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SHORT COMMUNICATION

Evaluating the effectiveness of installations for monitoring and control of *Ips cembrae* (Heer)

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ABSTRACT

The large larch bark beetle *Ips cembrae* (Heer) is the primary pest of *Larix decidua* Mill., and local outbreaks have been recorded in Europe. In 2020, the effectiveness of trap trees, tripods, poisoned tripods, and slots traps against *I. cembrae* was evaluated. The research was carried out at 3 sites with larch monocultures with differing *I. cembrae* population density. All four installations were set up at each study site in 4 replicates. Trap trees and tripods were installed in two series (Series 1 to capture the overwintering generation and Series 2 for summer generations of *I. cembrae*) with the recording of the numbers of nuptial chambers, maternal galleries, and the stage of *I. cembrae* development occurring in the center of all logs forming the tripods and in the 4 control sections in the trap tree. Poisoned tripods were installed and treated with a 1% solution of Vaztak insecticide every month. Both the poisoned tripods and slot traps (Theysohn) were baited with Cembräwit pheromone lure, and the lure was reapplied after 8 weeks.

The poisoned tripods and slot traps were checked at 14 day intervals. The number of *I. cembrae* adults was determined from samples stored in 75% ethanol.

The flight activity of *I. cembrae* (from 15 April-30 September) confirmed the presence of two generations. Trap trees captured a significantly larger number of adults than tripods in both the overwintering and summer generations of *I. cembrae*. Trap trees were infested throughout the trunk profile, while *I. cembrae* did not occur on 26% of tripod logs. We found that *I. cembrae* mostly infested larch trunks from 6 cm in diameter and infestation density increased with increasing trunk diameter. The poisoned tripods captured more adults of both the overwintering and summer generations of *I. cembrae* than the slot traps.

The sex ratio of *I. cembrae* was determined on traps and tripods from the number of maternal galleries on nuptial chambers, while in slot traps and on poisoned tripods it was established by the dissection of captured adults. The number of females on the trap trees and tripods was significantly higher than in the slot traps and on the poisoned tripods. In the slot traps and on the poisoned tripods, the number of females and males was equal. All installations were found to be effective and can be used in forest protection of larch against *I. cembrae*.

KEY WORDS

forest protection, *Larix decidua*, slot traps, trap trees, tripods

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Introduction

The large larch bark beetle *Ips cembrae* (Heer) (Coleoptera, Curculionidae, Scolytinae) is a facultative primary pest of European larch *Larix decidua* Mill. (Postner, 1974; Krehan and Cech, 2004). It may also develop on other European tree species of genera *Pinus*, *Picea* and *Abies* (Jankowiak *et al*., 2007; Holuša *et al*., 2014). During its outbreak, *I. cembrae* attacks healthy and weakened trees in young and old stands at lower and medium altitudes (Krehan and Cech, 2004; Grodzki 2008; Grodzki and Kosibowicz, 2009; Grodzki, 2020). *Ips cembrae* develops under bark in the phloem of larch which includes the maturation feeding of hatched adults and regenerative feeding of older individuals. The source of food can also be live low-diameter branches or fresh logging residues. Infestations of larch by *I. cembrae* can be identified by the altered color of needles, defoliation and tree dieback (Postner, 1974; Grodzki, 2008).

During their development, adults go through a stage of regenerative feeding at the end of maternal galleries or under bark of newly infested trees. After re-swarming, female beetles of *I. cembrae* establish sister broods (Šrot, 1976). The second swarming comes in July (Knížek, 2006; Grucmanová *et al*., 2014; Holuša *et al*., 2014). The hatched beetles of the second generation overwinter in feeding notches or in the litterfall (Schneider, 1977) either as larvae or pupae. In very warm autumn weather, a third generation may be established (Knížek, 2006; Holuša *et al*., 2014). Hot summers can, therefore trigger bark beetle outbreaks (Marini *et al*., 2012). It was found that *I. typographus* flight activity grows with higher temperature (Hinze and John, 2019), but precipitation reduces bark beetles flight activity (Faccoli, 2009).

Trap trees are felled or uprooted healthy trees used to capture bark beetles and interrupt their development cycle (Grégoire and Evans, 2004). Holuša *et al*. (2014) analyzed the infestation of trap trees by *I. cembrae*. Arač and Pernek (2014) and Grucmanová *et al*. (2014) confirmed the effectiveness of Cembräwit pheromone lures using slot traps. Resnerová *et al*. (2020) evaluated the efficiency between trap trees and untreated tripods as well as between slot traps and poisoned tripods in paired tests. None of the authors have yet verified the effectiveness of trap trees, tripods, poisoned tripods and slot traps in capturing *I. cembrae* placed at the same time in the same location in several repetitions. The fact that forest owners can choose between several types of installations to control *I. cembrae* was the impetus for us to compare the effectiveness of these installations. The sex ratio of *I. cembrae* in slots traps was evaluated by Grucmanová *et al*. (2014), and in slot traps and poisoned tripods by Resnerová *et al*. (2020). We wanted to verify the results of sex ratio in slot traps and poisoned tripods and describe the sex ratio in tripods and trap trees.

The aim of the study was to: (*i*) describe flight activity of *I. cembrae*; (*ii*) assess the effectiveness of installations in monitoring and control of *I. cembrae*; (*iii*) find relationships between the infestation density of *I. cembrae* and the diameter of tripod logs, and (*iv*) evaluate the sex index of *I. cembrae* adults in the installations with conditions of differentiated *I. cembrae* population density.

