Comparison of *Trypodendron lineatum*, *T. domesticum* and *T. laeve* (Coleoptera: Curculionidae) flight activity in Central Europe

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ABSTRACT: The main goal of work was to compare the flight activity of *Trypodendron lineatum*, *T. domesticum* and *T. laeve* in Central Europe. Field trapping experiments were conducted in 70- to 100-year-old Norway spruce stands located at three study sites in the Czech Republic. At each study site five pheromone traps were used. Pheromone-baited, black, window-slot traps (Theysohn, Germany) were used. Traps were placed at log landing areas 10–15 m apart from the nearest forest edge. Each trap was baited with a standard synthetic pheromone lure, XL Ecolure (Fytofarm, Slovakia). Three species of *Trypodendron* were recorded*.* *T. lineatum* was the most abundant, followed by *T. domesticum* and *T. laeve*. Flight activity began at the end of March or in mid-April. Only one another peak of the flight activity of *T. lineatum* and *T. domesticum* was observed at one study site in May 2011. Statistically significant relationships were found between catches of all species with the exception of *T. lineatum* vs. *T. laeve* and *T. domesticum* vs. *T. laeve* at one site. Males were more abundant than females mainly in *T. lineatum* samples. On the other hand, *T. domesticum* and *T. laeve* abundances of males and females were more equal, but in all cases of all *Trypodendron* species these abundances were not significantly different at all sites.

Keywords: striped ambrosia beetle; hardwood ambrosia beetle; pheromone trap; sex ratio; abundance

While the striped ambrosia beetle, *Trypodendron lineatum* (Olivier, 1795), is a serious forest pest in the Palearctic region and North America (Wood 1982), the importance of *Trypodendron laeve* Eggers, 1939 is unclear. *T. laeve* is widespread through Europe but is apparently rare (Muona 1994; Martikainen et al. 1996, 1999; Martikainen 2000; Daisie 2009; Kirkendall, Faccoli 2010; Knížek 2011; Lukášová et al. 2012). Only some authors consider *T. laeve* to be common (Krehan, Holzschuh 1999).

Trypodendron laeve was formerly considered an alien forest pest in Central Europe because the first specimens detected were thought to have originated from conifer wood imported from Eastern Europe (Holzschuh 1990a,b, 1995). However, its importance to forestry remains limited given that it is abundant in only a small number of locations (Lukášová et al. 2012). European hardwood ambrosia beetle [*Trypodendron domesticum* (Linnaeus, 1758)] is an insect pest of broadleaf hardwood trees (Schwenke 1974; Schwerdtfeger 1981).

According to many authors the species do differ in flight activity. *T. laeve* has a very early and rather short flight period compared to *T. lineatum* (Kvamme 1986; Holzschuh 1995; Krehan, Holzschuh 1999). Unlike *T. lineatum*, which overwinters in the soil (Martikainen 2000), *T. laeve* is suggested to overwinter in the bark of standing trees and in standing dead trees, which could allow beetles to fly even when the ground remains covered with snow. This probably could provide an important competitive advantage for *T. laeve* vs. *T. lineatum*, because snow cover in mountain forests often persists until late May (Martikainen 2000).

The main goal of work was to compare the flight activity of *T. lineatum*, *T. domesticum* and *T. laeve* in Central Europe and confirm if *T. laeve* beetles fly earlier in the season.

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Table 1. Location and altitudes of studied sites

Study site	Coordinates	Altitude (m a.s.l.)	Year of study	Norway spruce (%)
Kostelec nad Černými Lesy	49°58'53''N, 14°49'21''E	391	2013	49
Krašovice	49°35'13''N, 14°17'14''E	460	2013	75
Hradec nad Moravicí	49°51'04''N, 17°53'39''E	320	2011	40

MATERIAL AND METHODS

Field trapping experiments were conducted in 70- to 100-year-old Norway spruce (*Picea abies* Karsten) stands located at three study sites in the Czech Republic (Table 1). At all study sites damage caused by pathogens is minimal and the level of bark beetle infestation is low. At each study site five pheromone traps were used, each with a total active surface area of 4,284 cm^2 (42 × 51 cm on two sides). Pheromone-baited, black, window-slot traps (Theysohn, Germany) were used. The traps were placed at log landing areas 10–15 m distant from the nearest forest edge 1.5–2.0 m above the soil surface. Traps were spaced 50–100 m apart.

