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FLIGHT ACTIVITY, WITHIN THE TRAP TREE ABUNDANCE AND OVERWINTERING OF THE LARCH BARK BEETLE (*Ips cembrae*) IN CZHECH REPUBLIC

ROJENJE, GUSTOĆA I RASPORED POPULACIJE NA LOVNIM STABLIMA I PREZIMLJAVANJE ARIŠEVOG POTKORNJAKA (*Ips cembrae*) U ČEŠKOJ

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Abstract

The increasing threat to forests from the gradual increase in *Ips cembrae* abundance necessitates more precise information concerning its ecology, monitoring, and control.

Cembräwit® pheromone traps and trap trees were used to evaluate *I. cembrae* flight activity and infestations, respectively, during outbreaks in 2007–2009 in the Czech Republic. Emergence of the next generation was also evaluated from trap logs and forest litter.

Flight activity was detected from late April to early July and lacked clear peaks. Trap trees were invaded evenly along the entire profile of the trunk. Parent galleries were longer and numbers of larval galleries were fewer in the upper parts than in the lower parts of trap tree trunks. Gradual fly-out of beetles from infested larch wood under laboratory conditions during winter confirmed that adults, larvae, and pupae of the offspring generation overwinter in such wood. The trapping of beetles emerging from litter confirmed that *I. cembrae* also overwinters in the litter near the trees where development was completed.

KEY WORDS: *Ips cembrae*, pheromone-baited trap, trap tree, flight activity, dispersion, overwintering

Introduction
Uvod

The large larch bark beetle, *Ips cembrae* (Heer, 1836), occurs in Europe (Austria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Hungary, Great Britain, Italy, England, Wales, Scotland, Netherlands, Poland, Romania, Serbia and Montenegro, Slovenia, Slovakia, Sweden, Switzerland, and Ukraine) and Central Russia (OEPP/EPPO 2005). The natural distribution of *I. cembrae* was incorrectly indicated to include eastern Asia (Postner 1974), where it was confused with *Ips subelongatus* Motschulsky, 1860 (Stauffer al. 2001, Zhang et al. 2007). Other publications also confused the two species, i.e., the publications indicated

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that they described *I. cembrae* but they actually described *I. subelongatus* (Terasaki et al. 1987, Yamaguchi et al. 1989, Zhang et al. 1992, Suzuki and Imada 1993, van der Westhuizen et al. 1995, Yamaoka et al. 1998, Zhang et al. 2000).

The main host for *I. cembrae* throughout the area of its distribution, from the lowest altitudes to the subalpine zone, is the European larch (*Larix decidua* Mill.) (Postner 1974). The beetle occasionally colonizes Norway spruce (*Picea abies* (L.) Karsten) (Pfeffer 1989). An infestation on Swiss pine (*Pinus cembra* L.) reported by Eichhoff (1871) was revised by Pfeffer (1995), who determined that *Ips amitinus* had been incorrectly identified as *I. cembrae*.

Ips cembrae is generally considered a secondary pest in larch plantations (Grégoire and Evans 2004), breeding in logs (Elsner 1997), wind-blown trunks (Krehan and Steyer 2005), and storm-damaged (Luitjes 1974) and dying trees (Grodzki 2008) (Figure 1). Drought conditions at drier sites may promote the infestation of green trees (Bevan 1987). In such cases, *I. cembrae* breeds and subsequently acts as a primary pest on healthy trees and can threaten young and old stands in lower and medium altitudes (Grodzki and Kosibowicz 2009). *I. cembrae* can also damage apparently healthy larch trees when it increases to large numbers, in which case defoliation can result from maturation feeding by young beetles on thin twigs in the crowns or from regeneration feeding of older beetles in thin trunks or thicker branches (Postner 1974, Krehan and Cech 2004).

Ips cembrae is considered a serious pest in some European countries (Grégoire and Evans 2004). Short-term outbreaks were triggered in central Europe by extreme drought in 2003 (Krehan and Cech 2004, Knížek and Zahradník 2004, Stratmann 2004). In Poland, its breeding was promoted by wood left by the thinning of young larch forests (Hutka 2006). While wood infested by *I. cembrae* peaked in the Czech Republic in 2006 and then declined, the quantity of wood damaged by bark beetles in Poland increased six-fold between 2006 and 2007 (Grodzki and Kosibowicz 2009). Outbreaks are known from the past, e.g., *I. cembrae* occurred on spruce following a *Lymantria monacha* (Linné, 1758) outbreak during the 1920s in central Europe (Pfeffer 1955).

