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The relationships between *Pityogenes chalcographus* and *Nemosoma elongatum* in clear-cuts with different types of management

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Abstract: *Pityogenes chalcographus* (Linnaeus, 1758) is a significant pest of young spruce stands up to the age of about 20 years. Predation can be a significant part of decreasing its population density. The aim of the research was to determine the relationships between captured *P. chalcographus* and its major predator *Nemosoma elongatum* (Linnaeus, 1761). The research was conducted in 2006 and 2007 in five areas with the following conditions: two clear-cuts covered with freely distributed brushwood, two clear-cuts which had no brushwood remaining and the last locality was an older (more than two years older) clear-cut with no brushwood. The catches from the pheromone baited traps used to lure *P. chalcographus* showed a strong positive correlation between *P. chalcographus* and *N. elongatum.* Furthermore, comparisons were drawn between the *N. elongatum* catches from each clear-cut. The differences in the proportions of the predator *N. elongatum* to the trapped *P. chalcographus* were identified between the types of clear-cuts with the highest proportion of trapped *N. elongatum* in the clear-cuts with the brushwood and the lowest proportion in the clear-cuts with the removed brushwood.

Keywords: predator; spruce; brushwood; forest protection; control; flight curve

Pityogenes chalcographus (Linnaeus, 1758) is a significant pest of young spruce stands up to the age of about 20 years. In periods of reduced vitality due to long-term drought, even adult spruces are attacked, from the top to the lower and stronger parts of the trunk. As a result of the attack, these spruces are killed, which is often the result of the subsequent attack of *Ips typographus* (Linnaeus, 1758) in the lower part of the spruce tree. The significance of this pest is also evidenced by the fact that it is classified among the seven calamitous pests of the Czech Republic (Regulation No. 101/1996). Predation plays an important role in reducing the populations of a number of insect species, but reacts to the increase in population density with delays. Often, however, it can be a deciding factor that affects the pest population.

The aim of the experiment was to find out the impacts of the use of pheromone traps in the capture of *P. chalcographus* on the population of this predator. The underlying hypothesis worked on the presumption that the management of the brushwood destruction affects the *P. chalcographus* population, but it was not clear how the *Nemosoma elongatum* (Linnaeus, 1761) population is affected. The six-toothed spruce bark beetle *P. chalcographus* (Coleoptera: Curculionidae: Scolytinae) is an important pest of young coniferous forests in Central Europe with populations reaching the point where mature trees or the whole growths die. A great deal of attention has been paid to various defence methods against insect pests (Švestka a *et al.* 1996). An important, but often neglected element, is the possible trapping of the target species' predators.

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The most important predator of *P. chalcographus* is *N. elongatum* (Coleoptera: Trogossitidae), which comprises 1–4% of *P. chalcographus* catches (Zahradník 1995) and comprises up to 60% of all the predators captured in these traps (Zumr 1988). What effect does the trapping of one adult *N. elongatum* or one egg-bearing female have on *P. chalcographus* populations? If we consider that one adult *N. elongatum* consumes one adult *P. chalcographus* per day and actively predates for 4–5 months (Baier 1991), a possible conclusion is that one adult *N. elongatum* consumes, on average, 120 adults of the *P. chalcographus* in one year, and this is likely to be even higher in the case of egg-bearing females. Each fertilised female can lay an average of 60 eggs and, on average, one larva consumes approximately 30 larvae of *P. chalcographus* during its development. The trapping of one fertilised female, therefore, potentially saves 1920 (only a simple mathematical construction) *P. chalcographus* specimens (mortality excluded), with similar figures presented by Dippel (1996). It follows that *N. elongatum* can significantly affect the population of *P. chalcographus*. As previous experiments have shown, the type of brushwood destruction management does not play a principal role in reducing the *P. chalcographus* population (Zahradník & Zahradníková 2015).

It could be expected that the lowest catches in the traps would be achieved on the clear-cuts with the left brushwood. It was supposed that part of the beetles from the first swarming of *P. chalcographus* would be attracted to the brushwood; during the second swarming, an increase in the catches in the pheromone traps was expected, as there will be no longer any attractive material for *P. chalcographus*.