Materials and methods

Study sites. The research was conducted in an area severely affected by industrial emissions in the past, where stands with a dominant share of *Betula pendula* Roth, *Picea pungens* Engelm. and *Larix decidua* were established in the 1980s (Slodičák *et al*., 2008). The installations were placed in front of forest walls of larch monocultures in 4 repetitions at 3 locations (A, B and C) for a total of 12 repetitions. Differences in the population density of *I. cembrae* (Table 1) in the research stands of Děčín Forest District (Fig. 1) were derived from the volume of larch timber cut during salvage felling due to bark beetle infestations in 2019.

Trap trees. Trap trees (N=12) to capture *I. cembrae* adults from the spring generation were felled onto a sunlit place in front of the stand wall on 20 February, 2020 (with diameter at breast height (DBH): 20.4 ±3.6 cm and length: 19.6 ±1.97 m). Trap trees (N=12) to capture the summer generation were felled on 10 June 2020 in partial shade to slow down phloem drying (with DBH: 17.5 ±2.1 cm and length: 19.3 ±1.2 m). Logs with dead phloem were placed under the trap trees to put them 0.3 m above ground level.

Table 1.
Characteristics of study sites in the Děčín Forest District (2020)

Sites	GPS	Altitude m a.s.l.	Age	FSTC[1]	Share of larch [%]	KZ [m^3][2] 2019
A	50.7868556N 14.0619675E	600	41	6K[3]	100	4
B	50.8123056N 14.1225467E	500-510	35	5K[4]	100	45
C	50.8200231N 14.1249444E	460	35	6P[5]	100	137

[1] FSTC – Forest site type complex (Viewegh, 2003)
[2] KZ – wood volume infested by *I. cembrae* in the period from the beginning of August to the end of March of the following year
[3] 5K – acidic soil, 450-650 m a.s.l.; mean annual temperature 5.5-6°C; mean annual precipitation 800-900 mm; growing season 130-140 days
[4] 6K – acidic soil; (500 m on sandstone) 650-950 m a.s.l.; mean annual temperature 4.5-5.5°C; mean annual precipitation 900-1,050 mm growing season 115-130 days
[5] 6P – stagnic soil; 650-950 m a.s.l.; mean annual temperature 4.5-5.5°C; mean annual precipitation 900-1,050 mm; growing season 115-130 days

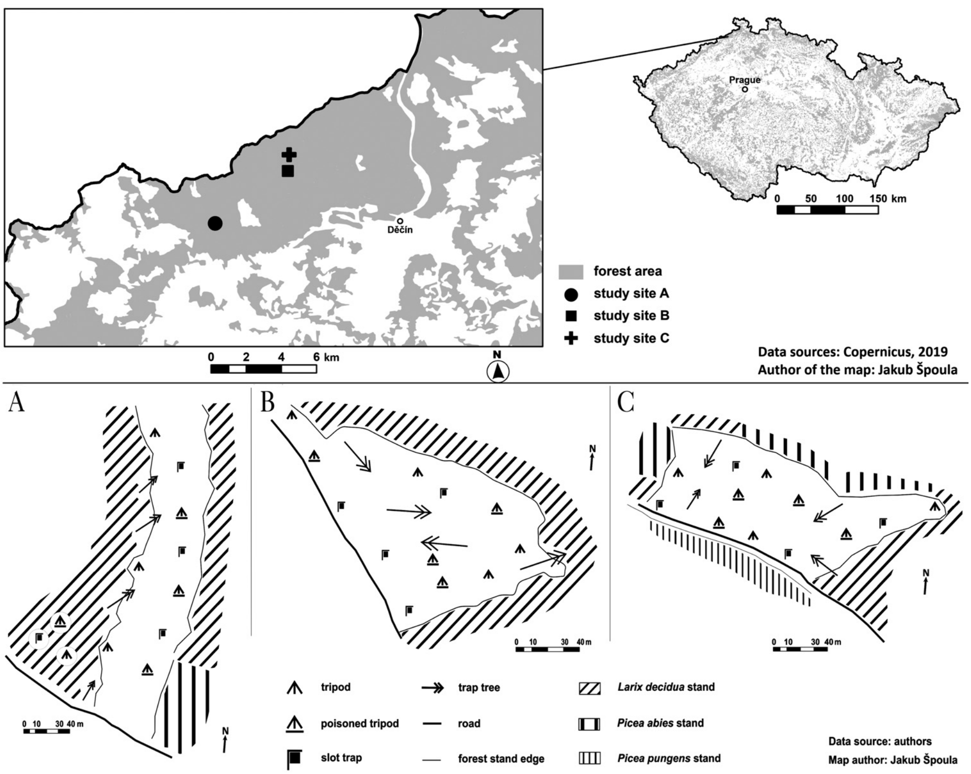

Fig. 1.
Location of study sites and layout of defensive installations (2020, FD Děčín)

Tripods. Felled trees cut into logs and assembled into tripods were tested as an optional method to the trap trees. Tripods were assembled from three to six logs (length=2 m). One tripod was always made from the odd logs and the other one from the even logs of a cut tree. The average diameters of tripod logs in the spring (N=12) and summer (N=12) series were 9.5 ±3.59 cm and 9.5 ±3.18 cm, respectively. Tripods were placed 10 m from the larch forest wall and 15 m from other installations.

