Effect of insecticide-treated trap logs and lure traps for *Ips typographus* (Coleoptera: Curculionidae) management on nontarget arthropods catching in Norway spruce stands

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ABSTRACT: The numbers of nontarget arthropods captured by Theysohn pheromone traps (TPTs) and insecticide-treated tripod trap logs (TRIPODs) were compared; both kinds of traps were baited with pheromone lures Pheagr IT for *Ips typographus*. In 2010, 15 TPTs and 15 TRIPODs were deployed (with a 10-m spacing) in a forest in the north-eastern Czech Republic. The TPTs and TRIPODs were inspected weekly during the entire period of *I. typographus* flight activity (30 April–1 October). The TRIPODs were sprayed with Vaztak 10 SC insecticide every 7 weeks; at each spraying, the pheromone evaporators were renewed. Higher numbers of entomophagous arthropods, including the predacious beetles *Thanasimus formicarius* and *T. femoralis*, were captured by the TRIPODs than by the TPTs. The number of *Thanasimus* spp. captured by TRIPODs was especially high at the end of April. The efficacy of TRIPODs for the control of *I. typographus* could be maintained while the kill of nontarget organisms could be reduced by deploying the evaporators 1 week later (in early May rather than in late April) in relation to the recommended date of dispenser installation.

Keywords: tripod trap logs, pheromone trap, Pheagr IT, alpha-cypermethrin, *Thanasimus*, *Ips typographus*

The spruce bark beetle, *Ips typographus* (Linnaeus, 1758), is one of the most serious pests of the Norway spruce (*Picea abies* [L.] Karsten) in Eurasia (Annila 1969; Schwenke 1974). It reproduces in the wood of spruce trees that recently died, but when abundant it can colonize and kill living trees (Schwenke 1974; Weslien et al. 1989). The species like *I. typographus* are key factors affecting forest succession in Europe and Asia (Weslien 1992; Viiri 1997).

For the control of *I. typographus* by mass trapping, pheromone traps, trap trees, trap logs, baited trees, and baited slash are commonly used (Grégoire, Evans 2004; Zahradník, Knížek 2007). Trap trees have been used to control *I. typographus* for more than 200 years (Pfeil 1827) but the use of felled (or artificially stressed) trap trees is expensive and time-consuming (Bakke 1989). The approach used to control *I. typographus* changed in the 1970s with the discovery and production of an aggregation pheromone for the species (Bakke 1970; Rudinsky et al. 1970; Bakke et al. 1977). The pheromone is used by the male beetles to attract both males and females to suitable breeding material. Since the 1970s, traps baited with pheromone lures (Bakke 1982; Furuta et al. 1984; Bakke 1989) have been commonly used for monitoring or mass trapping of *I. typographus* (Jakuš 1998; Schlyter, Birgersson 1999; Hrašovec et al. 2011).

The use of trap logs baited with pheromone lures and treated with an insecticide (hereinafter referred to as "TRIPODs") represents a combination of the three methods. The entire surfaces of fresh logs are sprayed with insecticide, and the

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logs are arranged into tripods with a pheromone lure positioned below the top. These TRIPODs are set up immediately before the predicted start of flight activity (Knížek 2005; Zahradník 2005; Zahradník, Knížek 2007). TRIPOD efficacy is maintained through the season by the repeated spraying of insecticide and by the changing of the pheromone lure (Knížek 2005; Zahradník, Knížek 2007).

A number of authors have suggested that TRIPODs should not be used other than in exceptional cases because, in addition to killing pest beetles, TRIPODs also kill large numbers of entomophagous arthropods (Werner et al. 1983; Okland et al. 1996; Zahradník 2004; Tomiczek 2009; Koleva et al. 2012; Lubojacký, Holuša 2013). The most common species among nontarget arthropods that are usually killed by TRIPODs are e.g. *Thanasimus formicarius* (Linnaeus, 1758), *Necrophorus vespilloides* (Portevin, 1903), individuals of Cerambycidae and Buprestidae (Tomiczek 2009) or *Pityogenes chalcographus* (Linnaeus, 1761), *T. formicarius* and individuals of Elateridae (Koleva et al. 2012). Only Hurling and Stetter (2012) reported almost no impact of TRIPODs on nontarget organisms.