MATERIAL AND METHODS

The research was conducted in 2006 and 2007 in the Forest Enterprise Dobříš (Forests of the Czech Republic, s.e.), in the forest district of Višňová. Three types of clear-cuts in five localities were selected: (*i*) An older clear-cut with no attractive material, where freshly uncovered younger stands were not be expected to be attractive (to some extent, the conditions were similar to a clear-cut with removed brushwood) (designated A); (*ii*) Clear-cuts with brushwood removed by burning (designated B, C); (*iii*) Clear-cuts with attractive brushwood (designated D, E). The distance between the localities was approximately 500 m due to keeping similar conditions. Each locality was equipped with five pheromone traps as the maximal number usable for its dimension. The traps were set in a line with a 20 m distance between the traps along the stand wall.

The research was initiated on 5 May, 2006. Theysohn slot pheromone traps (THEYSOHN, Germany) were equipped with a Chalcoprax pheromone dispenser (active ingredient: 6.15% chalcogran + 1.54% methyl-(2E,4Z)-2,4-decadienoate) (BASF SE, Germany). The pheromone dispensers were replaced on 11 July, 2006 and the collection was terminated on 8 September, 2006. In the second year, the experiment was initiated on 18 April, 2007, with the pheromone dispensers replaced on 27 June and the experiment was concluded on 27 August in the same year. The catches in the pheromone traps were collected regularly every week, counted, and the calibration method was used for the more numerous catches (1 ml = 550 *P. chalcographus*). The *N. elongatum* present in the catches were always counted individually in the laboratory. The ratios of *N. elongatum* to *P. chalcographus* according to the type of clear-cut was then determined. The other insect species were removed.

The numbers of *N. elongatum* trapped at the individual localities were statistically evaluated using the software STATISTICA (version 12) and a Kruskal-Wallis ANOVA on the level of significance $\alpha = 0.05$. The type of the clear-cut was chosen as the factor to evaluate the mutual correspondence of the mean values. The dependence of *N. elongatum* catches on the catches of *P. chalcographus* was evaluated by calculating their correlations in the same software.

RESULTS

The ratios of the trapped *N. elongatum* to the trapped *P. chalcographus* differed between the years. There were also differences between the two years: in the first year, the ratios of the trapped *N. elongatum* to the trapped *P. chalcographus* ranged from 0.5 to 1.1%, while in the second year they ranged from 1.8 to 2.8% Figure 1). The ratios of the trapped *N. elongatum* were for the clear-cuts the greatest with the brushwood and the lowest for the removed brushwood.

In both years, the ratios of the trapped *N. elongatum* decreased more or less regularly from the time *P. chalcographus* first took flight (Figure 2). In 2006, this decrease was relatively irregular for the individual clear-cut brushwood management types, but in 2007, the decrease was even. The ratios of the trapped *N. elongatum* were the greatest at the beginning of the

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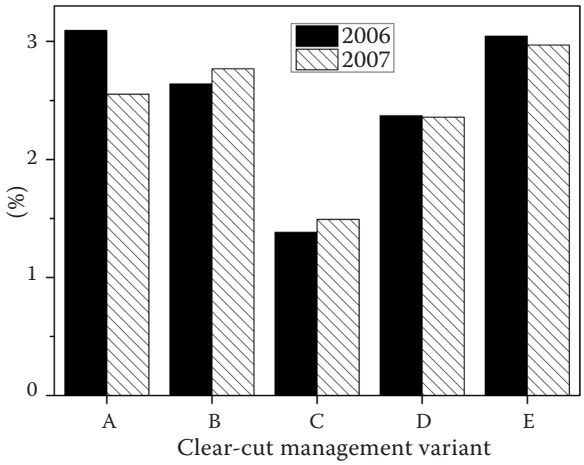

Figure 1. The percentage of *N. elongatum* in the catches of *P. chalcographus* in the different types of clear-cuts

A – older with no attractive material; B, C – with burned brushwood; D, E – with attractive material in 2006 and 2007

swarming of *P. chalcographus* and then later gradually decreased, with a slight increase at the beginning of the second swarming. The maximum values at the beginning of the spring swarming reached almost 3.5% in 2006 and almost 8% in 2007, but there were clear differences between the individual types of clear-cuts.