Poisoned tripods. Poisoned tripods (PT) (N=12) were constructed from three 2 m long logs (diameter 9-14 cm) firmly fixed at the top. A smooth iron log was inserted into the lower part of the log (diameter 10 mm, length 35 mm) which allowed the placement of the tripod above the terrain level and to place a catchment device (frass sheet) (1×1 m) under it to collect dead bark beetle adults and non-target insects. The bottom of the frass sheet was made of wire netting (1×1 mm) and the top of it was covered with a removable mesh to protect it from birds (Fig. 2). The surface of the logs was treated with insecticide every month from April to September using a 1% solution of Vaztak Active (Agrospol Czech, s.r.o.; active substance: alfa-cypermethrin 50 $g \cdot l^{-1}$) with 5 l being applied to 1 m^3 of wood (Zahradníková and Zahradník, 2019). The poisoned tripods were baited with a pheromone lure (Cembräwit, Witasek) every two months during the growing season (17 April, 11 June and 9 August, 2020). Poisoned tripods were placed 10 m from the larch forest wall and 15 m from other installations.

Pheromone slot traps. Pursuant to ČSN 481000, slot traps (Theysohn) (N=12) were placed 10-15 m in front of the larch stand wall and 15 m from other installations. Dead beetles from the catchment devices were collected every 10 days (17 April-26 September, 2020). The samples

Fig. 2.
Poisoned tripod at study site B

were stored in 75% ethanol solution and the numbers of adults were determined later in the laboratory.

The slot traps were baited with a pheromone lure (Cembräwit, Witasek) every two months during the growing season (17 April, 11 June and 9 August, 2020).

Analysis of trap trees and tripods. Every trap tree was debarked in 4 control sections of the stem profile (stem base, stem center, sub-crown, and crown center). The control sections 0.5 m in length were measured for diameter and debarked. The number of *I. cembrae* nuptial chambers and maternal galleries was recorded on the bark/stem, and infestation density per dm^2 was calculated.

All tripod logs were analyzed in their central section where their diameter was established and the bark removed at a length of 0.5 m around the entire stem circumference. The number of *I. cembrae* nuptial chambers and maternal galleries was recorded on the bark/stem, and infestation density per dm^2 was calculated as with the trap trees.

Sex index. The sex index (i_{sex}) was determined using the following formula:

$$i_{sex} = \frac{N_f}{N_m}$$

where:

N_f – number of females, *i.e.* maternal galleries,

N_m – number of males, *i.e.* nuptial chambers.

The sex index on tripods and trap trees was derived from the numbers of nuptial chambers and maternal galleries in the control sections. In order to determine the sex index of *I. cembrae* in the slot traps and on the poisoned tripods, at least 50 adults of *I. cembrae* were dissected from each sample collected during the growing season.

Climate characteristics. Daily precipitation amounts and average daily temperatures were provided by the climatological station in Sněžník (ČHMÚ, 2020, Ústí nad Labem, Kočkov) (GPS: 14°5'7.2954"E, 50°47'48.5874"N; 569 m a.s.l.). Total precipitation amounts and average, maximum and daily air temperatures were determined for periods between the individual control dates (Fig. 3).

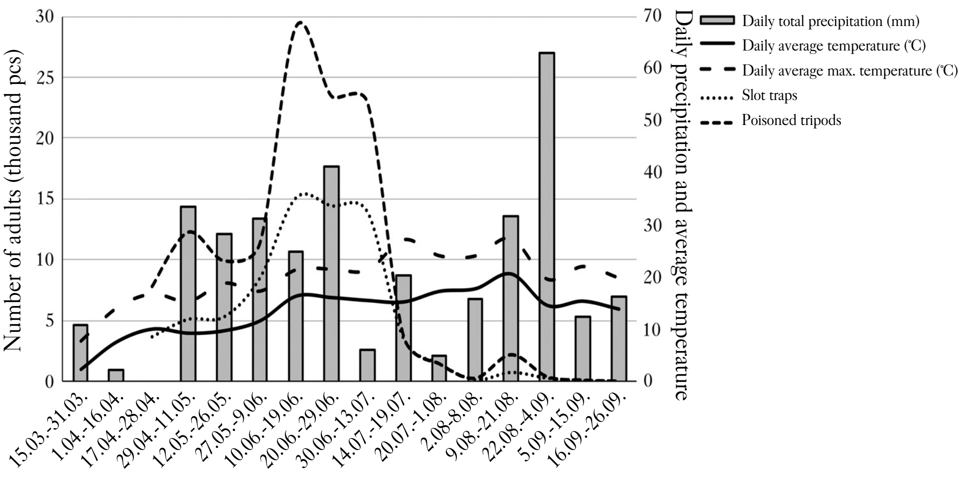

Fig. 3.

Climate conditions and numbers of *I. cembrae* adults captured in slot traps and poisoned tripods at study sites

Data analysis. Data analysis was performed using Statistica version 14.0.0.15 software (TIBCO, 2018). The normality of all datasets was tested using the Shapiro-Wilk test (SW) and based on the results, the datasets were subjected to the Kruskal-Wallis test (KW) to determine differences in the diameters of trap logs, effectiveness of slot traps and poisoned tripods, and the sex index. The T-test (T) was used to find differences in the infestation density of *I. cembrae* on the trap trees and tripods. The Mann-Whitney test (U) was used to find differences in the infestation density of overwintering and summer generations of *I. cembrae* on tripods. The Pearson correlation coefficient and general linear model (GLM) were used to find the correlation between the infestation density of *I. cembrae* and the diameter of tripod logs. All tests were performed at the confidence interval α=0.05.

