The Syrphidae, Coccinellidae, and Neuroptera (s.lat.) of a large Danish spruce forest

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In 1980 and 1981, the insect fauna of six well-managed, mature stands of Norway spruce in Gludsted Plantation, Central Jutland, Denmark, was sampled using trays and white bucket traps on the forest ground, as well as white buckets at three canopy levels. Here, we report on the species composition of three major taxa, generally recognized as important aphidophagous groups, viz. Syrphidae, Coccinellidae and Neuroptera (s. lat.).

Among c. 3000 adult syrphid specimens and 48 species, *Helophilus pendulus*, *Melanostoma scalare*, *Meliscaeva cinctella* and *Platycheirus cyaneus* were very dominant (>10% each). Conifer or spruce specialist species (*sensu* Torp, 1994) were far less numerous or even absent. Among c. 450 adult and larval coccinellids and only 5 species, *Anatis occellata* was very numerous and *Aphidecta oblitterata* and *Myzia oblongoguttata* fairly common. Among c. 200 adult Neuroptera and only 6 species, one species, *Hemerobius pini*, was very dominant and apart from *Wesmaelius quadrifasciatus* other species only occurred singly. The species composition showed considerable similarities across stands and years. Thus, the species composition of Norway spruce/conifer biotopes appeared sharply delimited from the well-known species communities of mixed farmland landscapes and of deciduous forests in Denmark and neighbouring countries.

Catches from ground-canopy trap transects varied greatly between groups and stages. Adult syrphids were almost entirely caught in ground traps whereas most other species were either caught in both ground and canopy traps (some syrphid, coccinellid and hemerobiid larvae) or almost entirely in canopy traps (adult coccinellids and hemerobiids, some coccinellid larvae). Other population features are also presented, viz. skewed sex catch ratios and temporal variation of the aphid-aphidophage community.

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Introduction

For many decades, Norway spruce (*Picea abies* L.) has comprised a high proportion of the forested area in Denmark – particularly on poor sandy acidic soils in mid- and western Jutland. During the last decades, however, many mature stands of this tree species have suffered severe damage from gales (1981 and 1999). As current afforestation and reforestation policies support the planting of deciduous tree species, both relative and absolute coverage of Norway spruce is expected to decline even further while total Danish forest area is increasing. However, it is still one of the most common and commonly planted species in Denmark.

Despite its high coverage, our knowledge of the fauna of spruce forests is scarce, probably because it is an introduced species and because the dense, dark monocultures are expected to host only an impoverished fauna (e.g. Asbirk et al., 1980). However, in its native range, it is not species poor and in England an unpublished study indicate, that even stands of introduced Norway spruce may not be poor in species (Tickell, 1994). The introduction and widespread planting of coniferous tree species (incl. Norway spruce) in Denmark during the last 150-200 years have been the basis for the subsequent immigration of a number of much valued bird, plant and insect species (Asbirk et al., 1980). Quite a number of insects are specific for spruce or conifer forest, many others utilize conifer forests as temporary habitat, e.g. hibernation habitat (e.g. Nielsen, 1970).

Reddersen & Jensen (1991) described the carabid community of a large spruce plantation. They found that the species richness was generally low and the community very much dominated by the same few species across stands and years. In particular, they documented the significance of employing canopy traps which demonstrated considerable arboreal activity of a number of small and specialized carabid species hardly ever captured in ground traps.

Based on material from the same plantation and trapping programme, the present paper attempts to expand the quantitative description of the arthropod community of Danish spruce forests by presenting data on three insect taxa which are important aphidophagous groups.

Methods and material

Site and stand description.

The study area was located in Gludsted Plantation in Central Jutland (UTM 32V NH 21). Gludsted Plantation covers c. 5000 ha and is further surrounded by other large conifer plantations together constituting the largest coherent conifer forest area in Denmark. In this area, in the late 1970'ies, stands of mature (80-100 yrs) Norway spruce (*Picea abies* L.) were very dominant, but during the winters 1981/82 and 1999/2000, many of them were felled or severely damaged by gales.

In 1980-81, trapping was carried out in six stands, all located within a 2.5 by 2.5 km central area of the plantation. Neighbouring farmland areas were few and more than 4 km away while a single village, scattered houses and moist and dry heathland patches and an oligotrophic lake occurred c. 3 km away. Within the plantation, forest clearings were scarce and open land biotopes mainly occurred as the forest dirt road network and fire belts. All six stands were pure stands of well-managed mature Norway spruce (c. 90 years old). Canopies were dense and forest floor vegetation was scarce, mainly scattered patches of Wavy Hair Grass (*Deschampsia flexuosa* L.), mosses and lichens. Stands 77 and 94 were sampled in both years, whereas stands 29 and 55 and stands 136 and 140 were only sampled in 1980 and 1981, respectively (Table 1).

Before and during the study, moderate to heavy outbreaks of the nun-moth *Lymantria monacha* L. occurred in some stands (Jensen & Bejer, 1985). Various insecticide treatments were applied in affected stands including some of those sampled (Table 1). Treatments varied from moderate (*diflubenzuron* (1/3 l/ha), trade name Dimilin®: a growth-regulator hormone analogue with exposure following ingestion) to heavy (*diflubenzuron* plus *endosulphane* (1/2 l/ha), trade name Thiodan®, a highly toxic contact insecticide).

Table 1. Details on stands in Gludsted Plantation, Central Jutland, sampled in 1980-81: the distribution of various trap types and of insecticide treatment before and during sampling. ( ): ground buckets not included in canopy:ground comparisons. D: diflubenzuron. E: endosulphane (cf. 'Methods' section).

Tabel 1. Detaljer vedrørende afdelinger i Gludsted Plantage, Midtjylland, med prøvetagning i 1980-81 mht. fordelingen af forskellige fældetyper og af insekticidbehandling før og under prøvetagningen. ( ): Jordspande ej inddraget i krone:jord sammenligninger. D: diflubenzuron. E: endosulfan (jf. metodeafsnittet).