TRIPODs have commonly been used by foresters since the 1990s and are also sometimes used in protected areas where their impact on nontarget organisms could be very important. The main aim of this research was to compare numbers of nontarget species killed by TRIPODs and black Theysohn pheromone slot traps (hereinafter referred to as TPTs). A second aim was to compare the ratio of bark beetle predators *T. formicarius* and *T. femoralis* (Zetterstedt, 1825) captured by TRIPODs and TPTs.

MATERIAL AND METHODS

The study was conducted in 2010 near Hlubočec, in the northeast of the Czech Republic, in an area where three clearcuts had been harvested in 2009. The area (150 ha) was a triangle defined by 17°57'11''E, 49°51'04''N; 17°56'21''E, 49°51'16''N; and 17°56'15''E, 49°51'46''N. The elevation at all locations within this area ranged from 475 to 495 m a.s.l. Spruce trees forming the forest edge were 96–109 years old. Fifteen pairs of TRIPODs and TPTs were installed along the forest edge with a 10-m spacing.

Each TRIPOD was constructed from three fresh logs that were 2 m long and at least 15 cm in diameter. The upper parts of the three logs were connected with an iron trident to create the tripod structure. The logs were cut from 50-year-old spruce trees in the stand where the traps were located. We avoided damaging the bark on the logs to prevent the increased release of monoterpenes. A 30-cm long steel rod was driven partway into the lower part of each log so that two-thirds of its length protruded outward from the perimeter defined by the TRIPOD. The free end of each rod rested on a wooden block ca 20 cm high.

The entire TRIPOD was thus raised, which allowed a collection frame for retaining dead insects to be inserted beneath the entire vertical projection of the TRIPOD. The collecting frame was in the shape of a square, 1 × 1 m, and was constructed from 10-cm high wooden planks. A layer of fine netting (1-mm mesh) affixed to the bottom of the frame retained beetles that fell from the logs. A layer of coarser netting (16-mm mesh) affixed to the top of the frame permitted the passage of falling beetles but prevented birds from feeding on fallen insects.

On 23 April 2010, the TRIPOD surfaces were sprayed with an insecticide mixture (1 l of the mixture per TRIPOD) composed of 0.5% Vaztak 10 SC® (suspension concentrate with 100 $g \cdot l^{-1}$ of the active ingredient alpha-cypermethrin; BASF AG, Ludwigshafen, Germany) and 1% colorant Scolycid C® (NeraAgro, Ltd., Neratovice, Czech Republic) diluted in water. This material was reapplied at 7-week intervals. On the same day, the pheromone lure (Pheagr IT®, SciTech Ltd., Prague, Czech Republic) was affixed to the top and was replaced with a fresh lure on 11 June and 30 July. The lure contained the active ingredients 2-methyl-3-buten-2-ol (91%) and (*S*)-*cis*-verbenol (3.9–4.3%) plus a stabilizer (2,6-di-tert-butyl-4-methylphenol; 4.7%). The evaporator was replaced according to the manufacturer's instructions.

The TPTs (Ridex s.r.o., Vrbno pod Pradědem, Czech Republic) were arranged on a metal trap stand 2 m above the ground. A 49 × 49 cm collection sheet was installed 1.5 m above the ground. The TPTs were baited using the same pheromone evaporator with the same dates of installation and replacement as for the TRIPODs. Invertebrates were collected from both kinds of traps each week from 30 April to 1 October 2010 and put into polyethylene vials with 70% ethanol. Determination of individual groups and species was carried out in the laboratory with a stereomicroscope.

The data were analysed in an MS Excel spreadsheet (Microsoft, Redmond, USA) and evaluated using the Wilcoxon signed-rank test in STATISTICA 9.0 (Statsoft, Tulsa, USA).

Table 1. Numbers of the most important entomophagous arthropods [means (± SD)] captured by tripod trap logs (TRIPOD) and Theysohn pheromone traps (TPT)

Species	Total number		Number captured per trap		WSRT
	TRIPOD	TPT	TRIPOD	TPT	
Order Araneae	480	21	32.0 ± 11.6	1.4 ± 2.2	3.41***
Order Opiliones	49	0	3.3 ± 2.6	0	3.18**
Order Hymenoptera	57	25	4.8 ± 2.4	2.1 ± 1.7	2.93**
Family Formicidae	56	9	3.7 ± 3.3	0.6 ± 0.9	2.98**
Thanasimus formicarius	50	9	3.3 ± 2.9	0.6 ± 0.8	3.06**
Thanasimus femoralis	89	13	5.9 ± 4.1	0.87 ± 1.4	2.95**
T. formicarius vs. *T. femoralis* (WSRT)			1.7 n.s.	0.1 n.s.	