Each trap was baited with a standard synthetic pheromone lure, which was XL Ecolure (Fytofarm, Bratislava, Slovak Republic). XL Ecolure is a pheromone dispenser designed for monitoring and decreasing the population density of the striped ambrosia beetle (*T. lineatum*) in forest stands and timber yards. After the trap is removed from a hermetically sealed, three-layered aluminium-plastic laminated pouch, the aggregation pheromone contained in a cellulose plate is gradually released through a permeable polyethylene film. XL Ecolure contains the main active chemicals: lineatin, 2-methyl-3-butyn-2-ol, 2-methyl-3-buten-ol and 2-metoxypropan-1-ol. These dispenser lures attracted both males and females of *T. lineatum*. The dispensers must be deployed just before the swarming of *T. lineatum* (http://www.fytofarm.cz; http://www.ichf.edu.pl/chemipan/); the same applies to the other three *Trypodendron* spp., based on our understanding of their biology.

The traps with aggregation pheromone were deployed during mid-March and were monitored until early June/July, i.e. until the time when two consecutive collections were negative. Beetles were collected every 7 days, stored in Eppendorf microtubes (2.5 ml), and kept frozen (< –5°C).

Individual beetles were identified to species according to Pfeffer (1989) and Bussler and Schmidt (2008). Sex was determined according to secondary sex characteristics (convex forehead in females and concave forehead in males) (Pfeffer 1989).

Source data on temperatures were taken from measurements of the closest weather stations of the Czech Hydrometeorological Institute at each study site.

Flight activity was compared between samples of each species in one pheromone trap. For the first and last samples a zero assumption was made before or after the flight activity of beetles. Abundance of beetles was normalized to the total number as a proportion of the total captures and was analyzed using Spearman's correlation regression analysis. Abundance was compared between males and females of *T. laeve* and between *T. laeve* and *T. lineatum* using the Mann-Whitney U test, Wilcoxon signed-rank test, Friedman test. All tests were performed in the STATISTICA 12.0 software (SPSS, Tulsa, USA).

RESULTS

A total of 6,427 beetles were captured, and three species of *Trypodendron* were recorded. *T. lineatum* was most abundant and most common (n = 5,660), followed by *T. domesticum* (n = 587) and *T. laeve* (n = 180) (Table 2). These ratios were the same at all studied sites. At the site of Hradec nad Moravici, *T. laeve* was absent.

Males were more abundant than females mainly in *T. lineatum* samples, but the abundances of males and females were not significantly different at all sites

Table 2. Numbers *Trypodendron lineatum* (li), *T. domesticum* (do) and *T. laeve* (lae) males (M) and females (F) caught into five pheromone traps and comparison of insect abundance using the Friedman test at study sites

Study site	*T. lineatum*		*T. domesticum*		*T. laeve*		Ratio
	M	F	M	F	M	F	li/do/lae
Kostelec nad Černými lesy	1,730	316	211	163	83	56	> >
Krašovice	1,011	231	19	22	31	10	> =
Hradec nad Moravicí	1,603	769	120	52	0	0	> 0

