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Ips typographus and other bark and wood-boring beetles on girdled spruces

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MAGISTERUPPSATS I BIOLOGI, D-NIVÅ, 30 HP

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Abstract

To decrease the number of spruce trees and to create dead wood in some areas several county administration boards have girdled spruces. Girdled spruces have been little studied in terms of the insect fauna. In this study the occurrence of the spruce bark beetle (*Ips typographus*) and other beetles are investigated in girdled spruce trees (*Picea abies*) in two provinces in Sweden, Uppland and Jämtland. Girdled trees have been compared with cut trees. The study contains 213 girdled and cut trees. To find out to which extent woodpeckers use girdled spruces as food resource estimation was also done with consideration of how much bark that was picked off each tree.

Girdled trees were more long-lived than expected. Most trees with a "normal" girdle was colonised by insects and dead the second season after the treatment while the "lifeline" trees was living even longer. The species composition was much the same in girdled and cut trees and did not seem to differ between below and above the girdle. However, no breeding spruce bark beetle was found below the girdle. Girdled trees were more utilised by spruce bark beetles than cut trees were. Even trees thicker than 25 centimetres in diameter were more utilised while no increase was visible regarding an increased sun exposure. The amount bark picked away by woodpeckers was equal at girdled and cut trees but in one locality there were a correlation between trees colonised by the spruce bark beetle and utilised by woodpeckers. In one another locality the correlation instead was between the larvae of *Tetropium sp*. and *Rhagium sp*. and woodpeckers.

Sammanfattning

Granbarkborren och andra bark- och vedlevande skalbaggar på ringbarkade granar

För att minska antalet granar i vissa områden, och för att skapa död ved, har flera länsstyrelser låtit ringbarka en del av träden. Ringbarkade granars insektsfauna är dåligt känd. I den här studien undersöktes artsammansättningen och den reproduktiva förmågan hos granbarkborren (*Ips typographus*) i ringbarkade granar (*Picea abies*) i två landskap, Uppland och Jämtland. De ringbarkade granarna har jämförts med fällda träd. Förekomsten av granbarkborre och andra skalbaggar uppskattades på fyra till fem barkprover från varje träd. Totalt ingick 213 ringbarkade och fällda träd i undersökningen. För att ta reda på i vilken utsträckning hackspettar utnyttjar ringbarkade granar som födokälla uppskattades även mängden borthackad bark på varje träd.

De ringbarkade granarna var mer långlivade än förväntat. Många av de träd som hade en ”normal” ringbarkning var koloniserade av insekter och döda den andra säsongen efter att åtgärden hade gjorts medan det tog längre tid för träd med en ”livlina” kvar i ringen att dö. Artsammansättningen var snarlik i ringbarkade och fällda träd men skiljde sig mellan stampartiet över och under ringen. Inga reproducerande granbarkborrar påträffades under ringen. Granbarkborren utnyttjade ringbarkade träd i större utsträckning än fällda träd liksom de utnyttjade fler träd över 25 cm i diameter. Däremot fanns ingen skillnad med avseende på ljusexponeringen. Mängden bark som hackats bort av hackspettar var lika stor hos de ringbarkade som de fällda träden. I ett område fanns ett samband mellan träd som var koloniserade av granbarkborre och utnyttjade av hackspettar. I ett annat område föredrog hackspettarna träd som hade koloniserats av larver av långhorningarna *Tetropium sp*. och *Rhagium sp*.

Contents

Introduction

Today the amount of dead wood in managed forests is low (Fridman and Walheim, 2000). This also applies to many nature reserves (Götmark and Thorell, 2003) when compared with old-growth forests. A lot of organisms require dead wood for their survival. According to Gärdenfors (2005) more than 50 % of the red-listed invertebrates living in forest ecosystems are saproxylic in Sweden. The environmental objects (formulated by the government) states that the quantity of dead hard wood has to increase by at least 40% until year 2010. The area of older broadleaved forests have to increase by 10% and the area of regenerated broadleaved forests should also increase by 2010 in Sweden (www, Miljömål, 2007).

To achieve the environmental objects it could be necessary to manually create dead wood and favour broadleaved trees using different methods. The knowledge about the effects on red-listed as well as pest species is still poor. To increase the volume of dead wood different methods are used. An obvious but important way is to let dead trees remain in the forest after disturbances like storm fellings, forest fires, outbreaks of insects or diseases. More actively would be just to cut trees or to create high stumps. A more sophisticated way could be to artificially infect trees with fungi or damage the tree mechanically to improve conditions for fungi colonisation.