Figure 1. Heavily attacked larch trees by *Ips cembrae* (A), dense galleries under the loose bark (B), newly formed maternal galleries with egg chambers in the beginning of the attack (C)

Slika 1. Jak napad ariševog potkornjaka (*Ips cembrae*) na grupi ariševih stabala (A), gusto premrežen galerijski sustav ispod lako odlupljive kore (B), svježe formirani materinski hodnici s vidljivim udupkama u kojima su ženke odložile jaja.

The ecology of *I. cembrae* differs in some details from that of other *Ips* species (Postner 1974). The ecology and control of this beetle in central Europe, however, has been the subject of only a few recent studies (Hutka 2006, Grodzki 2008, Grodzki and Kosibowicz 2009).

The aim of the research described in this report was to define: the period of *I. cembrae* flight activity in central Europe; the distribution of *I. cembrae* in time and space on trap trees; and the *I. cembrae* overwintering locations.

Materials and methods
Materijal i metode rada

the research was carried out near the villages of Slezské Rudoltice (50°12'37.827"N, 17°38'52.579"E) (2007–2008) and at Útěchov (49°17'12.646"N, 16°37'15.632"E) (2008–2009) in the eastern Czech Republic. At the Slezské Rudoltice locality, we selected a 1.55-ha forest stand that was 56 years old and had a closed canopy; the larch, which represented 90% of the trees in the Slezské Rudoltice stand, had an average $d_{1.3}$ of 23 cm and an average height of 23 m. At the Útěchov locality, we selected a 7.02-ha forest stand that was 88 years old and had a closed canopy; the larch, which represented 44% of the trees in the Útěchov stand, had an average $d_{1.3}$ of 29 cm and an average height of 27 m.

At Slezské Rudoltice, the seasonal period of *I. cembrae* flight activity was determined by trapping beetles using Theysohn® slot barrier traps and Cembräwit® lures. Five traps were placed 10 m apart along the stand edge in 2007 and 2008. Lures were added to traps in mid-April, just before the beginning of emergence, and were renewed 8 weeks later. The traps were inspected every 7–10 days from mid-April until the end of August in both years.

Six sets of trap trees (three sets at each locality) were used to estimate changes in *I. cembrae* abundance in wood from spring to summer. Each trap tree was a healthy larch that was cut about 0.5 m above the soil and left in place on the soil surface. Sets 1–3 were in the Slezské Rudoltice stand and were deployed from April to June in 2007 (seven trap trees), from April to June in 2008 (eight trap trees), and from July to August in 2008 (five trap trees). Sets 4–6 were in the Útěchov stand and were deployed from April to June in 2008 (three trap trees), from April to June in 2009 (three trap trees), and from July to August in 2009 (three trap trees). The trap trees were 10–15 m apart and were located along the edge of the stand if cut late in March (sets 1, 2, 4, and 5) and within the stand if cut late in June (sets 3 and 6). Four sections were designated on each trap tree according to the method of Grodzki (2004). The first section (bottom) was located from 0.0 to 0.5 m from the bottom of the tree; the second section (stem) was located midway between the bottom section and the beginning of the crown; the third section (middle) was located at the beginning of the crown; and the fourth section (crown) was located in the centre of the crown. Change in *I. cembrae* abundance was determined by counting the number of entry holes every 7 to 10 days in one strip (0.1 × 1.0 m) on the upper part of each section. Each entry hole was marked with a pin to facilitate counting.

We determined how position in the trap tree affected oviposition and larval development. For the four sections of each of three traps trees at Útěchov in 2008, we determined the number of galleries, the length of maternal galleries, the length of the 10 longest larval galleries, and the numbers of larval galleries.

To determine whether *I. cembrae* completed development and overwintered in trap trees, five 0.7-m-long logs (Σ 20) were cut from the upper part of each of four trees at Slezské Rudoltice in August 2008 and were left in place until they were moved to the laboratory.. At the end of September, October, November, and December 2008, and of January 2009, four logs (one from each tree) were placed in emergence traps in the laboratory (20 °C, 16 h of light and 8 h of dark); emergence was assessed every 14 days until the end of March 2009.

