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Species of bark beetles (Scolytinae) collected in the Bohemian Forest at Smrčina/Hochficht two years after the Kyrill hurricane

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Abstract
A faunistic study of bark beetles species occurring at Mt. Smrčina/Hochficht in the southern part of the Bohemian Forest was carried out in 2009, two years after the Kyrill hurricane. The study area was located on the border between the Šumava NP in the Czech Republic and private forests in Austria. The management policy is non-intervention in the core zone of the Šumava NP, whereas commercial forest management is applied on the Austrian side of the border. The original survey focusing on the migration of the bark beetles (primarily *Ips typographus*) in the border area recorded high number of different species and offered opportunity to study also the species diversity. This study presents its faunistic results. Species diversity was studied along three transects. There were five monitoring sites along each transect. At each site traps were arranged in the form of two crosses in which there was one pheromone trap ('active trap') and nine traps without pheromone ('passive trap'). Of the total of 150 traps set in the study area only fifteen were baited with pheromone. Eighteen species belonging to the family Scolytinae were caught by the traps during the five months of this study. Five of the species feed only on spruce, eleven are polyphagous feeding on *Picea* spp., *Pinus* spp., *Abies alba,* and *Larix decidua*. In addition, there were two species, *Scolytus intricatus* and *Xyloterus domesticus*, which probably feed on old maples growing in historically grazed parts of the forest. *Ips typographus*, *Pityogenes chalcographus*, *Dryocoetes autographus*, and *Dryocoetes hectographus* were the most common species. The first two species dominated the catches of the traps baited with pheromone. Several rare species, including *Pityogenes conjunctus*, were also caught. Species diversity and ecology of recorded bark beetles species are discussed to support current debates about more appropriate management of the forests in the National Park.

Key words: Šumava National Park, mountain spruce forest, species diversity, natural disturbances, rare species

Introduction

Natural disturbances are important determinants of forest development. Both wind and insect outbreaks are very important in central European forests (Frelich 2002). Bark beetles (Coleoptera: Curculionidae: Scolytinae), such as *Ips typographus* and *Pityogenes chalcographus*, play crucial roles in the dynamics of Norway spruce forests in Europe (Christiansen & Bakke 1988, Wermelinger 2004, Svoboda et al. 2010). The role of particular species of bark beetles in modifying the structure and function of natural spruce forests in the Bohemian Forest are well recognized (Pfeffer 1955, Skuhravý 2002, Müller et al. 2008).

The Bohemian Forest (Šumava Mts. in Czech) is situated on a long mountain ridge running along the Czech-Bavarian and Czech-Austrian borders in central Europe. This densely wooded landscape with mountain streams, marshlands, mires and bog woodlands is a refuge for many endangered species of plants and animals. Nature is protected here in two national parks: the Bayerischer Wald NP (Germany; established in 1970 and enlarged in 1997 to 24 250 ha) and the Šumava NP (Czech Republic; established in 1991; 68 064 ha). Periodically there are proposals to establish a national park in the Austrian part of the Bohemian Forest but so far they have not been accepted. The main reason is that Stift Schlägel, the private owner of this part of the forest, is not interested. At least, these forests are the largest terrestrial Natura 2000 sites in the respective countries (D: FFH-Gebiet Bayerischer Wald, FFH-Gebiet Hochwald und Urwald am Dreisessel, CZ: SAC Šumava, SPA Šumava; A: FFH-Gebietes Böhmerwald-Mühltäler; Husslein & Kiener 2007, Guttmann & Neubacher 2009). These forests constitute a significant part of the Natura 2000 network, which was established to protect the most endangered habitats and species in Europe, as defined in the 1992 Habitats Directive and 1979 Birds Directive (Sundeth & Creed 2008).

Over the course of the last few decades different strategies of forest management were applied along the borders. Bark beetle control and felling of infested trees were standard management practices at the Czech sites whereas the strategy in the Bayerischer Wald NP is one of non-intervention. For a long time the debate about the future of nature conservation in the Šumava NP have involved discussions on the zoning of the Park, which has undergone significant changes since its establishment (Křenová & Hruška 2012). Management of the Šumava NP has resulted in fragmentation of the core zone, political instability and lack of a long-term strategy for the National Park. There has been an ongoing discussion on the appropriate way of managing forests in the Šumava NP following the Kyrill hurricane in January 2007 (Křenová 2008, Šantrůčková et al. 2010). Mountain spruce forests were badly affected by this hurricane, which uprooted thousands of spruce trees. This damage was especially marked in fragmented parts of the forest where bark beetle infested trees were previously felled. After this a non-intervention management approach was implemented in some parts of the Šumava NP, primarily in areas where natural mountain spruce forests occur. The Stift Schlägel Forest Company is well known for its very good ecological forestry of mixed forests at low altitudes but its management in the highest part of the Bohemian Forest is not suitable for mountain forests and differs from that carried out in neighbouring protected areas. In particular the company has not operated a non-intervention management approach and as a result the majority of the trees in the mature montane spruce forests in this area that became infested with bark beetles over the last decade were felled. Unfortunately, they also do not actively protect the forests, which would be needed if they are part of a buffer zone. Non-native species (*Larix decidua*, *Pinus mugo*, and *Alnus viridis*) were planted in some parts. Different approaches to management along the state border, i.e. non-intervention management in the Šumava NP core zone No. 132 versus commercial forestry plus ski resort in Austria, result in many problems. The Stift Schlägel's Co. concern about bark beetles from infested trees in the Šumava NP attacking his private forests resulted in a long negotiation followed by a bilateral agreement that a 200-meter wide buffer zone, in which all trees infested with bark beetles are debarked, was established on the Czech side of the border.