	Stand number (according to local forest authorities)							
Sampled in 1980	94	77	55	29				
Sampled in 1981					94	77	136	140
Trap type/number:								
– trays (±window)	2	2	2	2	2	2	2	2
– ground buckets	4	4	(4)	4	4	4	(4)	(4)
– canopy buckets	6	3	0	3	6	3	0	0
Insecticide(s):								
– spring 1979	0	D	D	0	0	D	0	0
– spring 1980	0	D	0	D+E	0	D	0	D+E
– spring 1981	–	–	–	–	0	0	D	0

Arthropod trapping.

Arthropod activity was monitored on the forest floor ('ground') as well as in the canopies ('canopy') using white bucket traps (h: 17 cm; d: 22 cm). In each stand and year, four buckets were placed on the forest floor in the corners of a 20 by 20 m square (Table 1). Additionally, in some stands, 1-2 four level vertical bucket trap series was established, each comprising one of the ground bucket traps and with canopy traps located at mean heights 6.6 m (lower needleless canopy), 10.6 m (central green canopy) and 13.2 m (upper green canopy).

In all stands, additional ground trapping was performed using two yellow trays (H×W×L: 4×25×35 cm) placed within the ground bucket square – one of them with a vertical 25×18 cm window at the middle. Trays and buckets were half filled with a 1% formaldehyde solution with detergent added.

Trapping periods and emptying was rather irregular and varied from 5 to 43 days in 1980 and from 10 to 50 days in 1981 (Table 2) with a grand mean of c. 20 days. Emptying was most regular in April-July, when mean periods were 12 and 14 days in 1980 and 1981, resp. In August-October, the mean period increased to 32 and 49 days, resp. Other minor irregularities are also listed in Table 2. In phenological analyses, trapping periods are represented by trap period midpoints.

Extra specimens were collected by scattered supplementary sampling methods, viz. (1) searching for overwintering specimens in crevices and under bark flakes on lower trunks of mature spruce trees and (2) vertical sticky trap series (hanging bottles with plastic bags covered with glue ("Brunonia" Raupenleim, Germany).

Identification and nomenclature.

Identification, nomenclature and guild grouping are based on Esben-Petersen (1929), Hansen (1951), Hodek (1973), Silfverberg (1979), Aspöck et al. (1980) and Torp (1984) – in syrphids nomenclature was updated using Torp (1994). In adult syrphids and he-

Table 2. Outline of trapping periods with initial (I) and final (F) dates. *: no trays yet. §: no canopy traps. #: irregular trap efficiency due to occasional freezing of trapping liquid.
*Tabel 2. Oversigt over fangstperioderne med angivelse af start (I) og slut (F). *: Ingen fangbakker endnu.§: Ingen kronefælder opsat. #: Uregelmæssig fældeeffektivitet pga. lejlighedvis tilfrysning af fangvædske.*

Sampling year 1980:	I									F	Σdays
– emptying date	16/05	21/05	27/05	09/06	26/06	10/07	24/07	18/08	16/09	29/10	
– trapping period length	–	*5	6	13	17	14	14	25	29	43	166
– trapping period midpoint	–	19/05	24/05	03/06	18/06	03/07	17/07	06/08	02/09	08/10	
Sampling year 1981:	I									F	Σdays
– emptying date	30/03	09/04	30/04	14/05	27/05	12/06	24/06	08/07	25/08	14/10	
– trapping period length	–	#10	#21	14	13	16	12	14	§48	§50	198
– trapping period midpoint	–	04/04	20/04	07/05	21/05	04/06	18/06	01/07	01/08	19/09	

merobiids, the sex was also recorded. Generally, only 'true' coccinellids, i.e. Coccinellinae, were identified and counted.

Data manipulation and statistics.

Data were, in many respects, both unbalanced and scarcely replicated concerning variables year, stand, trap type, trapping periods and heigth (e.g. Tabs. 1-2). Hence, species and their individual numbers were not analyzed statistically. Various variables of the dataset were evaluated singly and thus, without considering interactions. Numbers are presented as totals or simple means: mean catch per trapyear or mean catch per 30 trapdays (mean number of trap samples per sampling date ≈ 30 traps).

Initial analyses showed that while abundances of some groups, seemed affected by the insecticide treatments, the relative abundances and thus species composition of treated stands only rarely differed considerably from untreated stands. Choosing between discarding material from treated stands or lowering stand replication critically, material from all stands were included in the analyses.

When examining vertical distributions, only bucket traps were analyzed including all ground traps from stands with vertical trapping series and excluding all ground traps from stands without vertical trapping series resulting in a total of 20 ground and 21 canopy traps.

In some cases, χ^2-tests were applied to total catches for tentative evaluation of differences in Canopy:Ground and Male:Female ratios.

Results

A total of 2974 adult syrphids in 48 species were collected in trays and buckets (Table 3a) along with 364 syrphid larvae (Table 3b). The identification of four syrphid taxa was uncertain and thus represented at least four species, viz. *Baccha elongata/obscuripennis*, *Parasyrphus* (other than *P. lineola*) spp., *Sphaerophoria batava* (females) and *Neoascia podagrica* (females). Further, the material consisted of a total of 195 adult neuropterans in six species (along with 671 larvae in two taxa) and 111 adult coccinellids in five species (along with 339 larvae in three species). Aphids were not identified, but a considerable proportion of individuals were Lachnidae, which were also, in 1980, observed abundantly on trunk and branches in upper Norway spruce canopies.