TRIPOD – treated with insecticide and lure-baited, TPT – lure-baited Theysohn window-slot traps, WSRT – Wilcoxon signed-rank test, n.s. – not significant; *significant at $P < 0.05$, **$P < 0.01$, ***$P < 0.001$; ratios of the two *Thanasimus* spp. are provided in the last row

RESULTS

Table 1 shows the total numbers of selected species and groups of entomophagous arthropods. The most numerous species and groups of entomophagous arthropods that have been reported in both types of traps were the order Araneae, order Hymenoptera and species *T. femoralis*. All investigated species and groups of entomophagous arthropods were more numerous in TRIPODs than in TPTs, whereas the largest differences in the number of individuals caught by TRIPODs and TPTs (in favour of the TRIPODs) concern the order Araneae and *T. femoralis*. The ratio of *T. formicarius* to *T. femoralis* did not significantly differ between the two trapping methods (Table 1).

Many more *T. formicarius* and *T. femoralis* individuals were trapped early than late in the season. Furthermore, more *T. femoralis* than *T. formicarius* were captured by both methods on most dates, whereas an opposite regularity was detected only in the case of beetles caught by TRIPODs in May and June 2010 (Fig. 1).

DISCUSSION

This study has confirmed that high numbers of nontarget invertebrates are killed by TRIPODs. Very similar results were obtained in another study concerned with TRIPODs treated with insecticides and pheromone lures for another bark beetle living on

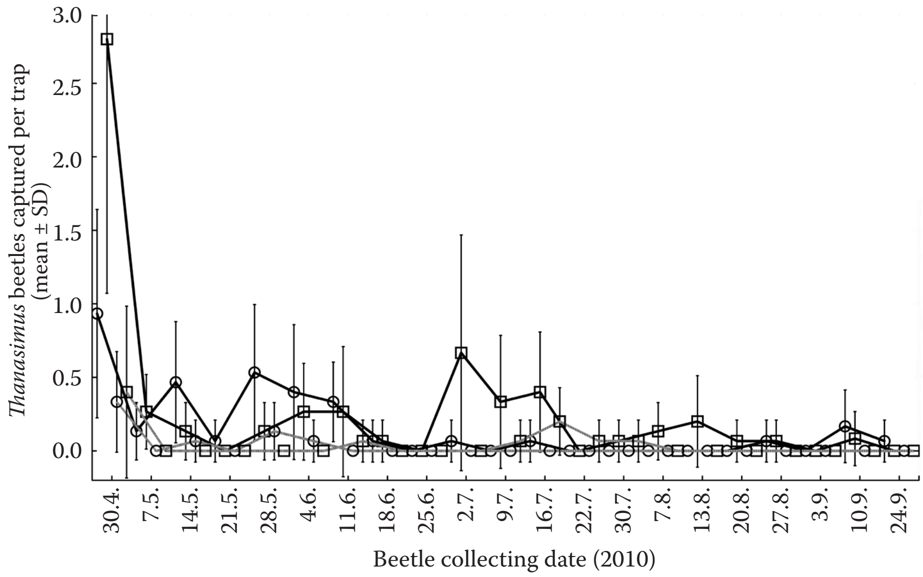

Fig. 1. Mean numbers of *Thanasimus femoralis* beetles (squares mean ± SD) and *Thanasimus formicarius* beetles (circles mean ± SD) captured by one tripod trap log (TRIPOD; dark line) and one Theysohn pheromone trap (TPT; grey line) during the entire period of flight activity in 2010, the TRIPODs were treated with insecticide, and both kinds of traps were treated with pheromone lure (active ingredient: cis-verbenol)

spruce, *Ips duplicatus* (Sahlberg, 1836) (Lubojacký, Holuša 2013). In contrast to TRIPODs, TPTs are designed to minimize effects on nontarget organisms (e.g. Kretschmer 1990; Pernek et al. 2003), and nontarget mortality in the present study was much lower with TPTs than with TRIPODs. In particular, spiders, harvestmen, bees, and ants are not attracted to TPTs and are unlikely to contact them.