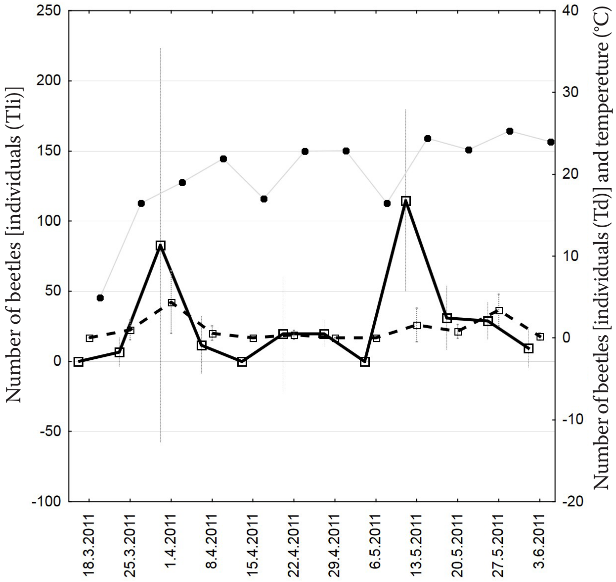

Fig. 1. Flight activity of *Trypodendron lineatum* (Tli, large square) and *T. domesticum* (Td, small square) at Hradec nad Moravicí site (mean ± SD) (maximum daily temperature during the whole week)

(Wilcoxon signed-rank test; Kostelec nad Černými Lesy: z = 0.40; P > 0.10; Krašovice: z = 1.06; P > 0.10; Hradec nad Moravicí: z = 1.18; P > 0.10; Table 2).

In the case of *T. domesticum* abundances of males and females were more equal and were not significantly different at all sites (Wilcoxon signed-rank test; Kostelec nad Černými lesy: z = 0.40; P > 0.10; Krašovice: z = 0.73; P > 0.10; Hradec nad Moravicí: z = 5.50; P > 0.01; Table 2).

T. laeve abundances of males and females were equal and were not significantly different at both sites (Wilcoxon signed-rank test; Kostelec nad Černými lesy: z = 0.40; P > 0.10; Krašovice: z = 1.60; P > 0.10; Table 2).

Flight activity of *Trypodendron lineatum* and *T. domesticum* at the site of Hradec nad Moravicí in 2011 began at the end of March and ended at the end of the first April decade. Later in May another peak was observed (Fig. 1). In 2013, a very short peak of the flight activity of all species at both sites was in mid-April (Fig. 2). Statistically significant positive relationships were found between catches of all species with the exception of *T. lineatum* vs. *T. laeve* at the site Kostelec nad Černými lesy and *T. domesticum* vs. *T. laeve* at the site Krašovice (Table 3).

DISCUSSION

Two species of *Trypodendron* were recorded at three sites in the Czech Republic in 2011 and 2013. *T. laeve* was absent at one site in Hradec nad Moravicí in 2011. *T. lineatum* was most abundant and most common, followed by *T. domesticum* and *T. laeve*. The obtained results confirm earlier observations that *Trypodendron* species are attracted by lineatin (Klimetzek et al. 1981; Schurig et al. 1982; Paiva, Kiesel 1985; Kvamme 1986; Krehan, Holzschuh 1999; Martikainen 2000).

(a) (b)