Bark beetles living in the Šumava National Park have been a matter of concern for decades, with usually only one species of spruce bark beetle (*I. typographus*) receiving most attention. Other species are much less common and little is known about their distribution, ecology and population dynamics. The brief reports of Zelený (2001) and Zelený & Doležal (2004) contain lists of the species of bark beetles associated with spruce trees in the Šumava NP, but little is known about the species diversity of bark beetles at different locations in the Bohemian Forest.

This study focuses on the species diversity of bark beetles in the Šumava NP core zone, No. 132 Smrčina, and a neighbouring part of the private forest in Austria. The diversity and dynamics of the species were studied in 2009, two years after the Kyrill hurricane and the start of the bark beetle outbreak when many of the wind thrown, uprooted and standing trees became infested in this area. The objective of the original study was to determine the extent of the migration of the bark beetles in the border area and help to optimize forest management measures (Jakuš 2010). High number of different species recorded in traps very soon after their installation offered opportunity to study also the species diversity. The results of this faunistic study are presented here.

Material and methods

Site description

The study area is located at Smrčina (Hochficht in German, 1332 m a.s.l., 48°44'25.7'' N, 13°55'18.8'' E), a mountain on the south-eastern edge of the Bohemian Forest, with the main summit on the border between the Czech Republic and Austria (Fig. 1). Most of study area is located in the core zone of the Šumava NP but it also includes the closest part of the private forest in Austria.

This area is one of the most valuable parts of the Šumava National Park, especially as it includes mountain forest ecosystems in which the zonation of the vegetation is well preserved. The highest ridge of the mountain is covered by spruce forests (as. *Calamagrostio villosae-Piceetum*) and the steeper slopes and rocky habitats by *Athyrium distentifolium*-rich spruce forests. *Dryopterido dilatata*-rich spruce forests (*Dryopterido dilatatae-Piceetum*) grow in some nutritionally poor debris. Acidophilous montane beech forest (as. *Luzulo Fagetum*) and beech woodland rich in herbaceous plants (as. *Dentario enneaphylli-Fagetum*) dominate at lower altitudes. Old, natural and valuable stands of primeval forests as well as young mixed forests with a natural structure and species composition are common in this area. Capercaillie (*Tetrao urogallus*), three-toed woodpecker (*Picoides tridactylus*), ouzel (*Turdus torquatus*), Tengmalm's owl (*Aegolius funereus*), and peregrine (*Falco peregrinus*) regularly breed in this area. The area is also an important part of the home range of several lynxes (*Lynx lynx*).

Some parts of this spruce forest are supposed to be the last fragments of the primary montane forests that previously occurred in this area (Jelínek 2005). There are different aged spruce forests with different types of forest floors and the species richness is poor in those parts where the canopy is dense, up to 90%. The mosaic of natural and semi-natural forests in this area has a very high potential for natural recovery (Boublík et al 2006). These forests are periodically strongly disturbed by high winds and bark beetle infestations.

Twelve study sites were located in a high part of the Šumava NP core zone No. 132 Smrčina, covering an area of 237.47 ha. Species composition and forest structure in this area are classified as natural or close to natural (Zatloukal 1998, Boublík et al. 2006). More details of the species structure are presented in Table 1. A large bark beetle outbreak affected this area in the 1990s. There were 30 ha of dead trees and logging areas in several parts of this first zone in 1998 (Zatloukal 1998). In 2006, individual trees and small groups of trees were infested with bark beetles in the study area. Serious damage, with about 650 m^3 of new wind uprooted and broken trees were recorded in the core zone Smrčina after the Kyrill hurricane in January 2007. The west part of the study area was also affected. Damaged trees were attacked by bark beetles in June 2007. The next year, in June 2008, the beetles infested trees in the edges of the surrounding forest. The peak in the bark beetle outbreak occurred in this area during 2008 and 2009.

Three monitoring sites were located in Austria close the state border, on the ridge plateau at altitudes of between 1250–1300 m a.s.l. Montane spruce forests occurring there were significantly affected by high winds after the ski resort was extended in the 1980s and strongly fragmented by salvage logging during the last decade.

The study area is located in the highest part of the Bohemian Forest, in mapping square 7249 (www.biolib.cz).