Forest fires are rare nowadays. This has favoured spruce while other tree species are restrained (Pennanen and Kuuluvainen, 2002). In some areas flooding has suppressed the spruce trees, which is beneficial for other tree species and vegetation types (Anon, 1999). Killing spruces by girdling is one way to decrease competition by spruce as well as increasing the amount of dead wood.

A surplus of fresh spruce wood could be beneficial for pest insects, e.g. the spruce bark beetle (*Ips typographus*). This bark beetle species usually reproduce in weak or recently dead trees. After disturbances, like a storm felling, they may build up high populations and subsequently attack and kill living spruces in nearby stands (Bakke, 1989; Hedgren and Schroeder, 2004; Lekander, 1972; Schroeder and Lindelöw, 2002; Økland and Berryman, 2004). Normally, the defence of growing spruce trees is difficult for bark beetles to overcome. The most important part of the defence is resin stored in reservoirs in the bark. The resin is used to flush away the bark beetles when they try to come into the tree. If the tree is weakened, or/and if the bark beetles are present in sufficiently large numbers, the beetles are able to colonise and kill the tree. *I. typographus* use the aggregation pheromone and pathogenic blue-stain fungi which is essential in the colonisation success.

Killing spruces by girdling has become common practise in Sweden during the last decade. The forest certifying organisation FSC has made girdling as an option to create high stumps (Anon, 2006). Many county administration boards and municipalities manage reserves to decrease the number of spruce trees. Here, girdling is one way to decrease the number of spruces as well as to create dead wood but the knowledge about mortality and insect colonisation of girdled spruces is poor. Lekander (1959) observed that both *I. typographus* and *Pityogenes chalcographus* may colonise spruces during summer, after girdling in May prior to the beetles' flight. If girdling was made later during summer the trees were not colonised until the next summer. The second summer half of the spruce trees were colonised by *Polygraphus poligraphus*. Lekander (1959) also noted that spruces with one third of the girdled bark still remaining (as a "lifeline") lived uncolonised at least two summers.

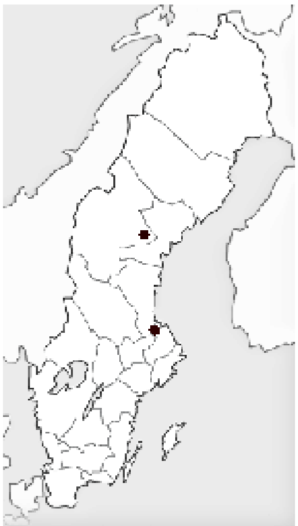
In this study, I examined spruce trees girdled by the county administration boards in Uppland and Jämtland. Tree mortality and insect colonisation was investigated first or second year after treatment. Colonisation pattern of bark and wood-boring beetles in girdled trees was compared with felled trees. The specific aim of this project was to study:

1. The mortality rate in girdled spruce trees (*Picea abies*).
2. To compare girdled and cut spruce trees regarding which bark and wood-boring beetles that colonises and breeds in the trees.
3. To compare production and reproduction rate of *I. typographus* in girdled and cut spruce trees.
4. To what extent woodpeckers use girdled and cut spruce trees as food resource.

Material and Methods

Study sites

The study was done during the summer 2007 in the provinces of Uppland and Jämtland (Figure 1, Table 1). The two investigated areas in Uppland are located in Båtfors Nature Reserve next to the river Dalälven. Since Dalälven is a supply source for water power the water level is controlled and often limited down stream in the Båtfors Nature Reserve affecting the vegetation. This has favoured spruces to become the dominant tree species in some areas because earlier spruce regeneration was inhibited by flooding (Anon, 1999). The area is characterised by river furrows, boulders, meadows, old broadleaved trees and conifer trees. In the more open landscape where haymaking has occurred, broadleaved trees such as oak, aspen and birch has been the dominant tree species, spruce have taken over (Anon, 1999). In some of those locations where haymaking and flooding have occurred, where spruces now are dominant, a few hundred trees have been girdled with chainsaw at breast height in the last few years. This leaves a fairly deep girdle (into the sapwood) shifting from 0.2 to 0.5 metres in breadth. In addition a number of trees have been cut and left on the ground. The areas selected for this study were Björkön (60°27'10"N, 17°17'50"E, Appendix)



and Norra Kvarnön (60°26’50”N, 17°19’40”E, Appendix). The numbers of trees included in the study are given in Table 1.