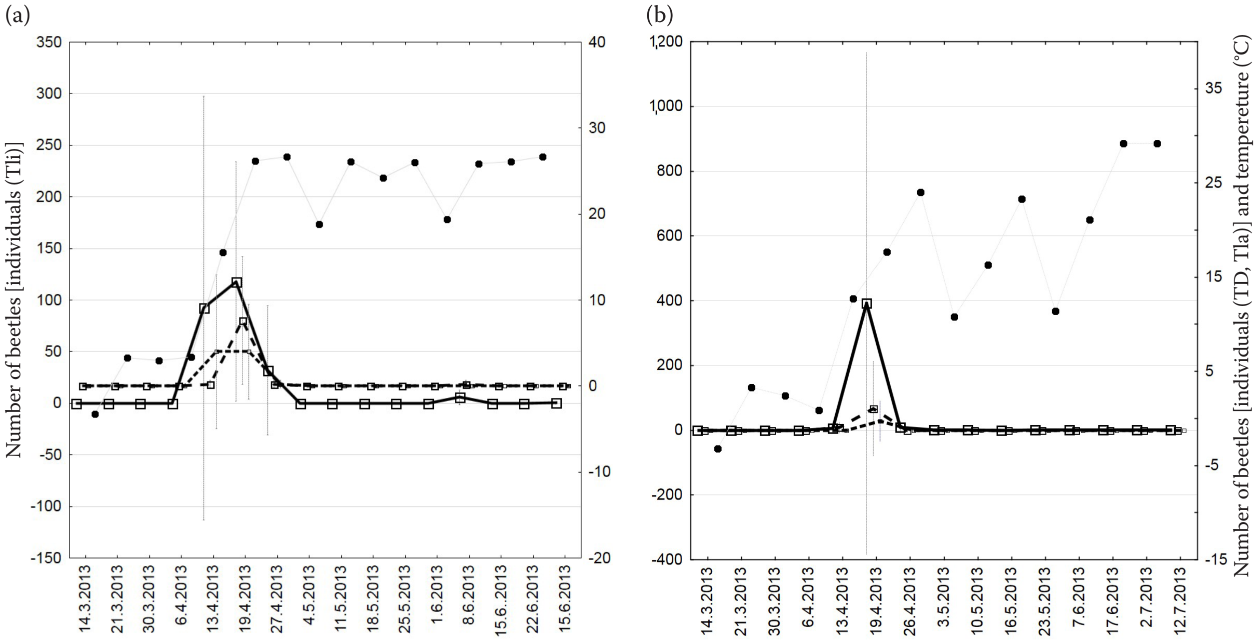

Fig. 2. Flight activity of *Trypodendron lineatum* (Tli, large square), *T. domesticum* (TD, middle square), *T. laeve* (Tla, small square) at Krašovice site (a), Kostelec and Černými lesy site (b) (mean ± SD) (maximum daily temperature during the whole week)

Table 3. Correlation analysis of the flight activity of all three *Trypodendron* species each to other

Study site	*T. lineatum* vs. *T. domesticum*	*T. lineatum* vs. *T. laeve*	*T. domesticum* vs. *T. laeve*
Kostelec nad Černými lesy	$r = 0.45$; $y = 1.1x^{*}$	$r = 0.37$; $y = 1.0x^{ns}$	$r = 0.44$; $y = -0.007+1.14x^{*}$
Krašovice	$r = 0.67$; $y = 0.02x^{**}$	$r = 0.79$; $y = 0.04x^{**}$	$r = 0.44$; $y = 0.001+0.40x^{ns}$
Hradec nad Moravici	$r = 0.47$; $y = 0.68x^{**}$	-	-

$^{*}P < 0.05$; $^{**}P < 0.01$, ^{ns} not significant

Although it is likely that the attraction of *Trypodendron* species in areas where several species are sympatric depends on (+)-lineatin, host-specific volatiles may be important for reproductive isolation (Lindgren et al. 2000). This is probably the reason for the small numbers of *T. domesticum* beetles captured in the present study. The failure to trap *Trypodendron signatum* (Fabricius, 1787), the last of the species of the genus *Trypodendron* occurring in the Czech Republic, can be explained by its host tree distribution (Lukášová et al. 2012). In the present study the pheromone traps were located in Norway spruce forests, being always apart from *T. signatum* populations. Recent confirmations of *T. laeve* occurrence in other areas support that this species is widespread and not a local species in Central Europe like it was suggested earlier by Lukášová et al. (2012). The XL Ecolure dispenser contains a mixture of pheromones including the lineatin active ingredient and can therefore be used to monitor *T. laeve*. But the composition of the lure could influence attractiveness to T. *laeve* and therefore its observed lower abundance could be a result of the type of lure. The alternative method of monitoring (i.e. rearing the species of *Trypodendron* from trap logs or attacked trees) is considerably more labour-intensive (Park, Reid 2007).