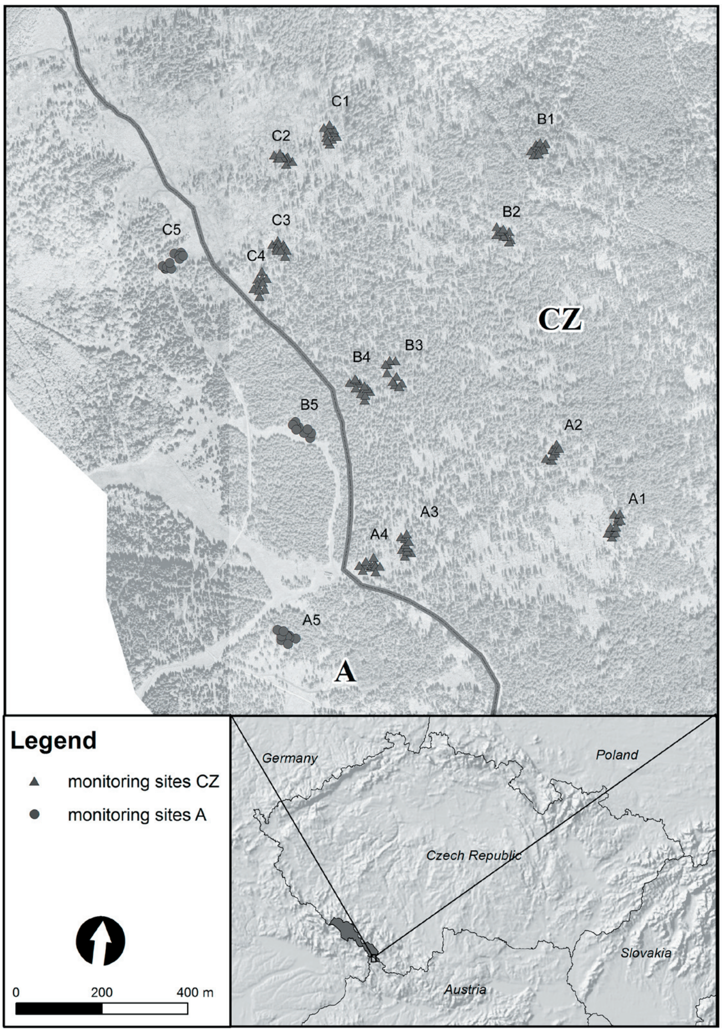

Fig. 1. Map of the study area showing the positions of the three transects and the 15 locations at which the numbers and species of bark beetles were monitored.

Table 1. Species composition of the trees in the Šumava NP core zone No. 132 Smrčina. Natural species composition and current species composition are compared (Zatloukal 1998).

Species composition	Natural		Current		Natural − Current
	ha	%	ha	%	ha
Picea abies	146.61	62	179.04	75	32.43
Abies alba	21.14	9	0.89	1	−20.25
Pinus sylvestris	0.27	0.1	0	0	−0.27
Pinus mugo	0	0	0	0	0
other conifers	0	0	0	0	0
Total conifers	168.02	71	179.93	76	
Fagus sylvatica	41.05	17	55.15	23	14.10
Acer pseudoplatanus	8.68	4	0	0	−8.69
other broadleaved	19.72	8	2.39	1	−17.33
Total broadleaved	69.45	29	57.54	24	

Data collection

Three transects were established in the study area in spring 2009, two years after the Kyrill hurricane when the activity of bark beetles was expected to be at its highest. Each of these transects (A, B, C) were perpendicular to the Czech-Austrian state border at altitudes between 1250–1330 m a.s.l. and along each were five locations at which the beetles were monitored (Fig. 1). Transect C was the nearest to the area most strongly affected by the Kyrill hurricane in January 2007. Locations C1 and C2 were just at the edge of the damaged area, C3 and C4 were 100 m from this area and C5 200 m. The five locations along each transect at which bark beetles were monitored were at least 100 m apart and at each location there were ten traps arranged in the form of two crosses, each consisting of five traps (see below). In summary, there were fifteen monitoring locations each with ten traps giving a total of 150 traps.

To monitor bark beetle migration three locations along each transect (A1, A2, A3, B1, B2, B3, C1, C2, C3) were located on the Czech side of the border, one (A4, B4, C4) at the border and one (A5, B5, C5) on the Austrian side. Numbers of samples in traps located in different positions were recorded. Monitoring occurred both in areas affected by the Kyrill hurricane and unaffected parts of the forest. Places where *I. typographus* beetles were active (i.e. fresh forest edges after wind damage or salvage cutting, bark beetle hot spots) were preferred.

A two-cross arrangement of traps was used at each monitoring location (Fig 2). The first cross of five traps had one pheromone trap (Theysohn type, pheromone Pheagr IT, SciTech spol. s r.o. Praha ČR) located in the centre of the cross arrangements plus four passive traps (without pheromone). Additional semipermeable covers were used to decrease intensity of pheromones up to 50%. The second cross consisted of five traps without pheromone. The traps with pheromone were called ‘active traps’ and the traps without pheromone were called ‘passive traps’. These uniform names of traps were used without respect to sensitivity of

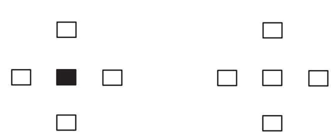

Fig. 2. The two-cross arrangement of the traps – one active trap (solid square) with pheromone and nine passive traps (open squares) without pheromone were exposed at each monitoring location.

different bark beetle species to used commercial pheromone. The distance between the two crosses ranged between 20–50 m. The distance between the central and peripheral traps in each cross was 12 m. To avoid an edge effect the minimal distance between a trap and a green tree (tree not infested with bark beetles) was 15 meters and between a trap and a wind-blown or a trap tree was 20 m.