In Jämtland two nature reserves dominated by spruce were selected. The girdles were made with a chainsaw and are approximately 0.1 to 0.3 metres wide and removed the bark and cambium. At Sättmyrberget (63°7’0”N, 16°12’10”E) hundreds of spruces had been girdled completely (Figure 2a) or with a “lifeline” left which was 5-10 centimetres wide (Figure 2b). Finnsjöberget (62°58’50”N, 15°48’30”E) had two different types of girdling; either the “normal” girdle or making two narrow cuts around the stem (Figure 2b). The numbers of trees with different treatments are given in Table 1.

Table 1. Descriptions of which treatments that were included for each locality and at what date the treatments and inspecion were established. All inspections were conducted in 2007. Figures in parenthesis represent the number of trees for each treatment that were included in the study.

Location	Treatments	Date of treatment	Date of inspection
Uppland			
- Björkön	normal girdled (37)	Feb.-March 2006	27 Aug.-5 Sept.
	cut (40)	Feb.-March 2006	26-29 June
- Norra Kvarnön	normal girdled (5)	Feb.-March 2007	27 Aug.-5 Sept.
	cut (39)	Feb.-March 2007	27 Aug.-5 Sept.
Jämtland			
- Sättmyrberget	normal girdled (22)	June-Sept. 2005	12-21 July
	girdled with “lifeline” (20)	June-Sept. 2005	12-21 July
- Finnsjöberget	normal girdled (12)	Aug. 2005	22-23 July
	two narrow girdles (9)	Aug. 2005	22-23 July
	normal girdled (9)	June 2006	22-23 July
	two narrow girdles (8)	June 2006	22-23 July
	cut (12)	June 2006	14 July

a) b)

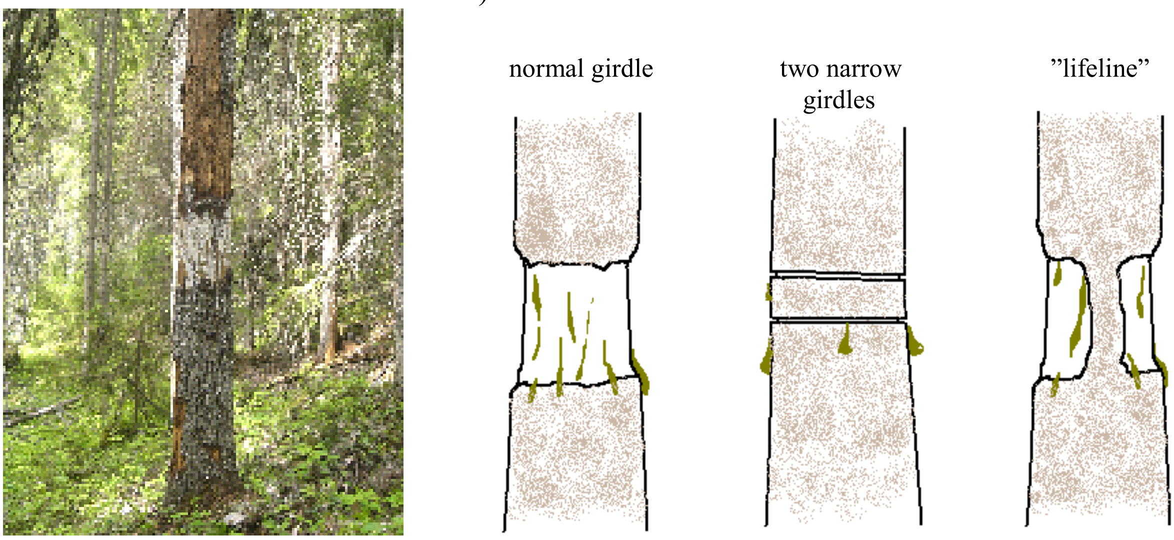


Figure 2. a) A girdled spruce tree at Sättmyrberget and b) the different girdling methods.

Tree sampling

Only trees over 13 centimetres in diameter at a height of 1.3 metres from the ground were included in the study. In Uppland all treated spruce trees in the two areas were numbered. Then a subsample of the trees on Björkön and Norra Kvarnön were randomly selected, (girdled trees) felled and inspected. Since the trees were uncolonised at Norra Kvarnön only five trees were felled there. In Jämtland approximately twenty positions in each area were randomly selected by coordinates. At every position the closest girdled spruce tree over thirteen centimetres in diameter was felled and inspected. Also all found cut trees at Finnsjöberget that was over 13 centimetres in diameter was investigated. The times of inspections are given in Table 1. The date of felling of the girdled trees were as most twelve days before the inspection of the tree.

The height and the diameter at 1.3 metres above ground was measured at the inspected trees. A subjective estimation of the sun exposure was made on all trees and divided into five categories, where 1 is a shaded tree and 5 is a sun exposed tree.