Table 3a-b. Species composition of aphids, Syrphidae, Coccinellidae, and Neuroptera (s.lat.) in Norway spruce insect samples listing total catches (individuals) from all trap types along with the number of stands and years where each species occurred (stands/yrs). Total catches from matching white buckets from ground and canopy, respectively, is also given with canopy:ground catch per trap ratio and test-results. § signifies uncertain identifications (cf. 'Methods').
Tabel 3a-b. Artssammensætning af bladlus, svirrefluer, mariehøns og netvinger i insektprøver fra rødgran med angivelse af de totale fangster (individer) fra alle fældetyper sammen med det antal afdelinger og år, hvor de blev fundet (stands/yrs). Totale fangster fra samhørende hvide spande fra hhv. skovbund og krone er også anført sammen med krone:jord fangst pr. fælde ratio og test resultater. § angiver usikre identifikationer (jf. metodeafsnittet).

Taxon/species	Larval biology	TOTAL (Indv.)	Occurrence stands/yrs	Ground (n=20)	Canopy (n=21)	Canopy: Ground	Chi-test result
SYRPHINAE:							
Baccha elongata/obscuripennis §	A	3	3/2	2	–		nt
Melanostoma mellinum (L.)	A	96	8/2	32	21	.63	NS
M. scalare (Fabr.)	A	579	8/2	250	10	.04	***
Platycheirus cyaneus (Müller)	A	368	8/2	181	4	.02	***
P. peltatus (Meig.)	A	4	3/1	3	1		nt
P. scutatus (Meig.)	A	103	6/2	50	–	.00	***
Chrysotoxum arcuatum (L.)	A	1	1/1	1	–		nt
Ch. bicinctum (L.)	A	1	1/1	–	–		
Ch. fasciatum (Müller)	A	5	3/1	3	–		nt
Ch. vernale Loew	A	1	1/1	–	–		
Syrphus ribesii (L.)	A	68	6/2	36	–	.00	***
S. torvus Osten Sacken	A	95	4/1	34	3	.08	***
S. vitripennis Meigen	A	4	4/1	2	–		nt
Eupeodes corollae (Fabr.)	A	22	3/2	4	–		nt
E. nielseni Dusek & Láska	A	1	1/1	–	–		
Dasysyrphus lunulatus (Meig.)	A	28	7/2	12	–	.00	***
D. tricinctus (Fall.)	A	1	1/1	1	–		nt
Parasyrphus lineola (Zett.)	A	98	8/2	26	–	.00	***
Parasyrphus spp. §	A	53	8/2	11	–	.00	***
Didea alneti (Fall.)	A	1	1/1	–	–		
D. fasciata Macquart	A	1	1/1	–	–		
Eriozona syrphoides (Fall.)	A	1	1/1	–	–		
Megasyrphus erraticus (L.)	A	17	4/1	1	1		nt
Meliscaeva cinctella (Zett.)	A	435	8/2	126	3	.02	***
Episyrphus baltheatus (Deg.)	A	60	6/2	31	2	.06	***
Sphaerophoria batava § Goeldlin	A	49	7/2	33	–	.00	***
ERISTALINAE:							
Pipiza quadrimaculata (Pz.)	A	7	5/2	1	–		nt
Neocnemodon latitarsis (Egger)	A	8	2/1	1	–		nt
Rhingia campestris Meig.	TS	53	8/2	23	3	.12	***
Volucella pellucens (L.)	TS	3	2/1	1	2		nt
Sericomyia lappona (L.)	AS	1	1/1	1	–		nt
S. silentis (Harris)	AS	4	3/1	1	–		nt
Neoascia podagrica § (Fabr.)	TS	67	8/2	40	4	.10	***
Sphegina clunipes (Fall.)	TS	12	6/2	6	–		nt
Brachyopa testacea (Fall.)	TS	31	7/2	9	6	.6	NS
Chrysogaster solstitialis (Fall.)	AS	1	1/1	1	–		nt
Helophilus hybridus Loew	AS	2	2/2	1	1		nt

H. pendulus (L.)	AS	666	8/2	389	12	.03	***
H. trivittatus (Fabr.)	AS	6	4/2	1	3		nt
Myathropa florea (L.)	AS	3	2/1	3	–		nt
Eoseristalis arbustorum (L.)	AS	4	2/1	2	2		nt
E. horticola (Deeg.)	AS	2	2/1	–	–		
E. interrupta (Poda)	AS	1	1/1	1	–		nt
E. intricarius (L.)	AS	1	1/1	1	–		nt
E. pertinax (Scop.)	AS	1	1/1	1	–		nt
Syritta pipiens (L.)	TS	3	3/2	1	1		nt
Xylota florum (Fabr.)	TS	1	1/1	–	1		nt
X. segnis (L.)	TS	2	2/1	–	–		
Total number of individual		2974	–	1323	80	.06	***
Total number of species		48	–	39	18		**

GROUP: Taxon/Species	Hibernation stage	TOTAL (Indv.)	Occurrence stands/yrs	Ground (n=20)	Canopy (n=21)	Canopy: Ground	Chi-test result
HOMOPTERA, Aphidoidea:							
Aphids		5663	8/2	329	4435	12.8	nt
DIPTERA, Syrphidae:							
Syrphid larvae	–	364	8/2	84	61	.7	*
COLEOPTERA, Coccinellidae:							
Anatis ocellata (L.) - adults	A	73	7/2	8	56	6.7	***
– larvae	–	301	5/2	14	245	17	***
Aphidecta oblitterata (L.)	A	26	6/2	3	21	6.7	***
– larvae	–	33	6/2	8	12	1.4	NS
Myzia oblongoguttata (L.)	A	8	4/2	0	7		nt
– larvae	–	5	2/1	1	4		nt
Calvia quattuordecimpunctata (L.)	A	2	2/2	2	0		nt
Coccinella septempunctata L.	A	2	1/1	2	0		nt
PLANIPENNIA, Hemerobiidae:							
Hemerobius pini Steph.	P, A	172	6/2	3	164	52	***
H. micans §	P, A	1	1/1	0	1		nt
H. humulinus L.	P, A	1	1/1	0	1		nt
Wesmaelius quadrifasciatus (Reuter)	E	17	3/1	0	17	>17	***
Hemerobiidae spp. larvae	–	636	8/2	137	164	1.14	NS
PLANIPENNIA, Chrysopidae:							
Chrysopa spp.	A	2	1/1	1	1		nt
RHAPHIDIOPTERA, Rhaphidiidae:							
Rhaphidia xanthostigma Schummel	L	2	2/1	1	0		nt
Rhaphidia spp, larvae	–	35	8/2	6	9	1.4	NS

Vertical distribution.