The clerid beetles *Thanasimus formicarius* and *T. femoralis* are the most commonly reported predators of spruce bark beetles in Europe (Bakke, Kvamme 1981; Dippel et al. 1997), and both species suffered substantially higher mortality in TRIPODs than in TPTs in the present study. The antennal olfactory receptors of *T. formicarius* are sensitive to *I. typographus* (Hansen 1983). In addition, the aggregation pheromone of bark beetles acts like a kairomone for *Thanasimus* beetles (Hansen 1983); as a consequence, these beetles are also captured in TPTs (see also Bakke, Kvamme 1978; Zumr 1983a,b, 1988). As documented in this report, however, fewer *Thanasimus* beetles are killed by TPTs than by TRIPODs.

Both *T. formicarius* and *T. femoralis* respond strongly to ipsdienol and less strongly to the prey aggregation pheromone (Hulcr et al. 2006). In a previous study, *T. formicarius* was more abundant than *T. femoralis* in TPTs that contained ipsdienol, which is used to attract *I. duplicatus* (Lubojacký, Holuša 2013); when the TPTs contained *cis*-verbenol, which is used to attract *I. typographus*, the numbers of *T. formicarius* and *T. femoralis* captured did not statistically differ. In the latter study, different numbers and ratios of *T. formicarius* and *T. femoralis* in TPTs containing *cis*-verbenol vs. ipsdienol can probably be explained by the fact that *T. formicarius* is strongly attracted to ipsdienol and ipsenol, while it is only moderately attracted to *cis*-verbenol (Bakke, Kvamme 1981; Hulcr et al. 2006). Hulcr et al. (2006) documented a weak response to *S-cis*-verbenol + methylbutenol by *T. femoralis* and no response by *T. formicarius*. Similarly, Bakke and Kvamme (1981) reported that *T. femoralis* responds to *(S)-cis*-verbenol and that the response is synergized by ipsdienol and ipsenol. *T. femoralis* displayed a strong preference to Pheroprax evaporators containing 2-methyl-3-butel-2-ol, *cis*-verbenol, and ipsenol rather than α-pinene and ethanol (Schroeder 2003).

T. formicarius is a generalist predator of more than 20 species of bark beetles on both coniferous and deciduous trees (Gauss 1954). In Sweden, *T. formicarius* initiates flight in early spring, at about the same time when the earliest flying bark beetles, *Tomicus piniperda* (Linnaeus, 1758) and *Hylurgops palliatus* (Gyllenhal, 1813), begin to fly (Schroeder 2003). The generation timing of *T. formicarius* coincides with those of two of its main prey species, *T. piniperda* and *I. typographus* (Schroeder 1999). Previous results from trap captures indicated that *T. formicarius* has a long flight period without marked interruptions that extends from early spring, when the first bark beetles fly, until the end of summer (Schroeder 1999). This corresponds to the flight activity until the end of June documented here. The new generation of *T. formicarius* emerges as larvae from June to August (Schroeder, Weslien 1994). *T. femoralis* responds to cis-verbenol (Bakke, Kvamme 1981; Schroeder 2003; Hulcr et al. 2006), and this explains the second peak of flight activity in June 2010 in the present study, which also corresponds to the flight activity of *I. typographus* in the northeastern Czech Republic (Lubojacky, Holuša 2011). In Sweden, the flight activity of *T. femoralis* also corresponds to the flight activity of *I. typographus* (Schroeder 2003).

In conclusion, the present study shows that more nontarget, beneficial arthropods (i.e. Araneae, Opiliones, Formicidae, and Cleridae) are captured by TRIPODs than by TPTs. The number of *Thanasimus* spp. captured was especially high at the end of April (i.e. in the earliest collections). Deploying the TRIPOD evaporators 1 week later (in early May rather than in late April) could reduce the number of beneficiaries that are killed while still resulting in the traps being present at the start of flight activity for *Ips* spp. Because they are easy to inspect, TRIPODs will continue to be used in forestry practice, especially in relatively inaccessible locations.

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