Beetle sampling

On each tree four bark samples (10 x 30 cm) were inspected. These were located at 20%, 40%, 60% and 80% of the height of the tree. An additional bark sample was also taken below the girdle on the girdled trees. The year of colonisation was determined by studying the development stages of insects present in the bark. The presence of different species in the bark samples was noted according to their species-specific shape of gallery. Samples of adult beetles were regularly taken for closer determination at home. The coverage of the galleries of each species was estimated in 10%-classes. For *I. typographus* all egg galleries and full grown larvae, pupae, adults and exit holes were counted. Production and reproduction for *I. typographus* was calculated as following:

Production = offspring plus exit holes / m^2

Reproductive success = daughters / mother gallery

Daughters = offspring plus exit holes / 2

An equal sex ratio is assumed.

Woodpeckers

The proportion of bark picked away by woodpeckers was estimated on all inspected trees. The degree of bark removed was divided into six classes: 0% (bark untouched), 1–20%, 21–40%, 41–60%, 61–80% and 81–100%.

Calculations and statistics

In the calculations the “lifeline” trees and the trees with two narrow girdles were pooled with the “normally” girdled trees because few trees were colonised. In the calculations of *I. typographus* only trees with three or more bark samples colonised by any species were included in the analysis. All figures and values show means of all trees in each treatment group. The numbers of observations in the estimations are either number of bark samples (at the species surface coverage, egg gallery density, reproductive success and production) or entire trees (trees containing *I. typographus* depending on diameter and sun exposure and woodpeckers). The density of egg galleries, reproductive success, production of *I. typographus* and the woodpeckers picking were tested between girdled and cut trees with a Mann-Whitney *U*-test. This test were used because data were not homogeneous and deviant variances. In all other comparisons χ^2-test were used.

Results

Out of 122 girdled trees, 61% were colonised by bark and wood-boring beetles. Of the 91 cut spruces, 96% were colonised and the difference in proportion colonised between cut and girdled trees was significant ($P < 0.05$, χ^2-test). There was no difference in the gallery coverage between colonised girdled and cut trees (38% and 40% respectively, $P > 0.05$, χ^2-test). In Table 2 the numbers of trees and percentage of bark sample colonised are given for each locality and treatment.

The time for colonisation differed between treatments and areas. By the inspection in August in Uppland the trees girdled in February–March 2007 were not colonised while the cut trees were. The trees girdled in 2006 were colonised in 2007, while trees cut in 2006 were colonised in 2006. In Jämtland at Sättmyrberget all “normally” girdled trees (girdled the summer 2005) were colonised in 2007, but only three “lifeline” trees. At Finnsjöberget one third of the girdled trees (girdled Aug. 2005 and June 2006, without consideration on when) were colonised during the summer 2007.

Species composition

In Uppland *P. chalcographus* was the most frequently occurring species in both girdled and cut trees. Of the girdled trees in Jämtland, *I. typographus* was common as well as *P. chalcographus* and *P. poligraphus.* Of the cut trees on Finnsjöberget *Pissodes sp.* was the most frequently occurring species (Figure 3). Other species noted occurred only in a few trees (Table 3 and 4). The species noted exclusively on girdled trees with more than one observation was *Crypturgus sp.* while *Hylurgops palliatus* was found on felled trees. Three species were only found below the girdle; *Dryocoetes sp.*, *Trypodendron sp.* and *Polygraphus punctifrons*.

Most trees were colonised along the whole stem or not at all. Twelve trees were only partly colonised. These trees were either colonised under the girdle or in the top by *Tetropium sp.*, *Polygraphus sp.*, *Pissodes sp.* and *Dryocoetes sp.* under the girdle and *P. chalcographus*, *Polygraphus sp.* and *Pissodes sp.* in the top.

No clear effect of sun exposure on species composition could be demonstrated.

Table 2. Number of trees inspected and colonised, percentage of bark samples colonised by bark and wood-boring beetles (of the colonised trees), mean sun exposure, tree diameter and length of the trees for the different treatment groups.