Most taxa examined exhibited considerable differences in catches between Canopy and Ground trap levels, but differences varied between major taxa. In general, Canopy buckets caught far fewer adult syrphids than did Ground buckets, viz. only 80 indv. in 21 canopy traps compared to 1323 indv. in 20 ground traps (Table 3a) equivalent to a Canopy:Ground catch ratio of only 0.06. Within the canopies, however, catches increased from lower through middle to upper canopy stratum, totalling 12, 19 and 49 individuals, resp. (χ^2=29.0, df=2; P<0.001), but even in the upper canopy, Canopy:Ground ratio was only 0.11.

The pattern was also found in catches of most single syrphid species where Canopy:Ground catch ratios rarely exceeded 0.1. Among species numerous enough to test (total catch ≥10), the only exceptions were *Melanostoma mellinum, Brachyopa testacea* and *Rhingia campestre* with ratios 0.63, 0.6 and 0.12, resp. (still below 1). The pooling of individuals from 24 less numerous syrphid species ('nt' in Table 3a), exhibited a similar pattern with a Canopy:Ground ratio of 0.3 (12:41; P<0.001). Also, within these less numerous species, the number of species with higher catches in ground buckets exceeded the number of species with catches higher or equal in canopy buckets (17:7; P<0.05).

Also more syrphid species was caught in ground traps: while 39 species occurred in catches from 20 ground buckets, only 18 species occurred in 21 canopy buckets and while 22 species were exclusively caught in ground buckets, only 1 species was exclusively caught in canopy buckets (*Xylota florum*: 1 indv.).

Canopy buckets, however, did not in general catch fewer individuals. Larvae of Syrphinae spp., *Aphidecta oblitterata, Hemerobiidae* spp. and *Raphidia* spp. were caught in equal or almost equal numbers in canopy and ground traps (Table 3b: Canopy:Ground ratios of 0.7, 1.4, 1.1 and 1.4, resp.). The remaining groups (aphids and several species of adult and larval coccinellids and adult hemerobiids) even had considerably higher catches in canopy buckets.

Species composition.

Ground trays (with and without windows) and ground buckets caught roughly similar numbers of individuals and species of the examined insect taxa. In adult syrphids, for example, mean total catch per trapyear was 61.5 and 56.5 indviduals in ground trays and buckets. Also, trays with windows did not catch many more syrphids than trays without windows. Consequently, they were pooled as 'ground traps'.

The syrphid species composition is given in Table 3a. Among the 48 species, 15 species each contributed >1% of all individuals (Table 4) and together constituted 95% of all individuals and in no standyear case less than 90%. *Helophilus pendulus, Melanostoma scalare, Meliscaeva cinctella* and *Platycheirus cyaneus* each contributed >10%. Another 7 species each contributed >2% (*Platycheirus scutatus, Parasyrphus lineola, Melanostoma mellinum, Syrphus torvus, Syrphus ribesii, Neoascia podagrica* and *Episyrphus baltheatus*) and another 4 species >1% (*Rhingia campestre, Parasyrphus* (other than *P. lineola*) spp., *Sphaerophoria batava* and *Brachyopa testacea*). Most species (even less frequent ones) were fairly evenly distributed among stands and years (Table 3a, column 4) and their relative abundance only varied moderately (Table 4).

Some uncommon syrphid species were recorded: *Chrysotoxum vernale* (1 male, stand 77, Apr 30–May 14 1981), *Metasyrphus nielseni* (1 female, stand 140, Jul 8–Aug 25), *Eriozona syrphoides* (1 male, stand 55, Sep 16–Oct 29 1980), *Didea alneti* (1 female, stand 77, Jun 17 1980), and *Brachyopa testacea* (31 indv. caught in 7 out of 8 standyear cases).

Species composition in other aphidophagous taxa was very simple (Table 3b). The coccinellids were strongly dominated by *Anatis ocellata* along with *Aphidecta oblitterata* and

Table 4. Between-stand variation in relative abundance of the fifteen most numerous syrphid species from trays and buckets. § as Table 3. Stands are sorted by increasing degree of insecticide treatment (* or **) in sampling year or ( ) previous year, cf. Table 1.
Tabel 4. Relativ hyppighed inden for afdelinger og totaler inden for år af hver af de 15 mest talrige svirrefluearter fra fangbakker og hvide fangspande. § som Tabel 3. Afdelingerne er ordnet (stigende) efter graden af insekticidbehandlinger (eller **) i prøvetagningsåret eller ( ) i året før, jf. Tabel 1.*

Stand (Afdeling)	94	55	77	29	Σ	94	77	140	136	Σ	ΣΣ
		(*)	*	**					*		
	%	%	%	%	*Indv.*	%	%	%	%	*Indv*	.%
Helophilus pendulus	33	11	6	17	*370*	54	27	27	20	*296*	22.4
Melanostoma scalare	18	31	27	12	*441*	9	18	15	19	*138*	19.5
Meliscaeva cinctella	22	19	20	15	*389*	5	4	4	8	*46*	14.6
Platycheirus cyaneus	11	11	15	9	*234*	9	15	15	21	*134*	12.4
P. scutatus	2	7	4	7	*99*	0	0	1	1	*4*	3.5
Parasyrphus lineola	2	4	4	6	*84*	1	<1	1	4	*14*	3.3
Melanostoma mellinum	1	1	4	5	*56*	7	3	4	4	*40*	3.2
Syrphus torvus	3	5	6	5	*95*	0	0	0	0	*0*	3.2
Syrphus ribesii	2	3	2	5	*64*	0	0	1	1	*4*	2.3
Neoascia podagrica §	<1	<1	1	1	*15*	5	10	4	2	*52*	2.3
Episyrphus baltheatus	1	2	2	4	*49*	0	0	4	1	*11*	2.0
Rhingia campestris	1	1	1	2	*25*	<1	4	3	5	*28*	1.8
Parasyrphus spp. §	<1	1	1	1	*13*	3	3	7	6	*40*	1.8
Sphaerophoria batava §	<1	<1	1	2	*19*	2	9	<1	0	*30*	1.6
Brachyopa testacea	0	1	<1	<1	*6*	3	2	3	3	*25*	1.0
Total percentage (15 most common spp.)	96.6	96.7	94.1	91.4	–	98.8	96.5	89.7	95.0	–	94.9

