Catches of *Ips duplicatus* and other non-target Coleoptera by *Ips typographus* pheromone trapping

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Catches of non-target Coleoptera in *Ips typographus* pheromone traps baited with Ipslure® were analysed along a geographic gradient running from southwestern Finland to eastern Finland and Russian Karelia. Besides *I. typographus*, two other bark beetles, *Pityogenes chalcographus* and *Ips duplicatus* were caught in high numbers. *I. duplicatus* occurred on northeastern sites only, suggesting a more restricted distribution than previously known. High numbers of *Thanasimus* spp. beetles indicate that *I. typographus* pheromone is also an effective attractant for bark beetle predators. In addition, the originally North American ambrosia beetle *Gnathotrichus materiarius*, now widely spread in Europe was found for the first time in nature in Finland.

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1. Introduction

The double-spined spruce bark beetle, *I. duplicatus* (Sahlb.), occurs throughout northern and middle Europe and Russia. It breeds in the upper parts of the trunk, mainly on spruce, *Picea abies* (L.) Karst., but occasionally also on pine *Pinus sylvestris* L. and *P. cembra* L. (Lekander *et al.* 1977, Freude *et al.* 1981). The distribution of *I. duplicatus* is not well known despite occurring over a wide area. Generally, it is considered a more northern species compared with the widespread *I. typographus* (L.) (Lekander *et al.* 1977, Freude *et al.* 1981). Under certain environmental conditions *I. duplicatus* has caused damage, and is sometimes considered as harmful a pest as *I. typographus* (Saalas 1919, 1949, Mrkva 1994ab). Currently *I. duplicatus* occurs in the Czech Republic and Poland locally in high numbers (W. Grodzki pers. comm., Mrkva 1994a). In northern Moravia in the Czech Republic this species causes damage and is the pest on Norway spruce (Mrkva 1994b). According to our field observations in 1992 and 1995 in eastern Finland at Liperi, *I. duplicatus* was more common in traps baited with Ipslure® pheromone than *I. typographus*.

The more well-known related species, *I. typographus*, is the most serious bark beetle pest in European spruce forests. For this reason, commercially available pheromone trapping methodology has been developed to monitor *I. typographus* under different population levels (Bakke *et al.* 1983, Bakke 1985, Ravn 1985, Weslien *et al.* 1989, Hübertz *et al.* 1991). *I. typographus* males produce *cis*-verbenol and ipsdienol as components of the aggregation pheromone. In addition, the spe-

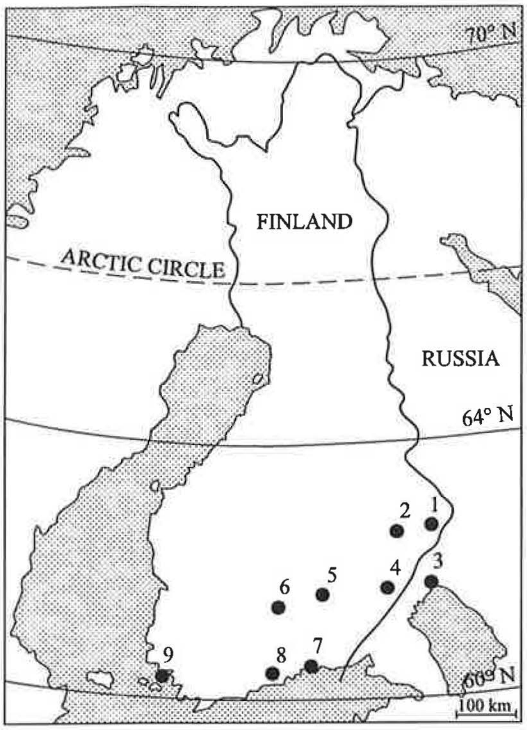

Fig. 1. Location of the study areas. 1 = Ilomantsi, 2 = Liperi, 3 = Harlu, 4 = Punkaharju, 5 = Ristiina, 6 = Padasjoki, 7 = Ruotsinpyhtää, 8 = Vantaa, 9 = Nauvo.

cies-specific 2-methyl-3-buten-2-ol (methylbutenol) is an active component in the aggregation pheromone (Bakke *et al.* 1977).

I. duplicatus males produce ipsdienol and *E*-myrcenol as an aggregating pheromone (Bakke 1975, Byers *et al.* 1990, Ivarsson *et al.* 1993). In commercial *I. typographus* baits, methylbutenol has been combined with *cis*-verbenol to achieve effective mass-trapping, and ipsdienol is the minor component of aggregation pheromonene. Although the commercial pheromones are specific, they also attract other non-target insects; bark beetles such as *I. duplicatus*, *Pityogenes chalcographus* (L.) and several predatory species (Schlyter *et al.* 1987, Holzschuh 1989, Babuder *et al.* 1996). The predators *Thanasimus formicarius* (L.) and *T. femoralis* (Zett.) respond primarily to pheromones produced by scolytids but also extracts produced by host trees (Saalas 1949, Bakke & Kvamme 1978, 1981, Zumr 1983).