Results

Flight activity of *I. Cembrae*. The flight activity of *I. cembrae* was recorded from mid-April to mid-September, 2020. The average temperature reached only 2.6°C in March, increased to 7.3°C in the first half of April and then to 10.2°C in the second half of April. *I. cembrae* reacted to average daily temperatures repeatedly exceeding 10°C and average maximum daily temperatures above 15°C with continual flight activity from 16 April onward. In March, the total amount of precipitation reached 47.1 mm, and in April only 3.5 mm. During May and June, the precipitation totals were similar (68.3 and 89.1 mm, respectively) with only a partial influence on swarming culmination. Development to maturity was completed by two generations, each lasting 8-10 weeks with a relatively long swarming period between the generations (culmination 4-5 weeks). Individuals of the second generation appeared in mid-August (Fig. 3).

Despite the relatively low differences in altitude between the sites (60-140 m), the culmination of *I. cembrae* swarming differed according to numbers of captured beetles in the slot traps. At the lowest Site C (460 m a.s.l.), the culmination was recorded in the second half of June, at Site B (500-510 m a.s.l.) it was recorded 10 days later, and the culmination of swarming at the highest located Site A (600 m a.s.l.) was recorded only at the beginning of July. The retrogradation stage was fast and occurred first on Site B (A – 3 weeks, B – 4 weeks, and C – 5 weeks) (Fig. 4).

The number of adults captured on the poisoned tripods indicated that the flight activity of *I. cembrae* was similar at all study sites during spring and summer swarming, including during the length of the culmination period (above the level of 6,000 adults) (Fig. 4).

Trap trees and tripods. No differences were found in the average infestation density of *I. cembrae* (mean+SD) between the spring generation with 6.36 ±3.75 adults/dm^2 and the summer generation with 5.96 ±4.31 adults/dm^2 captured by tripods (SW: W=0.90, p<0.001; U: z=0.445,

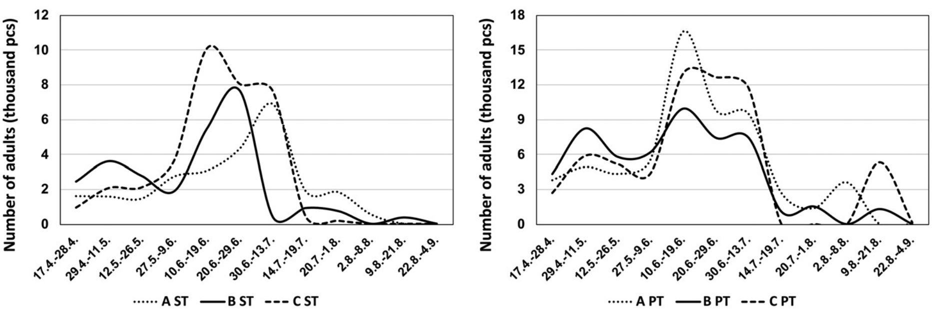

Fig. 4.

Seasonal flight activity of *I. cembrae* based on catchment in slot traps (left) and on poisoned tripods (right) at study sites *p*=0.656). However, the infestation density on sections with diameters <6 cm was significantly lower as compared to other diameter categories (KW: H (3, N=104)=13.43, *p*=0.0038) (Fig. 5).

No differences were found in the average infestation density of *I. cembrae* between the spring generation (11.2 ±3.98 adults/dm^2) and the summer generation (9.5 ±2.54 adults/dm^2) captured by tripods. Thus, a significantly higher capacity to capture adults was demonstrated by trap trees than by tripods (SW: W=0.95, *p*=0.05; T: t=3.77, *p*=0. 0004) (Fig 6).

A positive correlation was found between the diameter of tripod logs and the infestation density of *I. cembrae* (r=0.44, *p*<0.001). The regression model shows that the infestation density of *I. cembrae* on the logs increased with the increasing diameter of the logs (R^2=0.1867, *p*<0.0001) (Fig. 7).

Slots traps and poisoned tripods. Based on the numbers of captured adults, the slot traps (14,003 adults) captured only half the total number of adults captured by the poisoned tripods (30,007 adults). Both in spring and summer the poisoned tripods captured significantly more adults (441 ±456.5 and 2095 ±889.67, respectively) than the slot traps (411 ±337.47 and 1205 ±788.88, respectively) (KW: H (3, N=168)=75.55, *p*<0.0001) (Fig. 8).

Sex index. The number of females captured was significantly higher on tripods and trap trees as compared with those recorded by slot traps and poisoned tripods (SW: W=0.91, *p*<0.0001; KW: H (3, N=89)=64.65, *p*<0.0001) (Fig. 9). The number of females captured with tripods and trap trees did not differ (*p*=0.91) and were also similar with the slot traps and poisoned tripods (*p*=1).