Myzia oblongopunctata, together contributing 96% of all adults and 100% of all larvae. The relative abundance of these three species was similar in adults and larvae, viz. 9:3:1 and 60:7:1. The hemerobiids were strongly dominated by *Hemerobius pini* along with *Wesmaelius quadrifasciatus* (relative abundance 10:1) which together comprised 98% of adult Neuroptera particularly based on a striking abscence of Chrysopidae. *Raphidius* spp. were scarce.

Winter searches on spruce trunks only yielded few aphid predators, viz. 3 *A. ocellata* and 4 larval *Raphidia* spp. Spring-early summer sticky traps yielded 6 *A. ocellata* (larvae), 5 adult *A. oblitterata* and 13 *Scymnus suturalis*. Finally, early summer sweep-netting in green lower branches at stand fringes yielded 1 adult and 3 larval *A. ocellata*, 5 adult and 13 larval *A. oblitterata* and 3 adult *Propylaea 14-punctata*.

Between-year variation.

Species abundances and species composition varied greatly between the two years. The aphidophage food resources were extremely different with high aphid numbers in 1980 (Figure 1a, peak mean value c. 190 indv. per 30 trapdays on Jun 18) and very low num-

Table 5. Between-stand variation in abundance of aphids and adult (ad.) and larval (lv.) aphid predators shown as mean indv. catch per trapyear. Stands are sorted by increasing degree of insecticide treatment (* or **) in sampling year or ( ) previous year, cf. Table 1.
Tabel 5. Variation mellem afdelingerne mht. antal individer af bladlus og bladlusprædatorer i hhv. voksen- (ad.) og larvestadiet (lv.) angivet som gns. fangst pr. fældeår. Afdelingerne er ordnet (stigende) efter graden af insekticidbehandlinger (og **) i prøvetagningsåret eller ( ) i året før, jf. Tabel 1.*

Stand no.	94	55 (*)	77 *	29 **	*Mean 1980*	94	77 (*)	140 (**)	136 *	*Mean 1981*
Aphids (ground)	56	107	31	13	*64.6*	1	3	1	<1	*0.9*
– (canopy)	404	–	636	31	*481.0*	(1)	(3)	–	–	*(1.2)*
Syrphinae, ad. (ground)	65	70	60	71	*65.0*	12	23	23	20	*29.5*
– lv. (ground)	26	21	3	1	*16.7*	1	<1	0	0	*0.2*
– lv. (canopy)	9	–	3	0	*6.7*	0	0	–	–	*0*
Coccinellidae, ad. (ground)	2	1	<1	1	*0.9*	<1	<1	1	0	*0.3*
– ad. (canopy)	7	–	7	3	*6.8*	2	1	–	–	*1.7*
– lv. (ground)	3	8	1	<1	*3.9*	<1	1	0	0	*0.2*
– lv. (canopy)	20	–	57	1	*32.0*	<1	<1	–	–	*0.3*
Hemerobiidae, ad. (ground)	<1	1	0	1	*0.2*	0	0	0	0	*0*
– ad. (canopy)	10	–	4	34	*8.1*	1	<1	–	–	*1.0*
– lv. (ground)	17	19	6	1	*14.1*	10	14	4	2	*7.4*
– lv. (canopy)	17	–	13	4	*15.7*	<1	<1	–	–	–

bers in 1981 (Figure 1b, peak mean value c. 1.5 indv. per 30 trapdays on Jun 18). This pattern was largely similar across stands (data not shown).

The dramatic decline in aphid catches from 1980 to 1981 was accompanied by a similar decline in aphid predator catches (Figs. 1a-1f). Comparing peak mean values (catch per 30 trapdays) in 1980 vs. 1981 showed lower catches in 1981 in adult aphidophagous syrphid species (spring peak: 55 vs.19 and late summer peak: 5 vs. 1), in larval Syrphinae (peak values of 12 and 0.2, resp.), in adult coccinellids (1.5 vs. 0.7), in larval coccinellids (11 vs. 0.1), in adult hemerobiids (2.8 vs. 0.4) and in larval hemerobiids (9 vs. 2.5).

While total catches of almost all aphidophagous species declined from 1980 to 1981 (exceptions *Parasyrphus* spp. and *S. batava*), most non-aphidophagous syrphids (*H. pendulus, N. podagrica, R. campestris, B. testacea*) did not. In total, syrphids with aphidophagous larvae was 3.3 times more numerous in 1980, whereas those with aquatic saprophagous larvae showed almost no difference and those with terrestrial saprophagous larvae was even 2.1 times more numerous in 1981. This indicates that the relationship between aphid catches and aphidophagous syrphid catches was, in fact, a causal relationship.

Within-year variation.