The traps were set on May 13, 2009. An earlier setting of the traps was not possible due to deep snow cover in the study area. The traps were inspected and samples collected every seven to ten days. The first samples were collected on May 23, 2009. Samples from each trap were collected, stored separately and later analysed. Non-target species were separated and all specimens of Scolytinae were determined and counted.

This monitoring design was primary prepared only for monitoring of *I. typographus* and the main aim of the original study was to determine the extent of the migration of the bark beetles in the border area and help to optimize forest management measures (Jakuš 2010). But high number of different species recorded in traps very soon after their installation offered opportunity to study also the species diversity. Results of this faunistic study are presented in this paper with respect to obstacles of used methodology. Entomological terminology follows Pfeffer (1995).

Results

Eighteen different species of Scolytinae (Table 2) were caught by the traps during the five months of the study. A list of all the species recorded and a brief description of their ecology (Pfeffer 1955, 1995) follows.

Subfamily Hylesininae (Erichson, 1836)

Tribe Tomicini (Thomson, 1859)
Genus Xylechinus (Chapuis, 1869)
Xylechinus pilosus (Ratzeburg, 1837) – its host plant is Norway spruce (*P. excelsa*) on which it develops under the bark of sub-canopy slow-growing trees. This species usually occurs in mountainous regions.

Tribe Hylastini (LeConte, 1876)
Genus *Hylastes* (Erichson, 1836)
Hylastes brunneus (Erichson, 1836) develops under the bark of the roots of spruce (*P. excelsa*) and pine (*P. sylvestris*). This species is quite widespread in the highlands and mountains in the Czech Republic.
Hylastes cunicularius (Erichson, 1836) develops under the bark of fresh stumps or lying trunks with smooth bark of Norway spruce (*P. excelsa*, very often in the sides in contact with the ground. In the Czech Republic this species occurs in the lowlands and mountains.

Tribe Phloeotribini (Chapuis 1869)
Genus *Phthorophloeus* (Rey, 1883)
Phthorophloeus spinulosus (Rey, 1883) feeds on Norway spruce (*P. excelsa*); larval galleries of this species usually occur on undersides of dead branches. In the Czech Republic, this species occurs in the highlands and the mountains.

Tribe Polygraphini (Chapuis, 1869)
Genus *Polygraphus* (Erichson, 1836)
Polygraphus poligraphus (Linné, 1758) feeds on Norway spruce (*P. excelsa*) and occasionally on Scotch pine (*P. sylvestris*). In dense stands, this species usually attacks the thinner

Table 2. Numbers of specimens of 18 species of bark beetles caught by 15 active traps (AC) baited with pheromone and 135 passive traps without pheromone (either grouped or not grouped around a trap with pheromone) at Smrčina/Hochficht in 2009.

Species	**Active traps (n = 15)**		**Passive traps around active trap (n = 60)**		**Passive traps around passive trap (n = 75)**		**Total number (n = 150)**
	specimens	%	specimens	%	specimens	%	specimens
Xylechinus pilosus	2	50.0	1	25.0	1	25.0	4
Hylastes brunneus	5	12.2	15	36.6	21	51.2	41
Hylastes cunicularius	3	7.5	10	25.0	27	67.5	40
Phthorophloeus spinulosus	0	0.0	1	50.0	1	50.0	2
Polygraphus poligraphus	5	9.4	19	35.9	29	54.7	53
Crypturgus hispidulus	0	0.0	0	0.0	1	100.0	1
Scolytus intricatus	0	0.0	1	100.0	0	0.0	1
Dryocoetes autographus	17	5.7	98	32.8	184	61.5	299
Dryocoetes hectographus	11	7.4	50	33. 8	87	58.8	148
Pityogenes chalcographus	70	17.1	98	23.9	242	59.0	410
Pityogenes conjunctus	66	94.3	0	0.0	4	5.7	70
Ips typographus	14 709	93.0	260	1.6	855	5.4	15 824
Ips amitinus	3	14.3	7	33.3	11	52.4	21
Orthotomicus laricis	0	0.0	1	50.0	1	50.0	2
Pityophthorus pityographus	0	0.0	1	100.0	0	0.0	1
Cryphalus abietis	0	0.00	2	100.0	0	0.0	2
Xyloterus lineatus	4	5.1	21	26.6	54	68.4	79
Xyloterus domesticus	1	20.0	1	20.0	3	60.0	5

or weaker trees. In the Czech Republic this species occurs in the lowlands and mountainous areas.

Tribe Crypturgini (LeConte, 1876)
Genus *Crypturgus* (Erichson, 1836)
Crypturgus hispidulus (Thomson 1870) lives under bark of conifers and its tunnels usually start in the grub holes of other species. This species, which is not very common in the Czech Republic, replaces *Crypturgus pusillus* in the mountains.

Subfamily Scolytinae (Latreille, 1804)

Tribe Scolytini (Latreille, 1807)
Genus *Scolytus* (Geoffroy, 1762)
Scolytus intricanus (Ratzeburg, 1837) develops under the bark of oaks (*Quercus* spp.) and less commonly beech (*Fagus sylvatica*), elm (*Ulmus* spp.), poplar (*Populus* spp.) and hornbeam (*Carpinus betulus*). In the Czech Republic, this species occurs mostly in the lowlands and foothills.