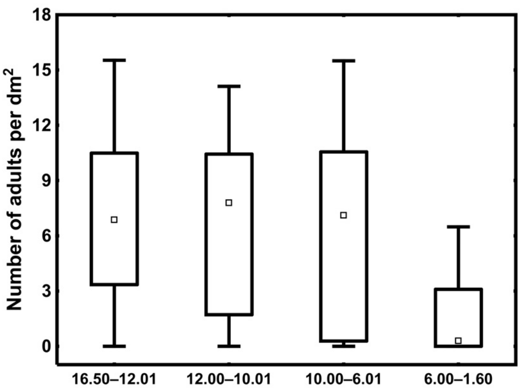

Fig. 5.
Infestation density of *I. cembrae* adults on tripod logs according to their diameter
Squares indicate medians, rectangles indicate interquartile range and whiskers indicate minimum and maximum values

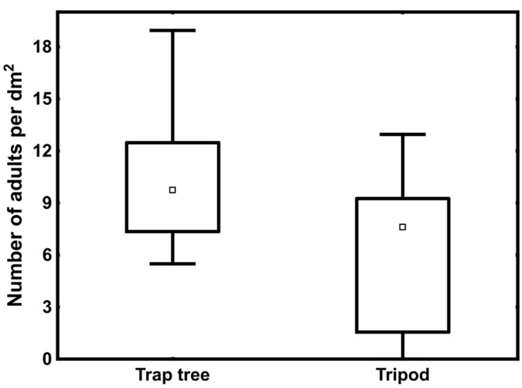

Fig. 6.
Infestation density of *I. cembrae* adults captured on trap trees and tripods
Squares indicate medians, rectangles indicate interquartile range and whiskers indicate minimum and maximum values

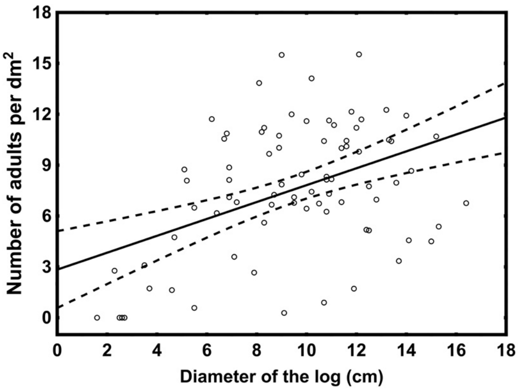

Fig. 7.

GLM model of relationship between the number of adults and the diameter of tripod logs

Line indicates the regression equation and dashed line indicates the confidence interval

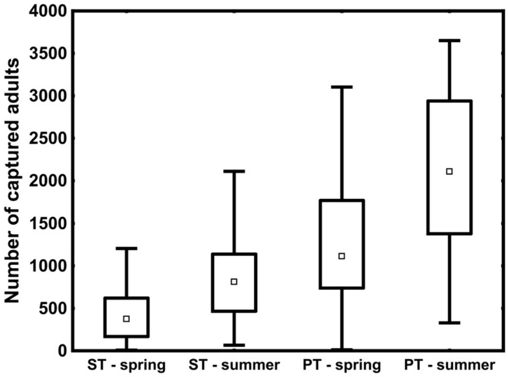

Fig. 8.

Numbers of *I. cembrae* adults in spring/summer slot traps (ST) and poisoned tripods (PT)

Squares indicate medians, rectangles indicate interquartile range and whiskers indicate minimum and maximum values

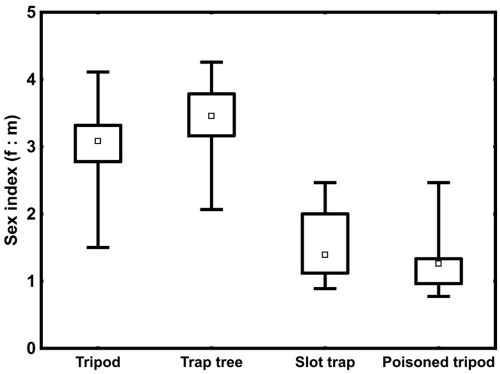

Fig. 9.

Sex index of *I. cembrae* adults on control and defensive installations

Squares indicate medians, rectangles indicate interquartile range and whiskers indicate minimum and maximum values

Discussion

During the growing season, two generations of *I. cembrae* were confirmed (Grucmanová *et al*., 2014; Špoula and Kula, 2023). The peak of flight activity of the overwintering generation of *I. cembrae* is strongly influenced by the conditions of the spring weather. Holuša *et al*. (2014) states the that the peak occurs in the second half of May (275 m a.s.l.), Grucmanová *et al*. (2014) says in July (300-400 m a.s.l.), but based on our evidence of 460-600 m a.s.l., we set the swarming peak in June 2020.

The most effective method for the mitigation of outbreaks of bark beetles is salvage logging of infested trees and their removal from the forest (Grégoire and Evans, 2004). We confirmed the results of Resnerová *et al*. (2020) and Holuša *et al*. (2021) that the most effective method for controlling *I. cembrae* outbreaks is through the installation of trap trees. We demonstrated that trap trees have the same efficiency in capturing the spring and summer generations of *I. cembrae*. The traps were infested by *I. cembrae* throughout the entire course of the experiment, while 26% of tripod sections were not infested. The lower attractiveness of tripods might have been caused by faster phloem drying due to their position above the ground. Compared to tripods, the installation of trap trees is operationally easier, but when they are placed close to the stand wall, there is a risk that healthy trees occurring near the trap trees may be infested (Byers, 1989). Traps and tripods must be removed before the development of a new generation of bark beetles is completed (Grégoire and Evans, 2004). Holuša *et al*. (2021) recommend that trap trees used to capture adults *I. cembrae* should be removed when the infestation density is 0.4 of entry hole per dm^2. In contrast with Resnerová *et al*. (2020), we found that the infestation density of *I. cembrae* increases with increasing wood volume.