To determine whether *I. cembrae* completed development and overwintered in the forest litter, 10 emergence traps (each covering an area of 0.5 m^2) were placed in pairs on the litter near the base of each of five trap trees at Slezské Rudoltice at the end of March 2009; the pairs of traps were 10 m apart, and the number of beetles in the traps was assessed every 14 days until the end of June 2009.

Numbers of entry holes and number of beetles trapped were compared with nonparametric tests (Mann-Whitney U test, Kruskal-Wallis test, median test) performed with Statistica 9.0.

Results
Rezultati

Period of flight activity

A total of 18,258 beetles were captured in the five pheromone traps at Slezské Rudoltice in 2007 and 2008. Flight activity began in the second half of April and ended at the beginning of August (Figure 2). Significantly more beetles were trapped in 2007 than in 2008 (U=1075.5**).

Seasonal increase in abundance in infested wood

The number of entry holes on trap trees at Slezské Rudoltice dropped significantly from spring 2007 to summer 2008 ($H[2, N=92] = 57{,}48^{****}$; Table 1). At Útěchov, the number of entry holes on trap trees increased significantly from spring 2008 to summer 2009 ($H[5, N=152] = 94.26^{***}$; Table 1).

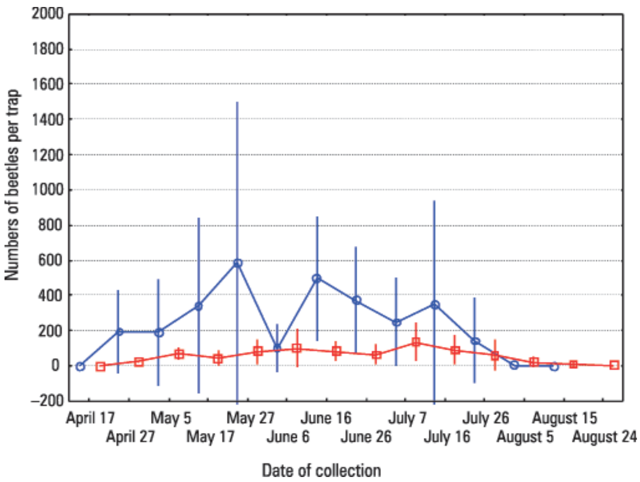

Figure 2. Seasonal flight activity of *Ips cembrae* based on the number of beetles captured in slot barrier traps at Slezské Rudoltice in 2007 (blue circles and line) and 2008 (red squares and line). Symbols indicate the mean numbers per trap, and bars indicate the ranges.

Slika 2. Prikaz rojenja Ips cembrae temeljen na ulovu imaga barijernim klopkama na lokaciji Slezské Rudoltice 2007. (plavo) i 2008. godine (crveno). Simbolima su označeni srednji ulovi po klopki, dok vertikalne linije preikazuju raspone ulova.

In all trap trees, all beetles were identified as *I. cembrae*, and all galleries were determined to have been formed by *I. cembrae*. Mean numbers of entry holes per dm^2 of trap tree were equal in individual years at Slezské Rudoltice (set 1: H [6, N=28] =13.72, p>0.01; set 2: H [7, N=32] =10.77, p>0.10; set 3: H [4, N= 20] =9.14, p>0.05) as well as at Útěchov (set 4: H [2, N=12] =1.93, p>0.10; set 5: H [2, N=12] =7.64, p >0.01; set 6: H [2, N=12] =3.51, p>0.10) (Table 1).

Table 1. Total number of *Ips cembrae* entry holes (per dm^2) on six sets of trap trees at two localities (values in the last column followed by different letters are significantly different according to the Kruskall-Wallis test at p <0.01).

Tablica 1 Ukupan broj ulaznih otvora *Ips cembrae* (po 1dm^2) na 6 grupa lovnih stabala (analiza Kruskall Wallis testom, signifikantno različite vrijednosti pri p <0.01 označene su različitim slovima a i b).

Set Grupa	Locality Lokalitet	Year Godina	Period Razdoblje	Number of trap trees Broj lovnih stabala	Number of entry holes (per dm^2±SD) Broj ulaznih otvora (na dm^2±SD)
1	Slezské Rudoltice	2007	April-June	7	3.2±1.4a
2	Slezské Rudoltice	2008	April-June	8	1.4±0.6b
3	Slezské Rudoltice	2008	July-August	5	0.3±0.4b
4	Útěchov	2008	April-June	3	2.3±0.6a
5	Útěchov	2009	April-June	3	3.4±1.2a
6	Útěchov	2009	July-August	3	5.1±1.8a

At Slezské Rudoltice, beetles of the overwintering generation infested trap trees continually from mid-May, the offspring generation infested trap trees from mid-July, and the number of entry holes increased (set 1: H [7, N = 3520] = 754.1***; set 2: H [6, N = 1400]=57.71***) (Table 2). At the Útěchov, beetles of the overwintering generation sought trap trees from mid-April, and the number in trap trees gradually increased in 2008 (H [10, N = 1320] = 827.72***) and 2009 (H [10, N = 1320]=457.93 ***) (Table 3). Entry holes were also observed on the 3-cm-thick branches of the trap trees of set 1.