The Kruskal-Wallis test showed that there were no statistically significant differences between the catches of *N. elongatum* from the different clear-cuts (Figure 3). The total effect of the factor was found to be not significant with the level of significance of $\alpha = 0.05$. probability $P = 0.955$ (in 2006) and also probability $P = 0.980$ (in 2007) reach a greater value than $\alpha = 0.05$.

The statistical evaluation of the correlation between the catches of *N. elongatum* and *P. chalcographus* (Table 1) revealed a strong positive correlation; the higher the number of *P. chalcographus* present in a

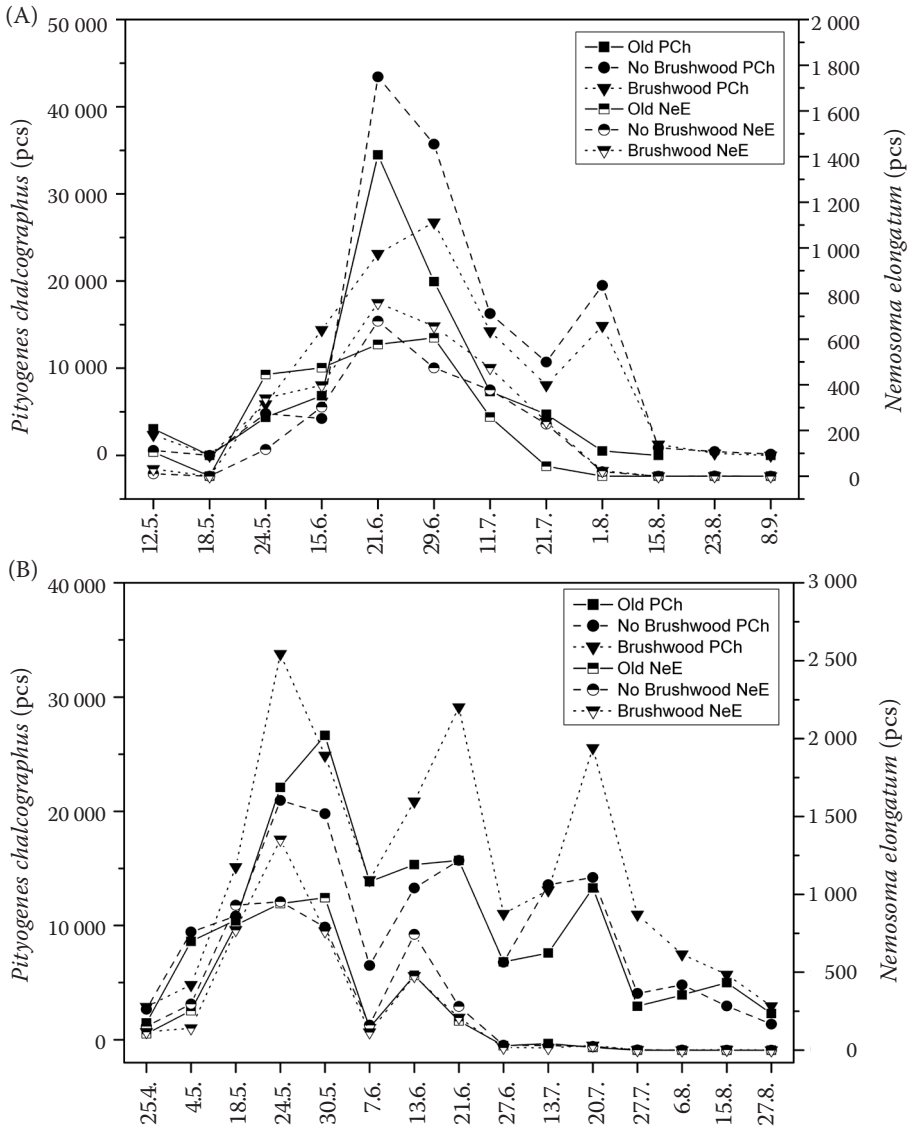

Figure 2. Swarming of *Nemosoma elongatum* (NeO) and *Pityogenes chalcographus* (PCh) in the different types of clear-cut management in (A) 2006 and (B) 2007