The total amount of *I. cembrae* adults captured on the poisoned tripods was two times higher than the amount captured in the slot traps. Their higher effectiveness was due to their significantly greater surface area. The form of the arriving adults is important when they land on the tripod logs. Arriving on the logs of the tripods may be more natural for bark beetles than on black barrier trap (*i.e.* slot traps). We conclude that slot traps should be used only for the monitoring of *I. cembrae* population density in forests. Compared to trap trees, the main advantage of poisoned tripods is their unlimited capacity (Lubojacký and Holuša, 2013, 2014). Due to the negative impact on non-target invertebrates (*e.g.* Juha *et al*., 2012; Jakuš *et al*., 2015), we recommend installing poisoned tripods only during mass outbreaks of *I. cembrae*. Also, it is necessary to determine negative impact of using poisoned tripods against *I. cembrae* in the future.

The sex ratio in new generations of *I. cembrae* is 1:1 (Arač and Pernek, 2014). The increased numbers of females on the trap trees and tripods can be explained by the increased mortality of pioneer male bark beetles in search of suitable host trees (Garraway and Freeman, 1990). Bark beetle females are attracted by aggregation pheromones emitted by males (Schlyter and Birgersson, 1989). In the initial stage of attacking a tree, the number of males and pheromone information is low, so females can fly away to look for trees with more males, which as a rule keeps their ratio at 1:3. In the case of *I. typographus* (Coleoptera, Curculionidae, Scolytinae), it was found that a tree is occupied by the same number of males and females (Paynter *et al*., 1990). Since *I. cembrae* establishes sister broods (Šrot, 1976), it is necessary remove the trap trees and tripods before the bark beetles pupate. A disadvantage for re-swarming females is the necessity of gnawing the entrance hole without the participation of males (Andebrant and Löfqvist, 1988; Vité, 1989) which increases their mortality.

The equal ratio of males and females on the trap trees and tripods was in line with results published by Grucmanová *et al*. (2014) and Resnerová *et al*. (2020).

Conclusions

- The flight activity of *I. cembrae* started in mid-April which had average daily air temperatures above 10°C. The length of the development of spring and summer generations was identical (8-10 weeks) with the flight activity culminating from mid-June to mid-July and with the confirmed occurrence of 2nd generation adults in mid-August.
- All installations were effective in capturing the spring and summer generations of *I. cembrae* and can be applied in forest protection. Trap trees were most effective in capturing *I. cembrae*.

Tripods were less effective than trap trees. Poisoned tripods were more effective than slot traps.

- A positive correlation was found between the infestation density of *I. cembrae* and the diameter of the logs.
- A significantly higher number of females was recorded on the trap trees and tripods than on the poisoned tripods and pheromone slot traps.

Authors' contributions

J.Š. – field, laboratory work, data analysis, creation of map, manuscript preparation and corrections; E.K. – research concept, methodology, field, manuscript supervision.

Conflicts of interest

The authors declare no potential conflicts of interest.

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References

Andebrant, O., Löfqvist, J., 1988. Relation between first and second brood production in the bark beetle *Ips typographus* (Scolytidae). *OIKOS*, 53: 357-365. DOI: https://doi.org/10.2307/3565536.

Arač, K., Pernek, M., 2014. Occurrence and spreading of the large larch bark beetle (*Ips cembrae*) in Croatia and possibilities of monitoring by using pheromone traps. *Šumarski List*, 138: 145-154.

Byers, J.A., 1989. Behavioral mechanisms involved in reducing competition in bark beetles. *Ecography*, 12 (4): 466-476. DOI: https://doi.org/10.1111/j.1600-0587.1989.tb00924.x.

ČHMÚ, 2020. Denní úhrny srážek a průměrně teploty vzduchu v metorologické stanici Sněžník v roce 2020 (Daily precipitation and average temperature in weather station Sněžník in year 2020). Available from: https://www.chmi.cz/historicka-data/pocasi/denni-data/Denni-data-dle-z.-123-1998-Sb [accessed: 20.02.2023].

Copernicus Land Monitoring Service, 2019. Corine Land Cover (CLC) 2018, Version 20. [dataset]. Available from: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018 [accessed: on 20.02.2023].

Faccoli, M., 2009. Effect of weather on *Ips typographus* (Coleoptera Curculionidae) phenology, voltinism, and associated spruce mortality in the Southeastern Alps. *Environmental Entomology*, 38 (2): 307-316. DOI: https://doi.org/10.1603/022.038.0202.

Garraway, E., Freeman, B.E., 1990. The population dynamics of *Ips grandicollis* (Eichhoff) (Coleoptera: Scolytidae) in Jamaica. *Canadian Entomologist*, 122: 217-227.

Grégoire, J.C., Evans, H.F., 2004. Damage and control of BAWBILT organisms – an overview. In: F. Lieutier, K.R. Day, A. Battisti, J.C. Grégoire, H.F. Evans, eds. *Bark and wood boring insects in living trees in Europe, a Synthesis*. Springer, pp. 19-37. DOI: https://doi.org/10.1007/1-4020-2241-7_4.

Grodzki, W., 2008. *Ips cembrae* Heer. (Col.: Curculionidae, Scolytinae) in young larch stands – a new problem in Poland. *Forstschutz Aktuell*, 44: 8-9.

Grodzki, W., 2020. On the vertical distribution of *Ips duplicatus*, *I. cembrae* and some bark- and longhorn beetles (Col.: Curculionidae, Scolytinae, Col.: Cerambycidae) in the Tatra National Park in Poland. *Folia Forestalia Polonica, Seria A*, 62 (2): 68-77. DOI: https://doi.org/10.2478/ffp-2020-0008.