Table 2. Abundance of *Ips cembrae* entry holes (per dm^2) in trap trees from spring to summer at two localities.

Tablica 2 Gustoća ulaznih otvora (intenzitet ubušivanja) *Ips cembrae* (na 1dm^2) u razdoblju proljeće ljeto na dva lokaliteta.

Locality Lokalitet	Year Godina	April 10	April 18	April 26	May 7	May 17	May 24	May 31	June 6	June 13	June 21
Slezské Rudoltice*	2008	0±0	0±0	0±0	0±0	0.3±0.6	0.4±0.7	0.7±0.9	0.8±1.0	1.0±1.0	1.0±1.1
Útěchov	2008	0±0	0±0	0.8±0.7	1.2±0.8	1.5±0.5	1.9±1.0	2.1±1.1	2.2±1.1	2.3±1.0	2.3±1.1
Útěchov	2009	0±0	0±0	0.3±0.5	0.5±0.6	0.7±0.3	1.4±1.3	1.7±1.5	1.9±1.6	2.1±1.7	2.3±2.0

*(July 7: 0.0±0.0 entry holes per dm^2; August 29: 0.3±0.6 entry holes per dm^2)

Table 3. Abundance of *Ips cembrae* entry holes (mean ± SD) in one strip (0.1 × 1 m) on each of four sections per trap tree at two localities.

Tablica 3 Gustoća ulaznih rupa *Ips cembrae* (srednja vrijednost ± SD) na 4 uzoraka kore (pridanak-deblo-sredina-krošnja) dugačkim 1 m i širokim 1 dm, skidanim sa lovnih stabala na dva lokaliteta.

Set Grupa	Locality Lokalitet	Year Godina	Period Razdoblje	Bottom Pridanak	Stem Deblo	Middle Sredina debla	Crown Deblovina u krošnji	Z values of Kruskal-Wallis test Z vrijednosti Kruskal-Wallis testa
1	Slezské Rudoltice	2007	April-June	35.1±7.1	40.9±12.9	29.6±12.8	21.6±8.9	9.06, p>0.01
2	Slezské Rudoltice	2008	April-June	7.6±1.7	14.0±1.7	14.3±1.3	18.9±1.6	12.56, p<0.01
3	Slezské Rudoltice	2008	July-August	1.0±1.0	1.8±3.5	6.2±5.1	2.6±1.7	5.21, p>0.01
4	Útěchov	2008	April-June	23.3±9.0	17.3±3.5	24.0±3.6	28.0±5.0	5.69, p>0.01
5	Útěchov	2009	April-June	19.5±19.1	39.5±0.6	39.5±3.6	36.5±2.1	c^2=3.00, p>0.01
6	Útěchov	2009	July-August	64.7±23.5	46.3±15.1	60.7±9.8	33.0±8.6	c^2= 6.67, p>0.01.

Table 4. Length of *Ips cembrae* maternal galleries as affected section (bottom, stem, middle, or crown) and numbers and lengths of larval galleries (mean ± SD) as affected by section and location relative to the maternal gallery. Values in a row followed by different letters are significantly different.

Tablica 4 Dužina materinskih hodnika, broj i dužina larvalnih hodnika (±SD) *Ips cembrae* ovisno o mjestu sakupljanja na lovnom stablu. Vrijednosti označene različitim malim slovima u retku predstavljaju signifikantno različite vrijednosti (pri p<0.001).