In both years, aphid catches showed a mid-summer peak (c. Jun 18) although only very weakly so in 1981 possibly due to poor data at low abundances (Figs. 1a-b). In general, aphid predator catches showed considerable timing in relation to aphid catch peaks:

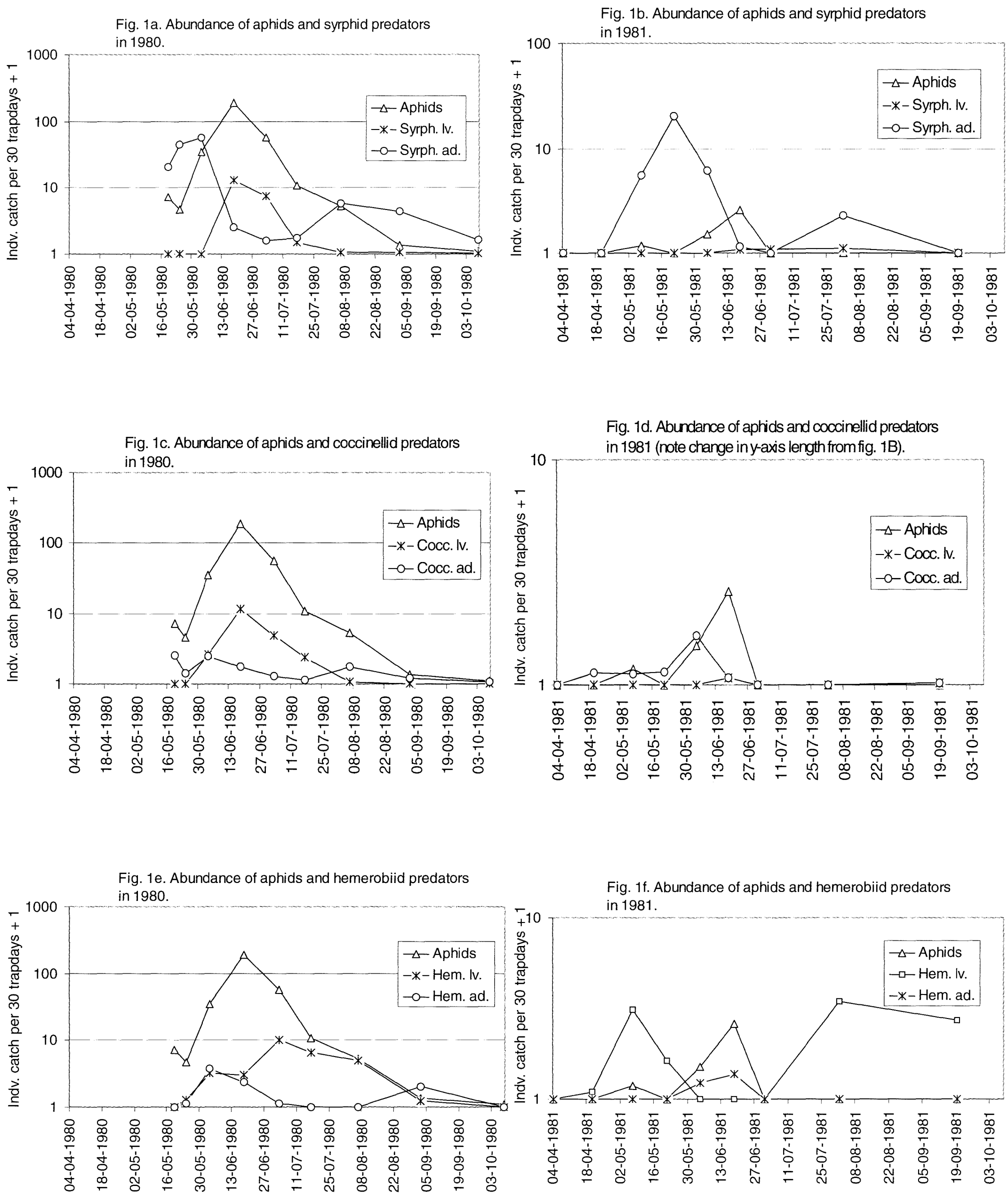

Figure 1a-f. Temporal variation in the abundance (mean indv. catch per 30 trapdays + 1, log-scale y-axis, all stands) of aphids and adult (ad.) and larval (lv.) aphid predators (aphidophagous syrphid species (a, b), coccinellids (c, d) and hemerobiids (e, f)) in 1980 (a, c and e) and 1981. Note compressed y-axis length in Fig. 1b compared to Figs. 1d and 1f.

Figur 1a-f. Variation over tid i hyppigheden (gns. indv. fangster pr. 30 fældedøgn + 1, logaritmisk y-akse, alle afdelinger) af bladlus og af hhv. voksne (ad.) og larver (lv.) af bladlusprædatorer (aphidofage svirrefluearter (a, b), mariehøns (c, d) og hemerobiider (e, f)) i hhv. 1980 (a, c og e) og 1981. Bemærk sammentrængt y-akselængde i Fig. 1b sammenlignet med Fig. 1d og 1f.

both syrphid, coccinellid and hemerobiid larval catches peaked simultaneously with or shortly after aphid peaking in 1980 and partly so in 1981 (weak data). At least some hemerobiid larvae appear in early spring along with the first hemerobiid adults (Figs. 1e-f) indicating that hemerobiids may overwinter both as larvae and pupae/adults. In general, however, most adult aphid predators appear in traps well before their larvae and exhibit a spring peak before the mid-summer (Jun 18) peaks of both aphid prey and larval predators.

Further, most adult predators exhibited a second and minor late summer peak, indicating the emergence of the first (and only) generation of the year. This was particularly evident in syrphids and coccinellids which most often had second peaks in early August. In 1981 when larval numbers were were low, the late-summer peak was almost absent. This one- or two-peaked pattern, however, also meant that adult predators were caught scarcely during most of the summer in any year, from late June and throughout July.

Far most fairly numerous species conformed to this general phenological pattern, and most less numerous species (with less reliable data) did not deviate substantially from this pattern. However, in *H. pendulus* the late summer peak in 1980 greatly exceeded the early summer peak. Also, *E. baltheatus* and *E. corollae* were only caught in late summer which was also the case in the hemerobiid, *W. quadrifasciatus* (N=17).

Sex-ratios.