Grodzki, W., Kosibowicz, M., 2009. Materiały do poznania biologii kornika modrzewiowca *Ips cembrae* (Heer) (Col., Curculionidae, Scolytinae) w warunkach południowej Polski. [Contribution to the recognition of the biology of *Ips cembrae* (Heer) (Col., Curculionidae, Scolytinae) in the conditions of southern Poland]. *Sylwan*, 153 (9): 587-593. DOI: https://doi.org/10.26202/sylwan.2009024.

Grucmanová, Š., Holuša, J., Trombik, J., Lukášová, K., 2014. Large larch bark beetle *Ips cembrae* (Coleoptera: Curculionidae, Scolytinae) in the Czech Republic: analysis of population development and catches in pheromone traps. *Forestry Journal*, 60: 143-149. DOI: https://doi.org/10.2478/forj-2014-0015.

Hinze, J., John, R., 2019. Effects of heat on the dispersal performance of *Ips typographus*. *Journal of Applied Entomology*, 144 (1-2): 144-151. DOI: https://doi.org/10.1111/jen.12718.

Holuša, J., Kula, E., Wewiora, F., Lukášová, K., 2014. Flight activity, within the trap tree infestation density and overwintering of the larch bark beetle (*Ips cembrae*) in Czech Republic. *Šumarski List*, 138: 19-27.

Holuša, J., Resnerová, K., Kula, E., 2021. Uplatnění zásad integrované ochrany rostlin proti lýkožroutu modřínovému (*Ips cembrae* (Heer, 1836)) [Application of the principles of integrated pest management against large larch bark beetle (*Ips cembrae* (Heer, 1836))]. Strnady: VÚLHM, 62 pp.

Jakuš, R., Blaženec, M., 2015. Princípy ochrany dospelých smrekových porastov pred podkôrnym hmyzom. Zvolen: Slovenská Akadémia Vied, 231 pp.

Jankowiak, R., Rossa, R., Mista, K., 2007. Survey of fungal species vectored by *Ips cembrae* to European larch trees in Raciborskie forests (Poland). *Czech Mycology*, 59 (2): 227-239.

Juha, M., Lukášová, K., Holuša, J., Turčáni, M., 2012. Netradiční způsoby boje s lýkožroutem smrkovým – *Ips typographus* (Coleoptera: Curculionidae). [Non-traditional methods of control the spruce bark beetle – *Ips typographus* (Coleoptera: Curculionidae)]. VÚLHM, 17 pp.

Knížek, M., 2006. Lýkožrout modřínový (*Ips cembrae*). [Large larch bark beetle (*Ips cembrae*)]. *Lesnická Práce*, 85: 1-4.

Krehan, H., Cech, T.L., 2004. Larch damage in Upper Styria. An example of the complex effects of damage agents. *Forstschutz Aktuell*, 32: 4-8.

Lubojacký, J., Holuša, J., 2013. Comparison of lure-baited insecticide-treated tripod trap logs and lure-baited traps for control of *Ips duplicatus* (Coleoptera: Curculionidae). *Journal of Pest Science*, 86: 483-489. DOI: https://doi.org/10.1007/s10340-013-0492-z.

Lubojacký, J., Holuša, J., 2014. Attraction of *Ips typographus* (Coleoptera: Curculionidae) beetles by lure-baited insecticide-treated tripod trap logs and trap trees. *International Journal of Pest Management*, 60 (3): 153-159. DOI: https://doi.org/10.1080/09670874.2014.944610.

Marini, L., Ayres, M.P., Battisti, A., Faccoli, M., 2012. Climate affects severity and altitudinal distribution of outbreaks in an eruptive bark beetle. *Climatic Change*, 115 (2): 327-341. DOI: https://doi.org/10.1007/s10584-012-0463-z.

Paynter, Q.E., Anderbrant, O., Schlyter, F., 1990. *Ips typographus*, on the bark of host trees during mass attack. *Journal of Insect Behavior*, 3 (4): 529-543.

Postner, M., 1974. *Ips cembrae*. In: W. Schwenke, ed. *Die Forstschädlinge Europas*. Hamburg, Berlin: Paul Parey, pp 458-459.

Resnerová, K., Holuša, J., Surový, P., Trombik, J., Kula, E., 2020. Comparison of *Ips cembrae* (Coleoptera: Curculionidae) capture methods: small trap trees caught the most beetles. *Forests*, 11: 1275. DOI: https://doi.org/10.3390/f11121275.

Schlyter, F., Birgersson, G., 1989. Individual variation in bark beetle and moth pheromones: a comparison and an evolutionary background. *Holarctic Ecology*, 12 (4): 457-465.

Schneider, H.J., 1977. Experience in the control of the large larch bark beetle in stands of low vitality. *Allgemeine Forstzeitschrift*, 32: 1115-1116.

Slodičák, M., Balkcar, V., Novák, J., Šrámek, V. *et al.*, 2008. Lesnické hospodaření v Krušných horách (Forestry management in the Krušné hory Mts.). Strnady: VÚLHM, 480 pp.

Špoula, J., Kula, E., 2023. Patterns of *Ips cembrae* (Herr) infestation on trap and standing trees of European larch (*Larix decidua* Mill.). *Journal of Forestry Research*. DOI: https://doi.org/10.1007/s11676-023-01627-0.