	Bottom Pridanak	Stem Deblo	Middle Sredina debla	Crown Deblovina u krošnji	Z values of Kruskal-Wallis test Z vrijednosti Kruskal-Wallis testa
Length of maternal galleries (cm) Duljina materinskih galerija	10.7±1.6a	11.5±1.9b	13.0±1.5bc	14.5±1.4c	38.64, p<0.001
Number of larval galleries (per dm^2) Broj larvalnih galerija (na dm^2)	39.3±6.3a	30.9±3.2b	24.0±2.4bc	24.0±1.3bc	49.32, p<0.001
Length of larval galleries (cm) Duljina larvalnih galerija (cm)	4.0±0.2a	4.4±0.4bc	4.7±0.3bc	5.3±0.2b	58.30, p<0.001

The abundance of *I. cembrae* entry holes was similar on the four sections of trap trees at Slezské Rudoltice for set 1 and set 3 but was lower in the bottom section than in the other sections in set 2 (Table 3). The abundance of *I. cembrae* entry holes was similar on the four sections of trap trees at Útěchov in all cases (Table 3).

Maternal gallery length and related parameters

Maternal gallery length and other related parameters were measured for trap trees in set 4 at Útěchov. Maternal gallery length was significantly longer in the crown and middle sections than in the stem and bottom sections (Table 4).

Larval galleries were significantly longer in the crown and middle sections than in the stem and bottom sections. Numbers of larval galleries were lowest in the crown section (Table 4).

Infested wood and forest litter as overwintering sites

The total number of beetles that emerged from Slezské Rudoltice logs in the laboratory was unaffected by the month in which the logs were moved to the laboratory (September–January) ($\chi^2 = 2.28$, p>0.10) (Figure 3). For all five months, *I. cembrae* beetles began to emerge within 2 weeks after being moved from the field to emergence traps in the laboratory. Emergence ended after 6 weeks (Figure 2).

Numbers of *I. cembrae* beetles collected by the 10 emergence traps that were placed by on the forest litter in March 2009 at Slezské Rudoltice were high (49.3±20.2 adults·m^{-2}). Beetles were first observed in the traps at the beginning of May 2009. Trapping peaked in the second half of May. The last beetles were trapped in the first half of June.

Discussion
Rasprava

In the current study, spring emergence of *I. cembrae* in central Europe began at the end of April, which agrees with published data obtained at lower and middle altitudes (Postner 1974, Grodzki and Kosibowicz 2009). Flight activity was continuous and lacked clear peaks. Offspring beetles emerged in late June/early July, when pupae and callow adults were found on trap trees. *I. cembrae* usually has two

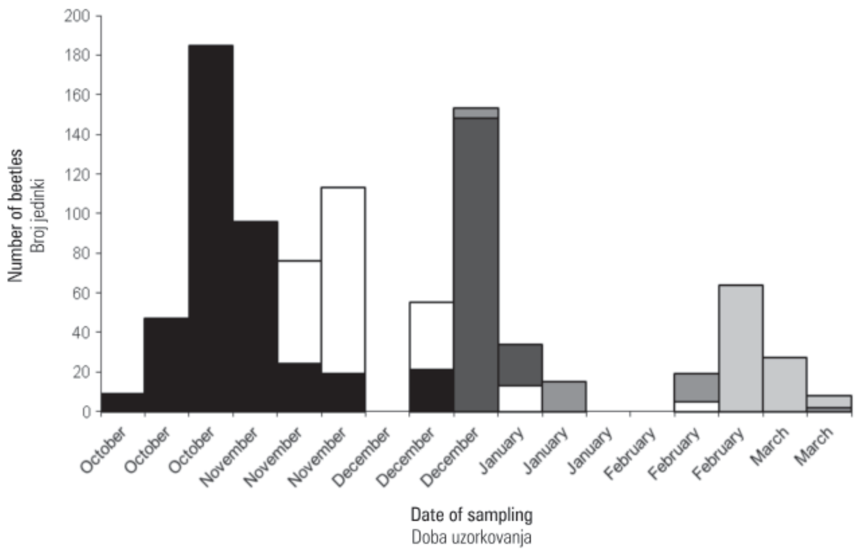

Figure 3. Emergence of *Ips cembrae* beetles from logs that were infested in the field and moved to the laboratory in September (black), October (white), November (dark grey), December (medium grey), and January (light grey).

Slika 3. Izlazak imaga *Ips cembrae* u laboratoriju iz lovnih stabala izloženih napadu na terenu i prenešenih u laboratorij u rujnu (crno), listopadu (bijelo), studenom (tamno sivo), prosincu (sivo) i siječnju (svjetlo sivo).

generations per year (Šrot 1976, Michalski and Mazur 1999, Krehan 2004, Knížek 2006, Zúbrik et al. 2008, Grodzki and Kosibowicz 2009), but the number of generations depends on the weather (Krehan 2004) and altitude (Grodzki and Kosibowicz 2009). Some re-emerging beetles of the overwintering generation may fly in June. The offspring generation adults have a maturation feeding period in late summer, either in the branches of younger trees (as observed in the current study) or near the larval galleries if fresh bark is still present (Postner 1974).