The aim of this investigation was to study the abundances of *Ips* beetles and associated coleopteran species with pheromone traps baited with Ipslure® in low beetle population density situations. The specific objectives were (a) to define the relative frequency and geographic variation of *I. duplicatus* in pheromone trap samples, and (b) to explore the non-target coleopteran fauna.

Table 1. Site characteristics of the study areas.

Site	Cutting area (ha)	Proportion of spruce in previous stand (%)
1. Ilomantsi	3.8	75
2. Liperi	9.2	75
3. Harlu	5.0	80
4. Punkaharju	1.3	88
5. Ristiina	2.0	59
6. Padasjoki	6.5	78
7. Ruotsinpyhtää	30.0*	100
8. Vantaa	2.5	90
9. Nauvo	≈ 0.3	≈ 50

*thinned with removal 70 m³/ha

2. Material and methods

2.1. Study areas

The study was conducted in clear-cut forests logged during the previous winter along a gradient running from southwestern Finland to easternmost Finland and Harlu, Russian Karelia (Fig. 1). Selection of the study areas was based on the characteristics of the logged stands. We chose areas that had been spruce dominated (basal area ≥ 50%) and were adjacent to mature spruce stands (Table 1). The study area in Ruotsinpyhtää was in a mature spruce forest thinned during the previous winter. The minimum distance between the areas was approximately 150 km.

2.2. Trapping

Beetles were trapped using the 1979 black drainpipe trap model (Bakke *et al.* 1983, distributed by Borregaard Ind. Ltd., Sarpsborg, Norway). The length of the trap tube is 135 cm, diameter 12 cm, and it has about 900 holes. This model does not catch as many individuals as some other models, but is suitable for monitoring purposes (Regnander & Solbreck 1981, Hübertz *et al.* 1991). The traps were baited with Ipslure® pheromone dispensers obtained from Borregaard. The dispensers contained 1 500 mg methyl-butenol, 70 mg *cis*-verbenol and 15 mg ipsdienol permeated in a cellulose sheet enclosed in a polyethylene bag. The containers were filled to the halfway mark with ethylenglycol to preserve the trapped material. A triangle (5-m side length) comprising three traps was placed in each collection area in the beginning of May, before the initial flight of bark beetles. In clearings, all the traps were approximately 50 m from the adjacent forest. The trapping period covered the main flight period 6.V.–27.VII.1996 and the traps were emptied twice during this period. In Harlu, the trapping period from 9–11.VI.1996 was covered. The pheromones were replaced with fresh ones on 24–28.VI.1996 in the middle of the flying period. The pheromones, traps, trap location in clear-cutting areas and the spacing correspond to those used in the Nordic monitoring studies during the 1980s (Weslien *et al.* 1989, Hübertz *et al.* 1991).

The beetles were stored at + 4°C until identified and washed with alcohol before identification. They were examined under a microscope and identified at the species level. The nomenclature and systematic arrangement follow Silfverberg (1992). The few specimens belonging to the families Nitidulidae and Chrysomelidae were identified at a higher taxonomic level.

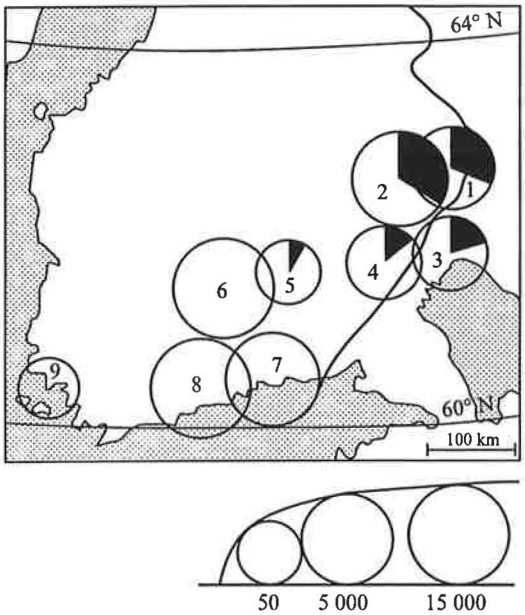

Fig. 2. Proportion of *I. duplicatus* out of the total catch of *Ips* species. Size of circle represents half of the log (x + 1) transformed value of the total catch of *I. typographus* and *I. duplicatus*, and size of the slice the relative proportion of *I. duplicatus*. 1 = Ilomantsi, 2 = Liperi, 3 = Harlu, 4 = Punkaharju, 5 = Ristiina, 6 = Padasjoki, 7 = Ruotsinpyhtää, 8 = Vantaa, 9 = Nauvo.