Subfamily Ipinae (Reitter, 1894)

Tribe Dryocoetini (Lindemann, 1876)
Genus *Dryocoetes* (Eichhoff, 1864)

Dryocoetes autographus (Ratzeburg, 1837) feeds on spruces and pines, preferring wet habitats such as shaded trunks and stumps. This species is common both in the lowlands and mountainous areas.
Dryocoetes hectographus (Reitter, 1913) tunnels under the bark of fallen spruce trees in wet locations. In the Czech Republic, it is a typical species of montane spruce forests.

Tribe Ipini (Bedel, 1888)
Genus *Pityogenes* (Bedel, 1888)
Pityogenes chalcographus (Linné, 1761) can develop in young stands or trunks with thin bark of different species of spruce (*Picea excelsa*, *P. obovata*, *P. orientalis*, *P. omorica*, plus several spruce species growing in Siberia), pine, and larch. This is a common species, occurring in the lowlands and mountainous areas, including dwarf pine (*Pinus mugo*) areas.
Pityogenes conjunctus (Reitter, 1887) develops in damaged branches of pines (*Pinus montana*, *P. uncinata*, *P. cembra*). In the Czech Republic this species occurs in mountainous areas.
Genus *Ips* (DeGeer, 1775)
Ips typographus (Linné, 1758) is an important pest of spruce forests. It is a common species in the Czech Republic occurring even in areas where spruce trees are uncommon.
Ips amitinus (Eichhoff, 1871) can be found under the bark of thin trunks or branches of spruce. This species is common in the Czech Republic.
Genus *Orthotomicus* (Ferrari, 1867)
Orthotomicus laricis (Fabricius, 1876) occurs in the branches of trees remaining after logging or damaged parts of spruce and pine trees (occasionally also firs). In the Czech Republic this species occurs in the lowlands and on the lower parts of mountains.
Tribe Corthylini (LeConte, 1878)
Genus *Pityophthorus* (Eichhoff, 1864)
Pityophthorus pityographus (Ratzeburg, 1837) develops in thinner parts of trunks or branches of spruce (*P. excelsa)*, fir (*Abies alba*) and pine (*Pinus* spp. including *P. mugo*). In the Czech Republic this species occurs in the highlands and up to tree line in the mountains.

Tribe Cryphalini (Lindemann, 1878)
Genus *Cryphalus* (Erichson, 1836)
Cryphalus abietis (Ratzeburg, 1837) develops in young stands or trunks with thin bark of several different species of spruce (*Picea excelsa*, *P. obovata*, *P. orientalis*, *P. omorica*), pine (*P. silvestris*) and fir (*A. alba*). It is a common species in the Czech Republic.

Tribe Xyloterini (Lindemann, 1876)
Genus *Xyloterus* (Erichson, 1836)
Xyloterus lineatus (Olivier, 1795) is recorded attacking various species of several different genera (*Picea*, *Abies* and seldom also *Pinus* and *Larix*). This bark beetle usually attacks damaged, wind thrown, stressed tree and fresh stumps. It is a common species in the Czech Republic and often occurs in mountainous and hilly areas.
Xyloterus domesticus (Linné, 1758) feeds on beech (*Fagus sylvatica*), alder (*Alnus glutinosa*), oak (*Quercus* spp.), maple (*Acer* spp.), birch (*Betula* spp.) and hornbeam (*Carpinus betulus*) in hilly and mountainous areas.

A total of five species feeding only on spruce and eleven polyphagous species feeding on *Picea* spp., *Pinus* spp., *Abies alba* and *Larix decidua* were recorded in the study area. In addition, two species (*S. intricatus*, *X. domesticus*) living on oak, beech, birch, common alder and maple were also recorded.

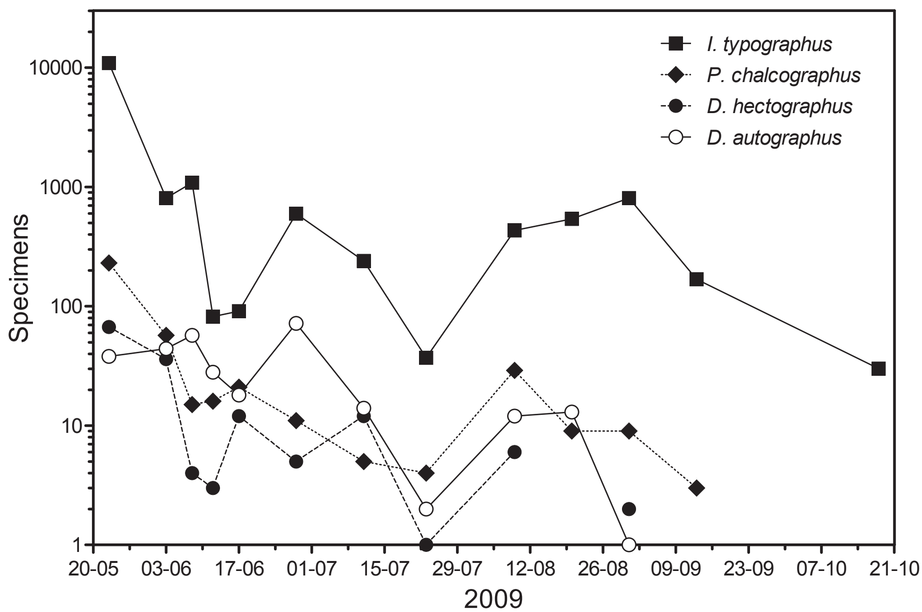

Fig. 3. Seasonal trends in the numbers (note logarithmic scale) of the four most common species of bark beetles caught in the study area.