In adult syrphids, the overall sex-ratio in catches was 0.82 and 1.1 in 1980 and 1981, resp., and thus not very far from 1:1. In both years, the overall proportion of males to females was initially high in May, 1.9 and 2.4, resp., after which it declined rapidly. In 1980, the sex-ratio declined to a level well below 1 (mean ratio 0.66). In 1981, it declined to a level close to 1 (mean ratio 0.97). Many single syrphid species conformed to this general pattern of greater initial male catches indicating protandric emergence or activity, viz. *M. scalare, M. cinctella, P. cyaneus, M. mellinum* and *S. torvus* whereas *P. scutatus, P. lineola* and *S. ribesii* did not (not shown).

In the dominant syrphid species *H. pendulus*, the male:female catch ratio was well below 1 throughout 1980 and 1981 (R=0.52; χ^2=65.0, df=1, P<<0.001). Similar strong female predominance in catches was observed within *N. podagrica* (R=0.6; χ^2=4.9, df=1, P<0.05) and *Eupeodes corollae* (R=0.2; χ^2=11.6, df=1, P<0.01). Most other common species showed a similar but weak tendency. An isolated case of overall male predominance was observed in *P. cyaneus* (R=1.7; χ^2=22.6, df=1, P<0.001) which was similar in both years.

In both hemerobid species, females were caught in far greater numbers than males. Male:female ratios was 0.2, viz. 31:133 in *H. pini* and 2:10 in *W. quadrifasciatus.*

Insecticide treatment.

In 1980, aphid catches reached maxima of 304, 139 and 328 indv. per 30 trapdays, resp., in untreated (or moderately insecticide sprayed) stands 94, 55 and 77 c. one-two weeks after spraying. In the *heavily sprayed* stand 29, however, aphid catches declined immediately after spraying and stayed very low, 2.5–5 indv. per 30 trapdays, for weeks after that (data not shown). On the other hand, aphid catches exhibited a small autumn peak in this stand which did not occur in the other unsprayed/moderately sprayed stands (data not shown).

Adult predator catches did not exhibit evident signs of negative insecticide effects (Table 5). In larval predators, however, there were strong indications of negative effects in the heavily sprayed stand 29, in which larval syrphid, coccinellid and hemerobiid catches were much lower than in other stands. Numbers were not consistently lower in the moderately sprayed stands compared to unsprayed stands. This pattern was largely parallel in ground and canopy catches. A comparison of postspray:prespray abundance ratios between stands (not shown) yields a similar result.

Discussion

The present study formed a part of a larger study describing, in time and space, the insect species composition of a Danish Norway spruce plantation (Jensen & Bejer, 1980; Jensen, 1988; Reddersen & Jensen, 1991). We trust that the present study is fairly representative as the study site is situated centrally in a very large spruce forest area in Central Jutland which, in itself, is located centrally in the main spruce plantation region of Denmark.

The study demonstrated considerable variation between years (1980 vs. 1981) and within the aphidophagous species we suggest that the annual variation was driven by the annual variation in aphid abundance. Also, we found large variation between vertical trap positions (canopy vs. ground) but far less variation among similar stands within year. Having identified this temporal (between and within years) and spatial variation (vertical), we claim that our results are relatively robust comprising data from two years, throughout each season from spring to late autumn, from a total of six different stands and from both ground and canopy traps.

In our analyses, we included data from moderate-heavily insecticide treated stands. This is far from ideal. However, while catches of aphids and larval predators was greatly depressed in the endosulphane treated stand, catches of adults (central for analyses of species composition) did not appear greatly affected in treated stands and thus, we chose to include data from all stands thus increasing the number of stand replicates. This choice, however, does not imply, that our data documents only minor effects of insecticides on forest arthropods.

The study clearly demonstrated the importance of employing several trap types and positions which, however, affected the various taxa differently. Aphids, adult coccinellids and hemerobiids and larval coccinellids were caught in greater (often far greater) numbers in canopy traps compared to ground traps. Reddersen & Jensen (1991) found that even among ground beetles (Carabidae), three arboreal *Dromius*-species were almost exclusively found in canopy traps. Jensen (1988) found that although almost all *Cephalicia*-sawflies were caught in ground traps, almost half of the rarely caught females appeared in canopy traps. Thus, it appears that within any major insect taxon, at least one or a few species (or sex) exhibit particular activity in canopies, at least temporally. This applies to mature spruce forests and probably to any Danish forest type (Nielsen, 1974a, b; Thiede 1977). Ground traps were, however, very efficient for monitoring the adult syrphid fauna catching 14 times as many individuals (in total), more individuals of almost any single syrphid species and twice the number of species compared to canopy traps. Syrphid and hemerobiid larvae were caught equally well in ground and canopy traps.

Syrphid larvae and aphids were very numerous in Canopy traps. Most aphids were recognized as Lachnidae and the syrphid larvae as aphidophagous Syrphinae, and both live in the canopy stratum. At least when feeding on honey-dew and at egg-laying, female Syrphinae must have been particularly active in the canopies. Still, canopy buckets caught far less syrphids of any species and of either sex than ground buckets. Clearly, factors other than syrphid activity may influence bucket catches when either standing on the open forest floor or hanging in dense canopy. Such factors may include apparency or attractiveness of white buckets or the flight and search behaviour of the syrphids in different environments.

In very mobile taxa like the syrphids, the description of local species communities may appear dubious. In many species, initial adult populations are partly or wholly based on immigration from southern countries rather than overwintering. Long distance migrating species are *E. baltheatus, E. corollae, Sphaerophoria scripta, Syrphus vitripennis, S. torvus* and *M. mellinum* and possibly also *P. lineola, H. pendulus, S. ribesii, P. cyaneus* og *M. cinctella* (Torp, 1994). Our most numerous syrphid, *H. pendulus,* has larvae which live in water rich in nutrients and organic matter. On the well-drained poor sandy alluvial soils of Gludsted Plantation, this habitat cannot have been common enough locally to yield such great numbers of *H. pendulus.* On the other hand, it is noteworthy that the very mobile and elsewhere very dominant *E. baltheatus, E. corollae* and *M. mellinum* were infrequent in our catches from a large spruce forests.