	No. of trees studied	No. of trees coloni-sed	% bark samples coloni-sed	Sun exposure	Diameter (cm) (at 1.3 m)			Length (m)	
					mean	95%	range	mean	range
Björkön girdled 2006	37	37	91	3.1	26.1	3.3	14-62	20.0	8-30
Björkön cut 2006	40	39	98	3.2	24.3	2.3	13-45	19.2	8-27
N Kvarnön girdled 2007	5	0	0	3.0	26.9	7.7	21-37	19.4	16-24
N Kvarnön cut 2007	39	36	87	2.8	21.6	2.2	13-40	16.5	9-28
Sättmyrberget girdled 2005	22	22	75	3.0	24.1	2.7	17-41	19.7	13-28
Sättmyrberget “lifeline” 2005	20	3	47	3.0	26.1	1.7	20-36	21.5	17-25
Finnsjöberget girdled 2005	12	6	63	3.3	26.9	1.2	24-30	17.7	14-20
Finnsjöberget two narrow g. 2005	9	1	20	3.0	30.1	1.8	27-33	21.0	18-24
Finnsjöberget girdled 2006	9	2	70	3.7	26.4	3.4	20-34	17.7	14-23
Finnsjöberget two narrow g. 2006	8	3	47	3.3	27.6	4.8	18-32	18.3	12-22
Finnsjöberget cut 2006	12	12	88	3.4	19.1	2.1	14-27	14.1	10-19

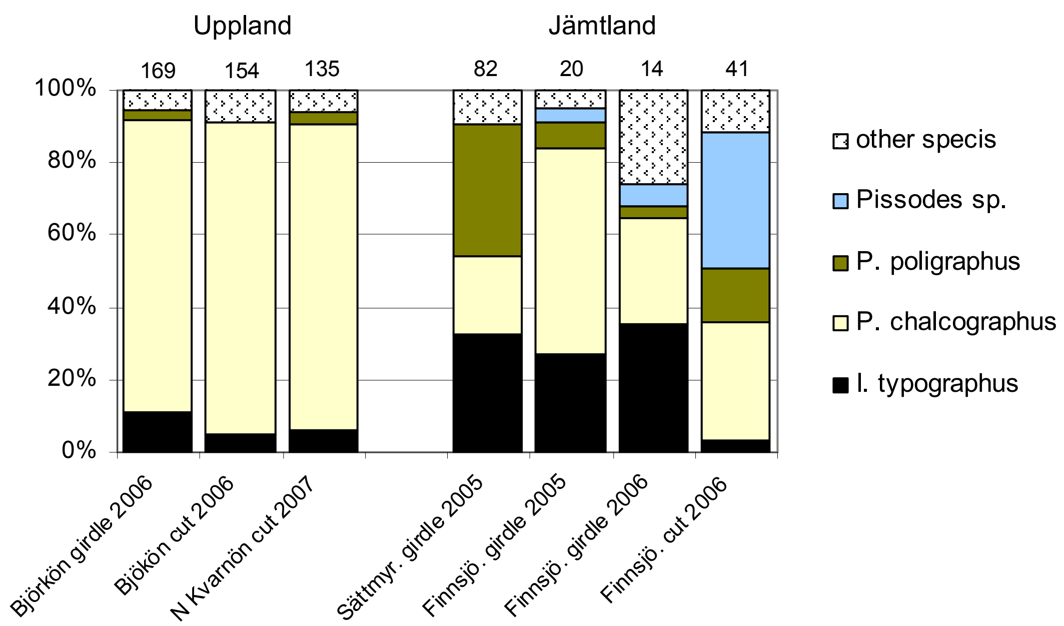


Figure 3. The mean proportion of the surface coverage by galleries of the different insect species in the different treatments and locations. Only the colonised surface of the bark samples is included in the analysis. The numbers above the bars is the number of bark samples.

Table 3. Number of trees in which the different species occurred in the different treatment groups in Uppland. Figure in parenthesis represents number of trees colonised. "n" at the bottom of the table represents the total number of colonised trees in each treatment group.

Björkön girdled 2006	Björkön cut 2006	N Kvarnön cut 2007
P. chalcographus (36)	*P. chalcographus* (38)	*P. chalcographus* (35)
I. typographus (13)	*Tetropium sp.* (20)	*Tetropium sp.* (13)
Tetropium sp. (9)	*I. typographus* (12)	*I. typographus* (8)
P. poligraphus (4)	*Dryocoetes sp.* (6)	*P. poligraphus* (8)
Rhagium inquisitor (2)	*Hylurgops palliatus* (3)	*Rhagium inquisitor* (4)
Crypturgus sp. (2)	*Trypodendron sp.* (3)	*Dryocoetes sp.* (3)
Serropalpus barbatus (1)	*P. poligraphus* (1)	*Pissodes sp.* (1)
Anthaxia qudripunctata (1)	*Anobium thomsoni* (1)	
	Molorchus minor (1)	
	Callidium sp. (1)	
	Crysobothris chrysostigma (1)	
	Monochamus sp. (1)	
n = 37	n = 39	n = 36

Table 4. Number of trees in which the different species occurred in the different treatment groups in Jämtland. Figure in parenthesis represents number of trees colonised. The first number is the "normal" girdled trees and the second the "lifeline" trees or trees with two narrow girdles. "n" at the bottom of the table represents the total number of colonised trees in each treatment group.