3. Results

3.1. Numbers of insects caught

The total catch consisted of 40 884 individuals belonging to 53 coleopteran species (Table 2). The most abundant species was *I. typographus*, forming 82% of the total catch, but the proportions of the six-toothed spruce bark beetle, *P. chalcographus* (10%), and *I. duplicatus* (5%) were also high. One location in eastern Finland, Liperi, accounted for 86% of the total *I. duplicatus* catch (Fig. 2). Ten or less individuals of 39 species were caught. The *I. typographus* catches per trap group varied greatly between locations, ranging from 33 in Nauvo to 13 941 in Padasjoki (Table 2).

3.2. Species

The number of species caught at the different areas varied from five in Harlu and 11 in Nauvo to 25 in Padasjoki. *I. typographus* and *P. chalcographus* were collected at every location. *I. duplicatus* was caught only at five locations along the transect in the easternmost part of the country (Fig. 2). The catch of *P. chalcographus* mainly consisted of males that responded evenly in the different trapping areas to the Ipslure® pheromone. The most abundant predators of bark beetles caught were *T. femoralis* and *T. formicarius*, which were collected from every location, except for Harlu where sampling lasted only a few days. The numerically dominant Elateridae species were also distributed evenly along the trapping gradient. The rest of the species occurred more or less sporadically. The catch included one specimen of ambrosia beetle *Gnathotrichus materiarius* (Fitch) that is an introduced species from North America.

4. Discussion

4.1. Occurrence of *Ips duplicatus*

The proportion of *I. duplicatus* has varied from 10 to 17% of the total catch of *Ips* species in previous pheromone trapping studies (Selander & Nuorteva 1980, Holzschuh 1989). Schlyter *et al.* (1987) have also shown that *I. duplicatus* is attracted to a blend of methylbutenol, *cis*-verbenol and ipsdienol produced by *I. typographus* in an

Table 2. Catch of coleopteran species with Ipslure® pheromone and pipe traps during 6.V.–27.VII.1996 at the study areas (see Fig. 1 for the locations of the study areas). Tree traps in groups. *Harlu, trapping period 9–11.VI.1996.

	1Ilo	2Lip	3Ha*	4Pun	5Ris	6Pad	7Ruo	8Van	9Nau	Total
Carabidae										
Dromius agilis (F.)		5			1	3				9
Dromius schneideri Crotch					2			1		3
Dromius fenestratus (F.)		2					1			3
Staphylinidae										
Anthophagus omalinus Zett.						1				1
Cantharidae										
Absidia schoenherri (Dejean)	14									14
Elateridae										
Athous subfuscus (Müller)	1	4			10	4	2			21
Liotrichus affinis (Payk.)						1				1
Ampedus pomorum (Hbst)		1								1
Ampedus balteatus (L.)	2	13		4	10	11		52	4	96
Ampedus tristis (L.)		1		1		1		1		4
Ampedus erythrogonus (Müller)						1		1		2
Ampedus nigrinus (Hbst)	20	17		8	10	21	4	11		91
Sericus brunneus (L.)	12	3		5	2	12		3		37
Dalopius marginatus (L.)				2	3	2	4	6	3	20
Cardiophorus ruficollis (L.)		1			2	1		7	1	12
Buprestidae										
Anthaxia quadripunctata (L.)					1			3		4
Dermestidae										
Megatoma undata (L.)									1	1
Anobiidae										
Hadrobregmus pertinax (L.)						1				1
Cleridae										
Thanasimus formicarius (L.)	3	18		37	45	42	11	66	1	223
Thanasimus femoralis (Zett.)	3	50		20	2	137	61	59	7	339
Melyridae										
Aplocnemus tarsalis (Sahlb.)						1				1
Nitidulidae										
Epuraea spp.		1	1							2
Cryptophagidae										
Cryptophagus abietis (Payk.)				5		1				6
Latridiidae										
Corticarina obfuscata Strand		2				1				3
Salpingidae										
Salpingus planirostis (F.)							1			1
Alleculidae										
Mycetochara obscura (Zett.)		1								1
Cerambycidae										
Tetropium castaneum (L.)					2					2
Rhagium inquisitor (L.)				1	1					2
Chrysomelidae										
Chrysomelidae spp.		1							1	2
Syneta betulae (F.)						5				5
Linaeidea aenea (L.)		1								1
Curculionidae										
Otiorhynchus scaber (L.)	10			227	1		1			239
Polydrusus pilosus Gredler		1							1	2

Continues ...

Table 2. Continued.