Using emergence traps in spring, we collected *I. cembrae* beetles that evidently overwintered in the forest litter. In the case of *I. typographus*, 80% of adults overwinter in forest litter directly under or near the infested trunk (Zumr 1985). According to the observed flight activity, overwintering *I. cembrae* beetles begin to be active in May.

The current report demonstrates the presence of overwintering *I. cembrae* beetles in logs and their immediate activity after being transferred to the laboratory. Adults overwinter in tunnels resulting from maturation feeding under the thicker bark of trunks lying on the ground or, more commonly, in the forest litter (Schneider 1977). The protracted emergence of adults from study logs indicates that part of the population overwinters as larvae and pupae. This is consistent with the previous report that *I. cembrae* may, in the case of incomplete development, overwinter as larvae or pupae (Postner 1974). Overwintering survival likely depends on temperature and other aspects of the winter weather.

The proportion of the *I. cembrae* population overwintering in the imaginal stage and the place of overwintering depend on the weather in autumn and on the possibility of completing development under bark before winter. Part of the early breeding beetles will leave the place of development and overwinter in forest litter or stay at the feeding site. For that reason, some findings document overwintering at the feeding site (Krehan and Cech 2004) and others document overwintering in forest litter (Schneider 1977, Grodzki and Kosibowicz 2009). The tendency to overwinter in forest litter is clear, and its explanation lies in the lower mortality that occurs in the litter than in tree trunks [see *Ips typographus* (Linné, 1758)] (Wermelinger 2004).

I. cembrae abundance was generally similar in different sections of traps trees but was occasionally higher in the crown than in the lower sections. Relative to lower sections, crown sections had longer maternal galleries with fewer larval galleries (Table 3). In *I. subelongatus*, the number of egg niches and adult offspring produced per gallery decline exponentially with infestation density (Zhang et al. 1992). These exponential relationships were attributed to intraspecific competition between adult females for breeding space and between larvae for limited food resources. Because *I. cembrae* abundance per unit area of bark was generally similar among sections in the current study, the beetles in the higher sections would have experienced increased competition for food because the phloem is thinner in higher than in lower sections. To reduce this intraspecific competition and to provide adequate food for larvae, females apparently deposit fewer eggs and at greater spacing in the crown, resulting in longer larval galleries in the crown than in lower sections.

Control of *I. cembrae* is identical to that for other bark beetles that attack conifers. In European countries, the intensity of control efforts varies depending on the severity of the damage, and control methods include: (i) silviculture management via clear cutting, selective thinning, and silvicultural selection; (ii) chemical treatment of felled trees; (iii) trapping with trap trees, trap logs, pheromone traps, and baited slash; and (iv) monitoring by pheromone attractants, trap trees/logs, visual survey, and questionnaire (Grégoire and Evans 2004).

At Slezské Rudoltice, trapping of adults in pheromone and trap trees decreased substantially in 2008 as a result of implemented protective measures (pheromone traps, trap trees, timely elimination of infested trees) in 2007.

Traps from trees of $d_{1.3}$ 30–45 cm prepared in our study in the second half of March on sunlit places became heavily infested with *I. cembrae*. Trap trees can remain active until the first pupae occur, because invasion continued even when there was a great abundance of entry holes. In addition, Elsner (1997) showed that timber from the April felling was infested first and more heavily than timber felled later in the season. Under laboratory conditions, however, *I. cembrae* breeding success in larch timber was greatest on trees felled during February–March (Elsner 1997).

The main problems in the control of *I. cembrae* are: (i) the beetle can develop on branches (our results, see also Knížek 2006), (ii) a considerable part of the population can overwinter in forest litter (our results), and (iii) trees processed by harvesters are not protected against infestation because they frequently retain their bark (Watzek and Niemeyer 1996).

Regarding the first problem, given that *I. cembrae* can develop on branches as small as 3 cm in diameter, logging residues and brushwood (burning and chipping) must be disposed of so that this material cannot be used for feeding or reproduction. Unprocessed logging waste from thinning in young stands can also be invaded and should be disposed of.