Sättmyrberget girdled 2005	Finnsjöberget girdled 2005	Finnsjöberget girdled 2006	Finnsjöberget cut 2006
P. chalcographus (11/1)	*P. chalcographus* (5/-)	*P. chalcographus* (2/1)	*Pissodes sp.* (11)
I. typographus (10/1)	*I. typographus* (4/-)	*Dryocoetes sp.* (-/3)	*P. chalcographus* (8)
P. poligraphus (10/1)	*P. poligraphus* (4/-)	*Pissodes sp.* (1/1)	*P. poligraphus* (6)
Tetropium sp. (7/2)	*Pissodes sp.* (2/1)	*I. typographus* (1/-)	*Dryocoetes sp.* (3)
Dryocoetes sp. (3/1)	*Dryocoetes sp.* (1/-)	*P. poligraphus* (1/-)	*I. typographus* (2)
Pissodes sp. (4/-)	*Tetropium sp.* (1/-)	*P. subopacus* (-/1)	*Tetropium sp.* (1)
Ips duplicatus (1/-)	*Crypturgus sp.* (1/-)	*Trypodendron sp.* (-/1)	
P. punctifrons (1/-)		*Tetropium sp.* (-/1)	
Rhagium inquisitor (1/-)			
Trypodendron sp. (1/-)			
Crypturgus sp. (1/-)			
Dendroctonus micans (-/1)			
n = 22/3	n = 6/1	n = 2/3	n = 12

Ips typographus

In Jämtland a significant higher proportion of the girdled trees (60%, n = 25) compared to the cut trees (18%, n = 11) were colonised by *I. typographus* (P < 0.05, χ^2-test) although in Uppland the difference was not significant (girdled: 35%, n = 37, cut: 27%, n = 74, P > 0.05, χ^2-test).

The surface coverage of *I. typographus* was significant higher in girdled trees (Uppland: 11.3%, n = 185, Jämtland: 18.2%, n = 140) compared to cut trees (Uppland: 5.3%, n = 296, Jämtland: 8.0%, n = 88, P < 0.05, χ^2-test).

The colonisation density (egg galleries/m^2) of *I. typographus* was three times higher on girdled trees compared to cut trees. The reproductive success did not show any major difference between girdled and cut trees. The production of *I. typographus* was significantly higher in girdled trees than cut trees (Table 5).

A higher proportion of trees larger than 25 cm in diameter were colonised by *I. typographus* in both girdled and cut trees compared to smaller trees (Figure 4).

I. typographus showed no preferences regarding sun exposure in girdled trees ($P > 0.05$, χ^2-test, Figure 5)

No egg galleries of *I. typographus* were found under the girdle. Only a few maturation feeding beetles were noted.

Table 5. The egg gallery density, reproductive success and production of *Ips typographus* in girdled and cut trees. n represents the total number of bark samples in each treatment. (Mann-Whitney *U*-test)

	Girdle			Cut			P
	Mean	Range	n	Mean	Range	n	
Egg galleries / m^2	141	0-533	75	43	0-167	34	< 0.001
Daughters / egg gallery	9.6	1.3-19	55	9.5	0.3-18	20	0.97
Offspring / m^2	2220	0-6700	75	762	33-2400	34	0.017

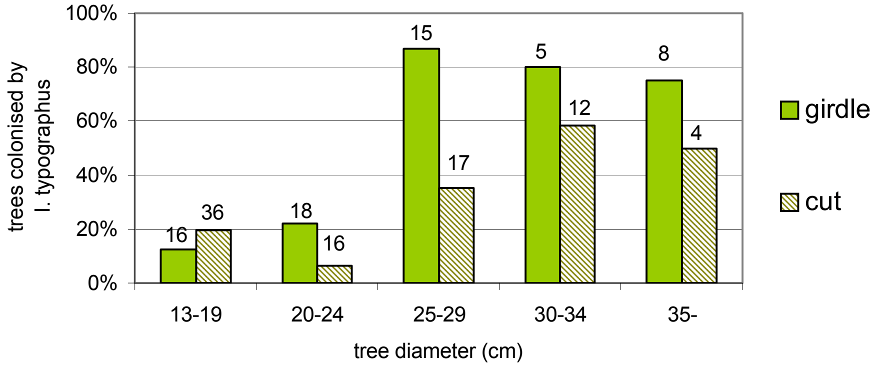


Figure 4. The proportion of trees colonised by *Ips typographus* in relation to the tree diameter. The numbers above the bars are the total numbers of trees.