	1Ilo	2Lip	3Ha*	4Pun	5Ris	6Pad	7Ruo	8Van	9Nau	Total
Polydrusus undatus (F.)	33			5						38
Strophosoma capitatum (Degeer)				3			5		1	9
Magdalis violacea (L.)					1					1
Hylobius abietis (L.)							1			1
Pissodes pini (L.)	1			1		1				3
Pissodes gyllenhalii (Sahlb.)	2			1						3
Pissodes harcyniae (Hbst)								1		1
Scolytidae										
Hylurgops palliatus (Gyll.)	2	1			2	2				7
Hylastes cunicularius Er.				1	3	1				5
Phloeotribus spinulosus (Rey)				2		1				3
Pityogenes chalcographus (L.)	407	370	116	553	422	1 326	274	267	197	3 932
Pityogenes bidentatus (Hbst)				1						1
Orthotomicus suturalis (Gyll.)					1					1
Ips duplicatus (Sahlb.)	202	1 729	40	26	4					2 001
Ips typographus (L.)	451	3 291	162	154	47	13 941	3 980	11 657	33	33 716
Crypturgus cinereus (Hbst)								1		1
Trypodendron lineatum (Ol.)	1	1	1	2		2	1	2		10
Gnathotrichus materiarius (Fitch)								1		1
Total catch	1 164	5 514	320	1 061	570	15 520	4 346	12 139	250	40 884

already colonized patch. The response to *I. typographus* pheromone is probably an advantage for *I. duplicatus* by directing pioneering males to the trees already colonized and weakened by *I. typographus* and associated fungi. *I. duplicatus* may have been overlooked and some of the cases of damage may have been erroneously identified as *I. typographus* damage. Here large variability in *Ips* catches between adjacent sites were found. Such a finding has also been common in other *I. typographus* pheromone trapping studies (Regnander & Solbreck 1981, Bakke 1985).

I. duplicatus occurred only in the northeastern study areas (Fig. 2). In Scandinavia this species is considered relatively rare and most recordings have been made between latitudes 60° and 63°N (Lekander *et al.* 1977). The species has occurred locally in high densities in Norway and Finland (Lekander *et al.* 1977, Bakke & Kvamme 1993). Nuorteva (1968) did not find any *I. duplicatus* in his detailed investigation of the bark-beetle fauna in southern Finland in 1964. However, the species had been present in the studied area in 1953–1954. Obviously the range of *I. duplicatus* has retreated from southern Finland towards the north, as is the case for two related bark beetles, *I. acuminatus* (Gyll.) and *I. sexdentatus* (Börner) (Lekander *et al.* 1977). The reasons for this or the extent of the decline of *I. duplicatus* are so far unknown.

4.2. Other coleopteran species

The impact of pheromone trapping on *Thanasimus* predators using components of Ipslure® as kairomones was considerable as they were equivalent to 1.6% of the total *Ips* number. This is probably caused by the trap model that prevents clerids escaping. The improved pipe trap model 1980 enables predators to escape and usually catches only two clerids per thousand *Ips* (Bakke *et al.* 1983). Ipsenol and ipsdienol are the main kairomonal components for *T. formicarius* (Bakke & Kvamme 1981). *T. formicarius* is less sensitive to *cis*-verbenol and does not respond to methylbutenol. However, when the compounds are combined there is a synergic effect. The main kairomonal component for *T. femoralis* is *cis*-verbenol, but a mixture with ipsdienol and ipsenol enhances the response (Bakke & Kvamme 1981). Also Babuder *et al.* (1996) have recently concluded that current synthetic pheromones cannot completely prevent the capture of predators and other useful insects. Unexpectedly, *T. femoralis* was a more frequently caught clerid than *T. formicarius*. In other *I. typographus* pheromone trapping surveys, *T. formicarius* has been the major predator, and Staphylinidae, Peltidae and Nitidulidae have been common associated species (Bakke & Kvamme 1981, 1993, Zumr 1983, Schlyter *et al.* 1987, Babuder *et al.* 1996).

All the caught click-beetles (Elateridae) live on decomposing trunks or in the soil. As many of these species prefer open areas, this might explain their abundance in the logging areas (P. Martikainen pers. comm.). Part of the species caught in the pheromone traps are very abundant forest species (e.g. *Absidia schoenherri, Athous subfuscus*) that are often trapped in numbers by flight-interception traps (Sippola *et al.* 1995). Individuals of such species may have entered the traps simply by chance. The males of *P. chalcographus* use a component of the *I. typographus* pheromone as a kairomone (Benz *et al.* 1986) and were specifically attracted to the traps. This was the first finding of the ambrosia beetle *G. materiarius* in nature in Finland (Valkama *et al.* 1997). The species originates from eastern parts of North America. It was introduced in 1933 to France and since then it has spread in many Middle European countries (von Hirschheydt 1992). Further research is needed to investigate whether the species has become established in the country.

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