traps shows that other behavioural aspects must be considered. For some reason Niemelä et al. (op.cit.) were able to catch high numbers of this species in common pitfall traps.

The results presented here are thought to be general to this habitat *and* soil type due to the extensively distributed traps (in time and space) and due to the large size and central location of Gludsted Plantation as a

representative of Danish spruce plantations. Although the trapping methods were certainly far from ideal, the carabid fauna was found to be similar to that reported from spruce forests in Sweden, Finland and Germany, and it is somewhat similar to the carabid-fauna of an oak forest on similar poor soils in the same part of the country. This fauna is sharply contrasted with that of a beech forest on the richer soils of East Jutland only 70 km. ENE of Gludsted Plantation (Jørum, 1976).

These similarities and dissimilarities confirm the general picture, that the watershed of Jutland, which at the same time is a main divide of soil types (structure and acidity), is a crucial divide for most dominant forest carabid species to a much higher degree than forest type. This conclusion parallels that of Niemelä et al. (op. cit.), that forest carabids "seem to be relatively unspecialized in their requirements concerning different forest types".

A few very eurytopic species, i.e. *P. niger, C. violaceus* and *C. nemoralis,* which occur in forests of all Danish regions, also occur in our catches, although their numbers were never high.

Comparison of our data with carabid data from areas of native spruce forests shows that the carabid fauna of the original Danish forests (i.e. oak and beech) contained all the dominant and subdominant epigaic species typical of spruce forests, thereby greatly facilitating the rapid colonization of this relatively new Danish forest type. Thus, the planting of spruce forests in Denmark have not and will apparently not contribute new habitat specific species to the Danish epigaic carabid fauna. This is probably partly due to the general trophic characteristics of carabids: being primarily polyphagous epigaic predators, carabids generally can not be expected to display narrow habitat requirements.

Still, it seems safe to conclude that the carabid fauna of mature spruce plantations of Jutland have their own species composition: *C. micropterus* and *P. oblongopunctatus* are very dominant and usually with the former being the more abundant, while *Carabus* spp. play a smaller role than they do in most deciduous forests in eastern parts of Denmark. This species composition might certainly not hold on richer soils in eastern Denmark even in large size spruce plantations.

The data has clearly demonstrated the separate importance of the arboreal carabid fauna, which was only poorly represented in our catches from buckets and trays on the forest floor. The arboreal carabids appear to be totally missing in catches from pitfall-traps (Jørum, 1976 & 1988; Nilsson, 1987) and this absence is particularly striking in the data of Jørum (1976) as Nielsen (1974) had collected large numbers of *D. quadrimaculatus* and small numbers of *D. agilis* in the very same stand of beech trees using arboreal photoeclectors.

The arboreal carabid fauna, viz. the genus *Dromius* s.str., seems to be somewhat more specific to forest type and tree species (Lindroth, 1986) with the main divide between coniferous and deciduous forests. Several arboreal *Dromius*-species belonging to the coniferous forest fauna have in fact recently become increasingly abundant and more widely distributed in Denmark, probably as a response to the increasing areas with conifers. None of these colonizing species were caught in Gludsted Plantation.

The vertical distribution of *Dromius* spp. with high numbers almost to the tree-tops and very low numbers in traps directly under canopies indicates that the arboreal carabids climb into the traps - incidental dropping off branches would tend to show increasing catches from top to bottom.

D. agilis was reported as uncommon by Bangsholt (1983) and were along with *D. spilotus* the rarer of the three occurring *Dromius*-species in the study of Nielsen (op.cit.), but this species was caught in all but one stand in Gludsted and was always and everywhere in our study the commoner of the three *Dromius*-species. *D. agilis* and *D. quadrimaculatus* occurred throughout the en-

tire canopy, and were readily found hibernating under barkflakes in mature stands of spruce. Thus, it is shown, that vertical trapping series are necessary to get a complete picture of the forest fauna, and that this applies even to carabids as well as other arthropod taxa (Reddersen & Jensen, unpubl.). White buckets in the canopies appear to be a simple and generally effective semiquantitative method, but at least in mature spruce stands with well-developed barkflakes hibernating arboreal carabid species can be collected by search and hand-picking on the lower parts of the tree trunks. In fact, we estimate the latter method to be the more efficient of the two, but for any comparative use it has the methodological disadvantage of being very dependent on the development of barkflakes on trunks of different individuals, provenances, age-classes and species of trees.

Dansk sammendrag

Løbebillefaunaen i en stor dansk rødgranplantage

Løbebillefaunaen i en stor dansk rødgranplantage (Gludsted Plantage, Midtjylland) blev undersøgt i en to-års periode, april 1980-september 1981 i forbindelse med undersøgelser af et større nonneangreb. Der blev ved undersøgelsen anvendt en række fældetyper på jorden (fangbakker, klækkefælder og hvide plastspande) foruden håndfangning af dyr under barkflager. Fangglas blev ikke anvendt. Plastspandene blev desuden også ophængt i træerne i forskellig højde, nemlig i den øverste og midterste del af kronen samt øverst i stammerummet. Seks forskellige afdelinger, alle med ca. 90-årig rødgran, blev undersøgt.

I alt blev der fanget 2688 løbebiller fordelt på 15 arter, hvoraf *D. quadrimaculatus* og *D. spilotus* kun blev taget i træerne, mens et mindre antal *D. agilis* tillige fangedes på jorden. Af de øvrige arter blev blot en enkelt *C. micropterus* fanget i træerne. Sidstnævnte art udgjorde langt den største del af de fangne dyr på jorden (85%); næsthyppigst var *P. obsoletus* (4%), *P. longopunctatus* (8%), *C. melanocephalus* (3%) og *D. agilis* (1%).

De fleste individer blev fanget i de lave fangbakker (89%), kun et fåtal af individer (5%) og arter blev fanget i klækkefælderne. De få individer af *Notiophilus biguttatus* i materialet er dog alle fra klækkefælderne.

Udfra Gludsted-undersøgelserne og øvrige danske og udenlandske kvantitative løbebilleindsamlinger kan det fastslås, at løbebillefaunaen i ældre veletableret granskov i området vest for hovedstilstandslinien har et begrænset, men karakteristisk artsspektrum, som er en delmængde af de arter, der allerede fandtes i ældre og mere oprindelige løvskovsområder. Ingen af de fundne epigæiske arter synes således at være specielt tilknyttet granskoven, men der synes dog klart at findes en karakteristisk dominansstruktur.

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