Two peaks in bark beetle activity were recorded in 2009. The first peak, the spring swarming, was recorded on May 23, 2009, when a total of 11 384 specimens of 15 species of bark beetles were caught by the traps. Some species showed some minor differences in their seasonal dynamics but were similar in terms of the main trends.

The European spruce bark beetle (*I. typographus*) was the most abundant species, with a total of 15 824 beetles caught. The spring swarming of this species in 2009 occurred at the end of May and beginning of June (Fig. 3). This was followed by a second smaller peak at the end of June and then at the beginning of August another with the highest numbers of *I. typographus* caught at the end of August. The spring swarming of the second most common species, *P. chalcographus* (410 specimens), also occurred in May and the second generation emerged in the middle of August. The two *Dryocoetes* species (*D. autographus* and *D. hectographus*) were also abundant (299 and 184 specimens, respectively). They were recorded especially in traps located close to wind thrown trees or in dense forest stands. The seasonal dynamics of *D. autographus*, the third most abundant species, was similar to that of *I. typographus* – the first swarming occurred at the end of May and second generation emerged in August. The highest number of *D. hectographus* caught, the fourth most common species, was recorded at the end May and several smaller peaks followed at two or three weeks intervals throughout summer (Fig. 3).

A rare species, *P. conjunctus*, was also recorded (70 specimens) and was one of the six most common species in the study area. The highest number of this species (51 specimens) was recorded on May 23, 2009 after which only a few specimens were caught. In contrast, *P. poligraphus* (55 specimens) was caught only in August and September.

There were big differences in the numbers of beetles caught by active and passive traps (15 482 vs. 1 521 specimens), it means that the bark beetle species attracted by used pheromone were more abundant in study area. There were also significant differences in seasonal sum of specimens caught by active traps (mean ± SEM: 993±310 specimens per trap), passive traps located around a pheromone trap (10±2.0 specimens per trap) and passive traps not located around a pheromone trap (20±2.4 specimens per trap). We found that there were no differences between the numbers caught by passive traps located around a pheromone trap and passive traps not located around a central pheromone trap.

Ips typographus and *P. chalcographus* dominated the catches of active traps, i.e., those with pheromone. Also most *P. conjunctus* (94%) were caught by active traps. In contrast, most *D. autographus* and *D. hectographus* were caught by passive traps. *Crypturgus hispidulus*, *P. pityographus*, *S. intricatus*, and *C. abietis* were caught only by passive traps (Table 2).

There were differences in the numbers of bark beetles caught by the passive traps located around central traps with pheromone (Fig. 4a) and passive traps around central traps without pheromone (Fig. 4b) only on the Czech side of the border (monitoring locations A1, A2, A3, B1, B2, B3, C1, C2, C3). The traps located on the south-west side of the central trap with pheromone caught most of the beetles. At the border (monitoring locations A4, B4, C4), most beetles were caught by traps located on the west side of the central traps. There were no differences in the catches of the passive traps located around central traps without pheromone.

Discussion

Eighteen different species of the family Scolytinae were caught by the traps during the five months of this study. Two of the species (*S. intricatus* and *Xyloterus domesticus*) feed on broad leaved trees, probably the several old maples (*A. pseudoplatanus*) present in the study area. It is also possible that *S. intricatus* was passively carried by the wind from a lower altitude but the weather conditions needed for this occur very rarely. Sixteen species, which feed on spruce, represent more than 55% of the Czech species of bark beetles that feed on spruce (Pfeffer 1955) and more than 66.6% of bark beetles reported by Pfeffer (1955) from the Bohemian Forest. Zelený & Doležal (2004), who collected bark beetles from logs, tree trunks, branches and roots of spruce trees, reported a total of 26 species from different loca-

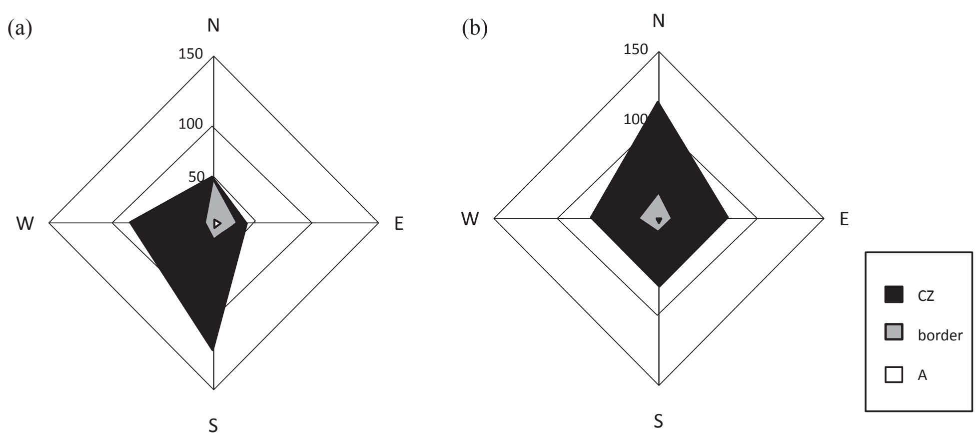

Fig. 4. Spatial distribution (in m) of the bark beetles caught by the passive traps positioned around traps with (a) and without (b) pheromone.