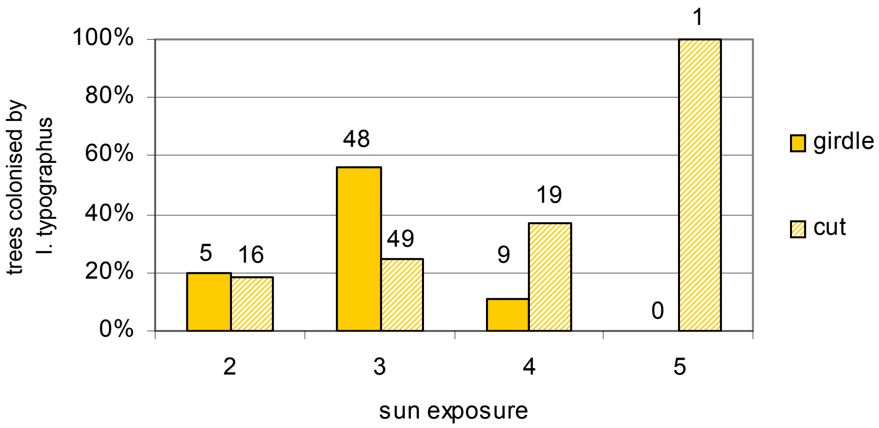


Figure 5. The proportion of trees colonised by *Ips typographus* regarding to the sun exposure. The numbers above the bars are the total numbers of trees. 1 = shaded, 5 = exposed.

Woodpeckers
In all areas where trees had been colonised by insects there were signs of feeding by woodpeckers. In Jämtland three-toed woodpecker (*Picoides tridactylus*) was observed by inspection. The mean amount of bark picked away was equal on girdled and cut trees (P = 0.80, Mann-Whitney *U*-test, Figure 6). In one locality the amount of bark removed by the woodpeckers was higher in girdled trees colonised by *I. typographus* compared to trees not colonised by this insect ($P < 0.05$, χ^2-test, Figure 7). In another locality all trees that contained signs of the larvae *Tetropium sp.* or *Rhagium sp.* (n = 6) bark was removed by woodpeckers.

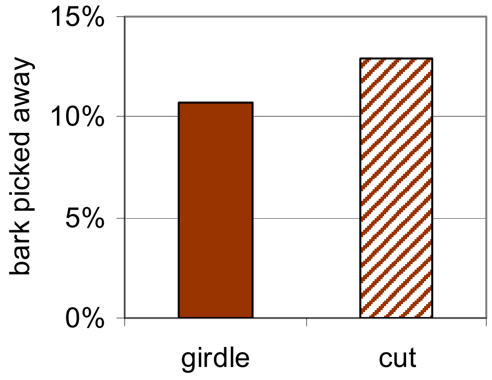


Figure 6. The mean bark picked away divided into girdled and cut trees. Girdle n = 63, cut n = 85. (P = 0.80, Mann-Whitney *U*-test)

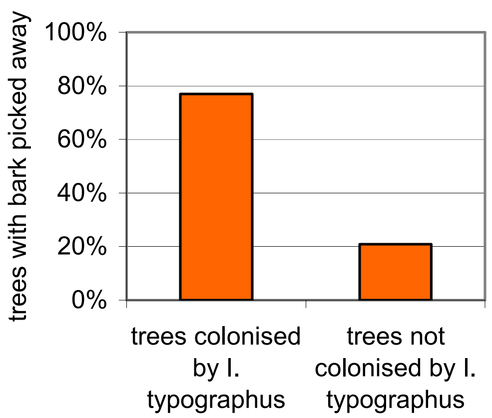


Figure 7. The percentage amount of girdled trees colonised by *Ips typographus* containing picking signs by woodpeckers compared to trees not colonised by this beetle in Uppland. Trees colonised by *I. typographus* n = 13, trees not colonised by *I. typographus* n = 24. ($P < 0.05$, χ^2-test)

Discussion

Most girdled trees remained uncolonised the first summer but were colonised by insects during the second summer or later. The trees with a "lifeline" in the girdle were still uncolonised efter two seasons. In some trees the girdle did not reach the floem, which may explain a higher survival rate (Noel, 1970).