Reports on syrphid fauna from systematic sampling in forests in Denmark or surrounding countries (Kula, 1982) are scarce. In the agricultural landscape, syrphids have been studied more often. In Denmark, Bolet & Jensen (1981) reported on the species composition of aphidophagous syrphids from a hegde-field interface only 30 km E of Gludsted and compared it with an English hedge-field interface (Pollard, 1971), Polish alphalpha fields (Bankowska, 1975) and an English dense garden (Banks, 1959). However, conclusions are difficult as very many factors vary simultaneously between such studies, e.g. country, biotope type, year, sampling method, size of material and replication.

Among aphidophagous species in Gludsted Plantation, it is unclear why *E. baltheatus* and *E. corrollae* were far less numerous than in almost any other study. It may be a general feature for spruce/conifer forests that *M. scalare* replaces *M. mellinum* (a very dominant species of open habitats), that *P. cyaneus* and *P. scutatus* replace *P. clypeatus, P. manicatus* and *P. peltatus* of open habitats (Bolet & Jensen, 1981). Also, *M. cinctellus* and *P. lineola* are primarily forest species (Torp, 1994), while *S. torvus, S. ribesii, S. vitripennis* and *H. pendulus* appear to be remarkably indifferent to even major differences in biotope type (Torp, 1994). Among syrphids with special affinity to conifer plantations listed by Torp (1994), only a few occurred in our material and, except for *P. lineola, Megasyrphus erraticus* and *B. testacea* only occurred in low numbers.

Coccinellid species composition largely agreed with Danish literature (Hansen, 1951; Baungaard, 2000). The observed species composition was very well-delimited from those of the well-known coccinellid communities from farmland and urban sites usually dominated by completely different species such as *C. 7-punctata, P. 14-punctata, Adalia bipunctata, A. decempunctata* and *Thea 22-punctata.*

Finally, quantitative Danish literature on Neuroptera is rare, but combining Nielsen (1974a), Nielsen (1977, unpubl. data) and Czechowska (1985) the neuropteran (s. lat.) fauna of spruce or conifer forests seems to be sharply delimited from that of beech/deciduous forests which had several very abundant *Chrysopa* species along with large numbers of *Hemerobius micans, H. humulinus, Micromus* spp. etc. In the present study, *Chrysopa* spp. hardly ever occurred while *H. pini* was almost totally dominant along with *W. quadrifasciatus.* The two latter are well-known conifer forest species but other common potential conifer species were not encountered. The much simplified Coccinellid and Neuroptera (s. lat.) species composition was, however, very similar to that reported by Thiede (1977) from a large mature spruce plantation in central Germany: using photoeclectors on forest bottoms, only *A. ocellata, M. oblongoguttata* and *H. pini* were numerous while trapping on spruce trunks added *A. oblitterata* and *W. quadrifasciatus.*

Conclusion

The insect fauna of very large and mature Norway spruce plantations seems to be fairly simple and well-delimited from both that of deciduous forests and of mixed farmland and in some of the aphidophagous groups, there was almost no species overlap. This conclusion may not apply to smaller plantations in mixed forests or in mixed farmland where species exchange with other neighbouring biotope types may be considerable. For example some deciduous forest insects (e.g. *Rhynchaenus fagi* L.) or arable field insects (e.g. *Sitona lineatus* L.) hibernate in nearby conifer plantations if present (e.g. Nielsen, 1970). Our study also demonstrated the importance of canopy sampling. Our sampling programme appeared to produce reliable results in terms of similarities across stands and years comparable to those obtained in German studies. The study also reproduced well-known phenological phenomena such as protandry in many syrphids and the phenological patterns of the aphid-aphidophage community.

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Dansk sammendrag

Svirrefluer, mariehøns og netvinger i en stor dansk granplantage.

I 1980 og 1981 blev der foretaget systematisk prøvetagning af insektfaunaen i seks veldrevne, modne rødgranbevoksninger i Gludsted Plantage i Midtjylland. Der anvendtes fangbakker og fangspande på skovbunden sammen med fangspande på tre niveauer i kronelaget. Her rapporteres om artssammensætningen af tre insektgrupper, der generelt rummer mange og vigtige arter af bladlusprædatorer: Svirrefluer, mariehøns og netvinger.

Materialet af voksne svirrefluer bestod af ca. 3000 individer fordelt på 48 arter, hvor *Helophilus pendulus*, *Melanostoma scalare*, *Meliscaeva cinctella* og *Platycheirus cyaneus* var meget dominerende (>10% hver). Nåleskovs- og granskovsspecialister (sensu Torp) var langt mindre talrige eller endda helt fraværende. Mariehøns, voksne og larver, udgjorde ca. 450 individer fordelt på kun 5 arter, hvor *Anatis ocellata* var meget dominerende og *Aphidecta oblitterata* og *Myzia oblongoguttata* forekom jævnligt. Ud af i alt ca. 200 voksne netvinger fandtes kun 6 arter, hvor en enkelt art, *Hemerobius pini*, var meget dominerende, og bortset fra *Wesmaelius quadrifasciatus* forekom andre arter kun enkeltvis. Artssammensætningen udviste betydelig overensstemmelse på tværs af bevoksninger og år. Derfor forekom artssammensætningen klart adskilt fra de mere velkendte samfund i blandet landbrugsland og løvskove i Danmark og omgivende lande.

Fangsterne fra krone-fælderne varierede stærkt mellem grupper og stadier. Voksne svirrefluer blev helt overvejende fanget i fælderne på jorden, mens de fleste andre grupper blev fanget enten både i krone og på jord (larver af svirrefluer, mariehøns og hemerobider) eller overvejende i kronefælder (voksne mariehøns og hemerobider, nogle mariehønslarver). Andre populationsparametre præsenteres også, fx ulige kønsratioer og sæsonvariation i bladlus-prædator samfundet.

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