Pheromone traps should catch more males than females, because the latter produce sex pheromones additionally attracting males (Schwenke 1974; Schwerdtfeger 1981). More males were actually recorded, but these differences were not statistically significant, probably due to the large variance in the values of individual catches. The first occurrence of *T. lineatum* (Figs 1–2) corresponds to the information in the literature that *T. lineatum* does not fly before the ambient temperature reaches 16°C, which is usually in March or April (Chapman, Kinghorn 1958; Harde et al. 2000). In 2011 at Hradec nad Moravicí site the second peak was observed probably as a result of the flight of reemerged beetles (Fockler, Borden 1972). *T. lineatum* does not produce the second generation, because it has a univoltine development cycle and hatched young beetles are not able to reproduce earlier than through a reasonably long period of cold temperatures (Urban, Kříštek 2004). Reemerging offspring beetles do not respond to pheromones until the next spring (Borden 1988).

For Central Europe *T. domesticum* is described in the literature as a univoltine species (Schwenke 1974; Schwerdtfeger 1981). This assessment is based primarily on the assumption of an analogy to the biology of *T. lineatum* (Schwerdtfeger 1963). Petercord (2006) suggested two generations per year in *T. domesticum* with swarming at the beginning of June. The existence of a second generation has been demonstrated by a study of Eichhorn and Graf (1974), but beetles collected in May/June in the present study could be only reemerged beetles. A sister brood flight in *T. laeve* apparently does not occur (Martikainen 2000) like in presented experiments in 2013.

Trypodendron domesticum overwinters in a gallery system in wood (Schwenke 1974), but it seems that the flight periods of the species and *T. lineatum* (overwintering in soil) could be identical. There were correlations in their flight activity at low temperatures in both climatically different years. Many authors suggest that *T. laeve* has a very early and rather short flight period compared to *T. lineatum* (Kvamme 1986; Holzschuh 1995; Krehan, Holzschuh 1999). They explained that there could be a difference in the place of overwintering. Unlike *T. lineatum*, which overwinters in the soil (Dyer, Kinghorn 1961; Annila et al. 1972; Zumr 1983; Borden 1988; Martikainen 2000), *T. laeve* is suggested to overwinter in the bark of standing trees (Martikainen 2000) but nobody brought the evidence. According to Martikainen (2000), *T. laeve* started to fly at 13°C and its swarming peaked at around 15°C, which was the threshold temperature for the flight of *T. lineatum*. It is hard to say if it is sufficient to start flight activity. The species was found only in 2013, when the temperature was increasing quickly in April and was insufficient for the flight of both species. But it has to be said that the air temperature alone is not a good signal for the forecast of flight activity. A proper model could be based only on the knowledge of threshold temperature for the total number of degree days (DD).

From a practical point of view, it is not necessary to distinguish wood attacked by *T. lineatum* and *T. laeve*, because the bionomics, damage, and control are very similar for the two species (Bussler, Schmidt 2008). Originally many authors (Kvamme 1986; Holzschuh 1995; Krehan, Holzschuh 1999; Martikainen 2000; Bussler, Schmidt 2008) suggested that *T. laeve* has a very early and rather short flight period compared to *T. lineatum*.

From a management perspective, the exponential increase in *T. lineatum* abundance with both live host tree abundance and stumps provides managers with ways to limit the economic impacts of *T. lineatum* (as well *T. laeve*) by choosing where to leave harvested boles (Park, Reid 2007). Consequently, fresh logs should be placed away from such stands, and preferentially stored in non-host stands. Limiting the volume of logs stored in one location should also reduce the local abundance of *T. lineatum*. In short, small changes in resource density can have large impacts on pests that use those resources (Park, Reid 2007).

In addition to the points discussed above, the behaviour of *Trypodendron* species is affected by many factors. The information about abundance of host material, air temperature, humidity, air-mass movements, altitude and melting of snow is very important for the choice of a locality for the wood storage (Chapman, Kinghorn 1958). Although lures with lineatin are useful for catching of *Trypodendron* species, they can be used mainly for monitoring. The population density of *T. lineatum* could not be substantially influenced by continuous mass trapping with pheromone baited traps (Dimitri et al. 1992). A cost/benefit analysis indicates that the expenses of mass trapping overcome the value of loss reduction (König 1992). Lures could be used for assessment of a suitable site for wood storing. If we catch more than 500 beetles from the beginning of flight, the risk of stored wood infestation is very high (Zahradník 2002).

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