With respect to problem 2, because *I. cembrae* can overwinter in forest litter, removal of infested trees may not be sufficiently effective in decreasing the population density. Extension of the vegetation period by favourable temperatures could increase the proportion of adults overwintering in forest litter and thereby increase the threat of larch infestation in spring.

Finally, larch harvested by modern harvesters can be colonized by *I. cembrae*—or at least those parts having thick bark can be colonized—and appropriate control (bark removal) is necessary. When thinning wood with bark is left in the stand, infestations may become severe; to prevent this, foresters should create spatial or temporal gaps between harvesting and thinning (Watzek and Niemeyer 1996).

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Sažetak

Na cijelom arealu, od najniže nadmorske visine do subalpinskog pojasa, glavni domaćin potkornjaku *Ips cembrae* je europski ariš, *Larix decidua* Mill. Samo ponekad ova vrsta naseljava i smreku, *Picea abies* (L.) Karsten. Osnovna bionomija potkornjaka *I. cembrae* razlikuje se od ostalih vrsta roda *Ips* i više-manje je poznata. Unatrag nekoliko godina publicirano je tek nekoliko istraživanja vezano za bionomiju i zaštitu šuma od ovog štetnika. Cilj ovog rada je stjecanje novih saznanja oRojenju, kroz pokus korištenja sintetskih mamaca; kornjaši *I. cembrae* su se lovili pomoću Theysohn® naletnih klopki te korištenjem feromonskih pripravaka Cembräwit®;

Prostornoj i vremenskoj distribuciji kornjaša na lovnim stablima; u drugom dijelu ožujka zdrava stabla ariša obarana su radi postavljanja prvog seta lovnih stabala u razmaku od 10–15 m na rubovima sastojina. Krajem srpnja drugi set postavio se unutar sastojine. Ulazne rupe evidentirane su na četiri sekcije svakog lovnog stabla;

Prezimljavanju kornjaša; pet trupčića dužine 0,7 m dobivene iz gornjeg dijela četiriju lovnih stabala. Četiri trupčića iz svakog lovnog stabla postavljeni su na pet mjesta u ariševoj sastojini. Od kraja rujna u mjesečnim intervalima (listopad–siječanj) setovi sekcija postepeno su se premještali u kaveze u laboratoriju.

Ukupna sanitarna sječa koja se u Češkoj provodi zbog napada potkornjaka *I. cembrae* mala je u odnosu ukupnu sanitarnu sječu radi potkornjaka. S druge strane, u nekim europskim zemljama takvi napadi predstavljaju ozbiljan problem. Primjerice ekstremna suša u 2003. godini uzrokom je gradacija u Srednjoj Europi. Drvna masa zaražena potkornjacima *I. cembrae* u Češkoj kulminirala u 2006. godini sa trendom opadanja (slika 1, tablica 1), dok je u Poljskoj količina potkornjacima zaražene drvne mase povećana za šest puta između 2006. i 2007. godine.

Potkornjak *I. cembrae* najčešće ima 2 generacije godišnje (Slika 2). Proljetno izlaženje iz zimovališta počinje na nižim i srednjim nadmorskim visinama početkom svibnja, rjeđe krajem travnja. Potkornjaci druge generacije izlaze na prijelazu lipnja i srpnja. Nova generacija imaga obavlja dopunsko žderanje u kasno ljeto u granama mladih stabala ili u blizini larvalnog hodnika gdje ima svježe kore. Nakon dopunskog žderanja imaga prezimljavaju dijelom u hodnicima ispod tanke kore oblovine ili češće u šumskoj stelji.

U slučaju kada se ne stignu potpuno razviti, prezimljavaju kao ličinka ili kao kukuljica. Tada njihovo preživljavanje ovisi o vremenskim prilikama u zimi. Razmjer populacije koja prezimljava u stadiju imaga i njihova niša prezimljavanja ovisi o vremenskim prilikama u jesen i uvjetima koji vladaju kada završavaju razvoj. Dio potkornjaka koji rano završi razvoj napušta to mjesto i prezimljava u šumskoj stelji ili ostaje na mjestu gdje se hrani. Ispitali smo prisutnost prezimljujućih potkornjaka u trupčićima u zimi i njihovu aktivnost nakon što su premješteni u laboratorijske uvjete (slika 3). Produženo vrijeme napuštanja pokusnih trupčića potvrdilo je kako dio populacije prezimljuje kao larva i kukuljica. Potkornjaci koji prezimljavaju u stelji to čine blizu stabala na kojemu završavaju svoj razvoj.