tions in the Bohemian Forest (mapping squares 6947, 7046, 7047, and 7048). It is likely they recorded a higher number of species because they sampled a larger area and more diverse locations than we studied. In any case their methodology was very effective and less time consuming than periodic trapping. They assumed that different methods of collecting bark beetles can result in significant differences in species diversity and number of specimens collected. They found the same species as Pfeffer (1955) plus two other species, *P. micrographus* and *X. laeve*. These two species together with *P. conjunctus* were categorized as rare species, which may be important for nature conservation (Zelený & Doležal 2004, Knížek 2005). We also recorded *P. conjunctus* in our study area, where it was one of the six most common species.

There are no published records of bark beetle species diversity in other parts of the Šumava National Park but Modlinger et al. (2009) report a similar species diversity in the Žofínský Prales National Natural Reserve (NNR, 97.72 ha) in southern Bohemia, which was similarly damaged by the Kyrill hurricane in January 2007 (ca. 2 000 m^3 of spruce wood damaged). Ca. 300–400 m^3 of spruce wood was infested with bark beetles in 2007 and the volume of infested wood increased by approximately 1 000–1 200 m^3 in 2008. At total of twenty two bark beetle hot spots consisting of between several single to dozens of standing trees were found in 2008. For investigating bark beetle species diversity Modlinger et al. (2009) used barrier traps without pheromones and searched for bark beetles on fallen trees. In total they found 17 species. *Ips typographus* was the most common species but only half of the species they recorded were the same as those recorded in this study because beech and fir trees dominate in the Žofínský Prales NNR. Similar species diversities of bark beetles are recorded from other locations in central European montane spruce forests. For example 19 species of bark beetles species were caught by window traps located in montane spruce forests growing in three valleys in the Tatra National Park, Slovakia (Zach et al. 2010).

Ips typographus was the most abundant species in the study area and more than 90% of them were caught by the active traps baited with pheromone designed to attract this species (Table 3). It is well known that two semiochemicals, 2me-3-buten-2-ol and cis-verbenol, in the commercial pheromone Pheagr IT are both a pheromone and attractant for *I. typographus* (Francke et al. 1995, Schlyter et al. 1987). Also more than 90% of *P. conjunctus* were caught by active traps because this species is also attracted by this pheromone dispenser (Table 3; Baader 1989). It is documented by Benz et al. (1986) that traps containing a mixture of attractants for *I. typographus* also catch other species of bark beetles as they caught high numbers of *P. chalcographus*, *P. conjunctus*, and *T. lineatum* in these traps. Occurrence of *P. conjunctus* at our study site was a little surprising because this species supposedly does not feed on spruce trees (Pfeffer 1955, Zach et al. 2010). Its source of food in the study area is unknown. The second most abundant species in our study, *P. chalcographus*, was also caught by active traps, which was predicted (Table 3, Benz et al. 1986), but a significant number were also caught by the passive traps. This species, which often colonizes the thinner parts or branches of trees already infested with *I. typographus*, utilizes 2me-3-buten-2-ol and cis-verbenol as attractants. It is likely that the commercial pheromones were less attractive for *P. chalcographus* because of the high concentration of tree volatiles in the study area.

In contrast, most *D. autographus* and *D. hectographus*, the third and fourth most common species, were caught by passive traps without pheromone. Both species were recorded especially in traps located close to areas of wind thrown trees or in denser forest stands. This fits their ecological preferences, with *D. autographus* usually feeding in the bases of fractured trunks or stumps in moist places, and *D. hectographus* in fallen trunks at wet sites. These species do not utilize 2me-3-buten-2-ol and cis-verbenol, but lineatin, alpha-pinene, or some

Table 3. Species of bark beetles recorded in the study area and their response to semio-chemicals present in the commercial pheromone (Pheagr IT): 2-methyl-3-buten-2-ol (2me-3-buten-2-ol) and cis-4,6,6-trimethyl-bicyclo[3.1.1]hept-3-en-2-ol (cis-verbenol).

Species	**2me-3-buten-2-ol**	**cis-verbenol**
Xylechinus pilosus		
Hylastes brunneus		
Hylastes cunicularius		
Phthorophloeus spinulosus		
Polygraphus poligraphus		
Crypturgus hispidulus		
Scolytus intricatus		
Dryocoetes autographus		
Dryocoetes hectographus		
Pitiogenes chalcographus	A[*)]	A
Pityogenes conjunctus	P	P
Ips typographus	A,P	A,P
Ips amitinus		
Orthotomicus laricis		
Pityophthorus pityographus		
Cryphalus abietis		
Xyloterus lineatum	A	A
Xyloterus domes		

[*)] A – attractant: chemicals that are not naturally produced by organism but found to be attractive in either field or laboratory experiments; P – pheromone: any substance secreted by an organism that stimulates specific reactions in a receiving organism of the same species (e.g. host location by beneficial insects); source: http://www.pherobase.com.

other semiochemicals for communication (Camacho et al 1993, 1994). Therefore were more likely to be caught by passive than active traps which were more abundant in our study area. Also several other rare species of bark beetles were caught only by passive traps but because so few were caught their association with passive traps is not significant.