Šrot, M., 1976. Některé nové poznatky o zakládání sesterského pokolení lýkožrouta modřínového (*Ips cembrae* Heer.) v ČSR [Some recent findings on the establishment of the sister brood of the larch bark beetle (*Ips cembrae* Heer.) in Czechoslovakia]. *Lesnictví*, 22 (12): 979-996.

TIBCO Software Inc., 2018. STATISTICA (data analysis software system), version 14.0.0.15.

Viewegh, J., 2003. Czech Forest (Site) Ecosystem Classification. Praha: ČZU, 208 pp.

Vité, J.P., 1989. The European struggle to control *Ips typographus*: past, present and future. *Holarctic Ecology*, 12: 520-525.

Zahradníková, M., Zahradník, P., 2019. Seznam povolených přípravků a dalších prostředků na ochranu lesa 2019. (List of permitted products for forest protection 2019). Kostelec nad Černými lesy: Lesnická Práce, 135 pp.

STRESZCZENIE

Ocena skuteczności narzędzi stosowanych do monitoringu i ograniczania liczebności *Ips cembrae* (Heer)

Ips cembrae jest najgroźniejszym szkodnikiem drzewostanów modrzewiowych *Larix decidua* Mill. w Europie. Kornik ten atakuje drzewa osłabione i zdrowe, w drzewostanach zarówno młodszych, jak i starszych klas wieku, na niższych i średnich wysokościach nad poziomem morza. *I. cembrae* rozwija się w łyku, pod korą modrzewi. Żer uzupełniający wylęgłych chrząszczy oraz żer regeneracyjny osobników starszych odbywa się pod korą.

Badania przeprowadzono w drzewostanach z dominującym udziałem brzozy brodawkowatej *Betula pendula* Roth, świerka kłującego *Picea pungens* Engelm. i modrzewia europejskiego *L. decidua*. Narzędzia służące do monitoringu i ograniczania liczebności *I. cembrae* (drzewa pułapkowe, wyrzynki ustawione w postaci piramidek, opryskane insektycydem i nieopryskane, oraz pułapki szczelinowe) umieszczono przed ścianami monokultur modrzewiowych w 4 powtórzeniach w 3 lokalizacjach (ryc. 1). Różnice w zagęszczeniu populacji *I. cembrae* w badanych drzewostanach Nadleśnictwa Děčín określono na podstawie miąższości drewna modrzewi zasiedlonych przez kornika, pozyskanych w 2019 r. (tab. 1). Stosunek płci *I. cembrae* na drzewach pułapkowych i na piramidkach określono na podstawie liczby chodników macierzystych i komór godowych. Natomiast w pułapkach szczelinowych i na piramidkach opryskanych insektycydem (ryc. 2) ustalono go na podstawie sekcjonowania chrząszczy.

Aktywność rójkową *I. cembrae* rejestrowano od połowy kwietnia do połowy września 2020 r. *I. cembrae* wykazywał ciągłą aktywność lotną przy powtarzających się średnich dziennych temperaturach przekraczających 10°C i średnich maksymalnych dziennych temperaturach powyżej 15°C, co trwało od 16 kwietnia. W maju i czerwcu sumy opadów były zrównoważone i tylko częściowo wpływały na kulminację rójki (ryc. 3). Rozwinęły się 2 generacje, a rozwój każdej z nich trwał 8-10 tygodni ze stosunkowo długim okresem rójki między generacjami (kulminacja 4-5 tygodni). Osobniki drugiej generacji pojawiły się w połowie sierpnia (ryc. 4). Nie stwierdzono różnic w średnim zagęszczeniu *I. cembrae* między odłowionymi na piramidkach generacjami wiosenną i letnią. Jednak zagęszczenie populacji na odcinkach wyrzynków o średnicy <6 cm było znacznie niższe w porównaniu z innymi klasami średnicy (ryc. 5).

Analiza wykonana na 24 drzewach pułapkowych potwierdziła wyższe zagęszczenie osobników dorosłych *I. cembrae* w generacji wiosennej niż w letniej. Tym samym wykazano istotnie wyższą skuteczność drzew pułapkowych niż wyrzynków ułożonych w postaci piramidek (ryc. 6). Stwierdzono dodatnią korelację między średnicą wyrzynków w piramidkach a nasileniem występowania *I. cembrae*. Model regresji wskazywał, że nasilenie występowania osobników dorosłych *I. cembrae* w łyku wzrastało wraz ze wzrostem średnicy wyrzynka (ryc. 7).

Stwierdzono, że w pułapkach szczelinowych odłowiono tylko połowę całkowitej liczby chrząszczy odłowionych na piramidkach opryskanych insektycydem. Zarówno wiosną, jak i latem opryskane wyrzynki ułożone w piramidki przywabiały znacznie więcej chrząszczy niż pułapki szczelinowe (ryc. 8). Liczba samic była znacznie wyższa na piramidkach i drzewach pułapkowych niż w pułapkach szczelinowych i na opryskanych piramidkach. Liczby samic na wyrzynkach ułożonych w postaci piramidek i na drzewach pułapkowych nie różniły się między sobą. Liczby samic w pułapkach szczelinowych i na opryskanych piramidkach również były zbliżone (ryc. 9).

Wszystkie narzędzia do monitoringu i ograniczania liczebności były skuteczne w odłowach wiosennej i letniej generacji *I. cembrae* i mogą być stosowane w ochronie lasu. Najskuteczniejsze okazały się drzewa pułapkowe, a następnie kłody ułożone w formie piramidek i piramidki z dodatkiem związków chemicznych, które były bardziej skuteczne niż pułapki szczelinowe.