Potkornjaci prve generacije naseljavaju lovna stabla kontinuirano od polovice svibnja, a druge generacije od polovice srpnja (tablica 2). Naseljavanje donjih dijelova stabla bilo je jednoliko u gotovo svim slučajevima, a samo je ponekad veća abundanca nađena u gornjem dijelu.

Duži materinski hodnici s manjem brojem položenih jaja i larvalnih hodnika (tablica 3) karakteriziraju sekcije iz gornjeg dijela debla lovnog stabla. Taj je odnos eksponencijalan, što se tumači interspecifičnom kompeticijom na prostoru za polaganje jaja između ženki i ograničenog resursa hrane između ličinki. Kako je gustoća hodnika na lovnim stablima bila jednolika, ženke su u tanjem floemu reagirale manjim brojem položenih jaja i povećavanjem udaljenosti između materinskih hodnika. Na taj način larvama su omogućile izradu dužih larvalnih hodnika i pristup adekvatnoj hrani.

Kontrola potkornjaka *I. cembrae* istovjetna je sa drugim vrstama potkornjaka koji dolaze na četinjačama i obavlja se:

(i) uzgojnim zahvatima: čistom sječom, selektivnom proredom, selekcijom;
(ii) kemijskim tretiranjem oborenih stabala;
(iii) mjerama izlova: lovnim stablima, lovnom oblovinom, klopkama, lovnom sječkom;
(iv) monitoringom uz pomoć feromonskih atraktanata, lovnih stabla/oblovine, vizualnim nadzorom, upitnicima.

U Europi se koriste četiri tipova feromonskih pripravaka: Cembräwit® (www.witasek.com), Cemprax (Shell Agrar Ltd.) (www.witasek.com), Cemsan (www.fluegel-gmbh.de) i Cembrodor. Feromonski pripravak Cembräwit® koristi se za ciljani ulov *I. cembrae*; tijekom pokusa i pregledavanjem ulova feromonskih klopki nisu zabilježeni ulovi neciljane floemofaune.

U terenskim pokusima, drvo posječeno u travnju prvo jer bilo napadnuto i intenzivno naseljavano. Za vrijeme pokusa lovna stabla promjera $d_{1.3}$ 30–45 cm pripremljena u drugoj polovici ožujka na osunčanoj poziciji bila su intenzivno napadnuta, a lovna stabla ostala su aktivna sve do prve kukuljice. Bez obzira na veliku abundancu ulaznih rupa, naseljavanje lovnih stabala nije se zaustavilo. Moguće je i da su se prethodno ubušeni potkornjaci ponovno ubušivali.

U usporedbi s drugim europskim vrstama potkornjaka roda *Ips*, evidentan je problem zaštite protiv *I. cembrae* iz razloga što se: (i) razvija u granama; (ii) određen dio populacije može prezimiti u šumskoj stelji (kao i druge *Ips* vrste), i (iii) stabla obrađena harvesterom nisu zaštićena protiv napada.

I. cembrae se razvija u granama koje su od 3 cm promjera. To se mora uzeti u obzir prilikom poduzimanja zaštitnih mjera. Uz to treba uništiti drvne ostatke i izbojke (paljenjem i malčiranjem) kako ne bi došlo do žderanja i rasploda štetnika u tom materijalu. Prorjedama u mladim sastojinama nezbrinuti drveni ostaci također budu napadnuti.

Kako *I. cembrae* može prezimiti u šumskoj stelji, uklanjanje stabala napadnutih potkornjacima, vjerojatno nije dovoljna učinkovita mjera u smanjivanju gustoće populacije. Produljen vegetacijski period te povoljne temperature povećavaju broj imaga koji prezimljuju u šumskoj stelji, što intenzivira opasnost od napada u proljeće.

Ariš nakon obrade modernim harvesterima u proljeće može biti uspješno koloniziran jedinkama *Ips cembrae*, ponajprije dijelova s tankom korom, što znači da je zaštita i dalje potrebna. Kada prorjedom materijal dodatno ostaje u sastojini, napad postaje ozbiljniji, zbog čega treba ostaviti prostorni ili vremenski razmak između sječe i prorjede.

KLJUČNE RIJEČI: *Ips cembrae*, lovno stablo s feromonskim pripravkom, lovno stablo, rojenje, disperzija, prezimljavanje