The results of this study indicate that the commercial pheromone Pheagr IT (SciTech spol. s r.o. Praha ČR), which is the most often used pheromone, not only in the Šumava NP, can attract not only *I. typographus* but also other species, including rare species like *P. conjunctus.* Bark beetles are not the only insects attracted by the semiochemicals in Pheagr IT but also other insects, including the natural predators or parasitoids of *I. typographus*. The checkered beetles *Thanasimus femoralis* and *T. formicarius* respond to 2me-3-buten-2-ol and cis-verbenol as kairomones, chemical substances that benefit the receiver but not the emitter (Bakke & Kvamme 1978, 1981). This is also the case for *Medetera* sp. (Diptera: Dolichopodidae), which are important predators of bark beetles worldwide (Bickel 1987, Dippel et al.1997, Hedgren & Schroeder 2004). *Medetera* larvae inhabit galleries made by scolytid beetles in the bark of trees, and feed on scolytid eggs, larvae, pupae and emerging adults. These species in the Šumava NP respond to tree volatiles plus the pheromones of their prey and a mixture of pheromones was considerably more attractive to *M. setiventris* and *M.*

melancholica than individual chemicals (Hulcr et al. 2005). *Medetera* species seem to respond to the stage of decay of the tree and the intensity of bark beetle infestation by means of the ratio of tree volatiles and/or prey pheromones.

Pheromone traps can be used to determine predator–prey relationships, especially the detection of particular species of prey and the natural population dynamics of prey and their predators. These facts should be taken into consideration in the management of forests in national parks and other protected areas.

The highest number of beetles was caught on May 23, 2009 only 10 days after the traps were set, when fifteen species were recorded and for many of them the highest numbers of specimens were also recorded. Later the numbers caught decreased possibly because of weather conditions. But there is a high probability that the spring swarming of some species occurred before the traps were set. Unfortunately an earlier setting of the traps was prevented by a deep covering of snow in the study area.

The seasonal dynamics of *I. typographus,* with a spring swarming in the middle of May and emergence of a sister brood two or three weeks later, which occurred in our study, has previously been recorded in other areas (Zahradník & Knížek 2007). Summer swarming did not result in a steep peak as the next generation started emerging at the beginning of August and the numbers caught increased slightly during the next few weeks. The highest number of *I. typographus* trapped was recorded at the end of August. This pattern is reported in other mountainous areas (Jakuš et al. 2003, Jönsson et al. 2009). Short photoperiods and low temperature at the end of summer limit successful development of the filial generation of the beetles (Doležal et al. 2007). *Pityogenes chalcographus* and *D. autographus*, the second and third most common species, also had similar seasonal dynamics. The spring swarming of *D. hectographus* occurred at the end May followed by several smaller peaks at two or three week intervals during summer. This pattern fits Pfeffer's (1955) observation that some species of *D.* have a biannual life cycle or some populations can have either an annual or biannual life cycle. In addition, the highest number of *P. conjunctus* (51 of the total of 70 specimens) was caught at the end of May with only a few specimens caught later. Although only a low number of specimens were caught it is likely that this species has only one generation per year in the study area. In contrast, *P. poligraphus* (55 specimens) was caught only in August and September. The spring swarming of this species usually occurs in April or May (Pfeffer 1955) and, therefore, was probably missed in 2009 because of the delay in setting the traps, and we caught only adults of the next generation that emerged in August.

There is insufficient data for a statistical analysis of the numbers of beetles caught by the passive traps located at different positions around the central trap with pheromone, but the higher numbers caught by the passive traps south-west or west of the active trap, might indicate that most of the beetles attracted by the pheromone arrived from the south-west or west. This may be due to local forest conditions or predominance of south-westerly or westerly winds determining the direction of bark beetle migration. In order, to determine the pattern of migration of bark beetles in this border area a more detailed study, including a spatial analysis, is needed.

However, this study provides unique data on the species diversity of bark beetles in the southern part of the Bohemian Forest. The total number of 18 species we recorded corresponds with that recorded at other central European locations (Modlinger et al. 2009, Zach et al. 2010). The dominant species, *I. typographus*, *P. chalcographus*, *D. autographus*, and *D. hectographus* were accompanied by some rare species. *P. conjunctus* is a rare species, which is associated predominantly with *Pinus*, which does not occur in the study area. However, Zelený & Doležal (2004) also report several specimens of *P. conjunctus* from locations in the Šumava NP, where there are no pines other than the rare *Pinus mugo*. Whether this species can also feed on spruce needs to be tested in the future. The other rare species, *S. intricatus* and *X. domesticus*, probably are associated with old maple trees growing in the eastern part of the study area, which was historically used for the summer grazing of cows.

We conclude that a better knowledge of the species diversity and ecology of all the species of bark beetles occurring at target locations is an essential prerequisite for appropriate management of forests in National Parks. In addition, the fact that commercial pheromones are attractive to species other than the target species, including the predators of bark beetles, should be taken into account and pheromone traps should be used in protected areas only with the greatest caution and responsibility.

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