Both Lekander (1959) and Olsson et. al. (2005) found that spruces that were girdled in May or the beginning of June respectively often were colonised by bark beetles the first summer. In Olsson et. al.'s study there is no information about insect species, but the late date of girdling may indicate that the trees were colonised the same summer by the late swarming *Polygraphus spp.* In Lekander's study some trees were colonised by *I. typographus* and *P.*

chalcographus. When the girdling was done later during the summer the trees were colonised the following summer. This show that girdled trees may be colonised faster than the trees did in my study and this difference may be explained by a low population of *I. Typographus* in my study. However, the "lifeline" trees in Lekander's study were still uncolonised the summer the girdled trees got colonised which is in accordance with my "lifeline" trees.

This study show no comprehensive difference in species composition at girdled compared to cut trees. Probably there are similarities between girdled and cut trees concerning the species preferences of substrat. Almost all trees in the different treatments were more or less utilised by *P. chalcographus*, which is a common species. The high amount is presumably a result of the absence and subsequently low colonisation of larger competing bark beetles e.g. *I. typographus*. Also *P. poligraphus* was found on girdled as well as cut trees, although this species is known to mainly colonise standing trees (Ehnström and Axelsson, 2002). The insect species composition was also similar in the trees with two narrow girdles and normally girdled trees.

When studying the species composition above and below the girdle most species that were common above were also found under the girdle. The exception was the three species *Dryocoetes sp.*, *Trypodendron sp.* and *P. punctifrons* which only were found under the girdle. At least the first two species are usually found in lower and more shaded parts of the tree (Jakus, 1998; Ehnström and Axelsson, 2002). No *I. typographus* could be found under the girdle. A low colonisation success in the lowest 1-1.5 m of the stem is shown by Weslien and Regnander (1990). The differences between above and under the girdle in water and nutrient content and during the time after the girdle is made may explain the differences in the bark beetle species different preferences (Olsson et. al., 2005; Shibata, 2000; Wang et. al., 2006).

No clear effect of sun exposure on species composition was observed in girdled or cut trees. This may be due to too few observations.

Both the egg gallery density and the production were higher in girdled trees than in cut trees. However, the reproduction rate was similar at girdled and cut trees. The higher egg gallery density of *I. typographus* in girdled trees was excpected since the girdling is expected to lower the defence capacity but not totally as in cut trees. However, the low density of the girdled trees may indicate a quite low resistance in the trees. This could indicate that girdling weakens the trees very much and that there is a low beetle density in the area.

The reproductive success of *I. typographus* in girdled trees is rather high compared to earlier studies with standing beetle killed trees (Hedgren and Schroeder, 2004; Lekander, 1972; Weslien and Regnander, 1990) which probably depend on a low beetle density in the area.

Regarding the production the values differed between girdled and cut trees, but are comparable to earlier studies with values with approximately 500-3000 offspring/m^2 (Hedgren and Schroeder, 2004; Carlsson, 1983).

A preference of *I. typographus* to colonise larger trees is in accordance with other studies involving standing beetle killed and wind felled trees (Eriksson et. al., 2005; Göthlin et. al., 2000; Hedgren, 2004; Lekander, 1972; Weslien and Regnander, 1990). Likewise, it is expected that trees with a higher sun exposure would be attacked in a greater extent than shaded trees, but this was not obvious (Göthlin et. al., 2000; Lekander, 1972; Peltonen, 1999; Schroeder and Lindelöw, 2002).

The woodpeckers utilised girdled and cut trees to the same extent. In Uppland the results indicate that the woodpeckers hade a preference for girdled trees colonised by *I. typographus*. Although, locally in Jämtland the Cerambycidae larvae *Tetropium sp.* and *Rhagium sp.* were preferred.

Conclusions

- Girdled trees experienced a delayed colonisation compared to cut trees.

- The species composition did not differ much between girdled and cut trees. The only species that not appeared in girdled but in cut trees to a somewhat larger extent was *Hylurgops palliatus*.

- Most of the more common species appeared both above and below the girdle, but *Dryocoetes sp.*, *Trypodendron sp.* and *Polygraphus punctifrons* was only found below the girdle. In none of the trees *I. typographus* had bred under the girdle.

- Girdled trees were more preferred by *I. typographus* than cut trees.

- *I. typographus* preferred girdled and cut trees larger than 25 cm in diameter, but did not show any preference in an increased sun exposure.

- Woodpeckers utilised girdled and cut trees to the same extent. In some areas the woodpeckers hade a preference by trees colonised by *I. typographus* or by *Tetropium sp.* and *Rhagium sp.*

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Appendix

The areas in Båtfors nature reserve. The dark greens are the areas with girdled spruces.