pcs – number of caught individuals present per variant

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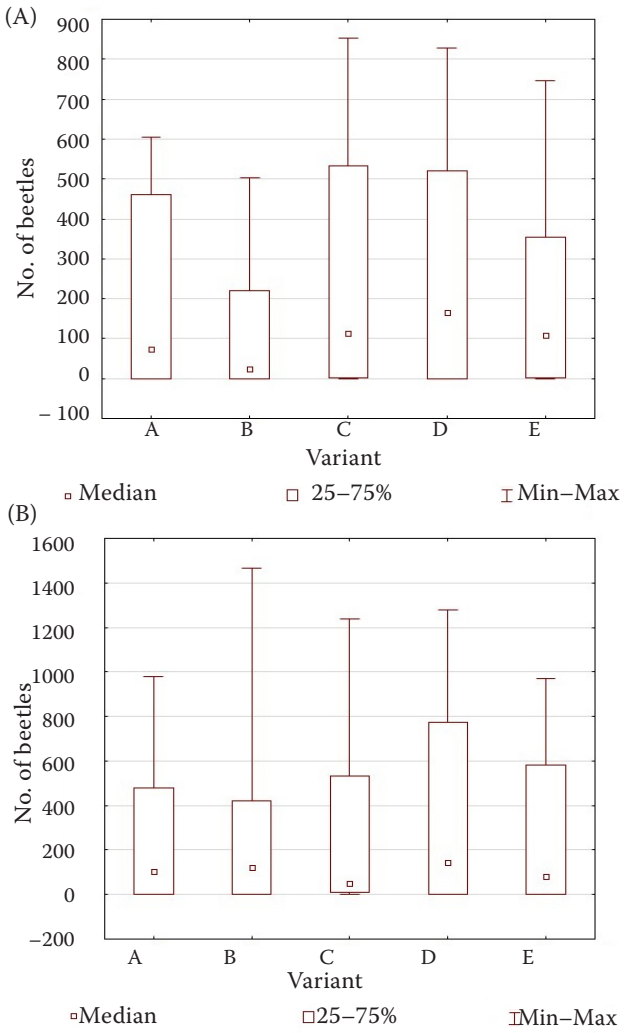

Figure 3. Characteristics of the catches of *N. elongatum* in the different types of clear-cut management in (A) 2006 and (B) 2007

A – older with no attractive material; B, C – with burned brushwood; D, E – with attractive material

Table. 1. The correlations between the catches of *P. chalcographus* and *N. elongatum* at the individual localities in 2006 and 2007

Year		Variant				
		A	B	C	D	E
2006	*r*	0.7859	0.9368	0.8234	0.8447	0.8640
	P	0.0041	0.00001	0.001	0.0005	0.0003
2007	*r*	0.7871	0.5908	0.7566	0.5869	0.7588
	P	0.0005	0.0204	0.0011	0.0214	0.001

r – correlation coefficient; *P* – probability

trap the more *N. elongatum* individuals were caught in the trap. Lower correlation coefficients were only identified for the localities B and D in 2007; but were still significant.

DISCUSSION

The results showed that leaving or removing the brushwood from the clear-cut does not greatly affect the amount of *P. chalcographus* catches. Comparable results were also found on the old clear-cut, where no more attractive material for *P. chalcographus* was available. In the other localities, a comparable capture in the pheromone traps was expected. Similarly, the ratio between the captured *P. chalcographus* could be expected to be comparable to *N. elongatum.* but it did not happen.

From the point of view of the practice of removing brushwood, it is not relevant because the occurrence of *N. elongatum* (a significant predator of *P. chalcographus*) is not strengthened or weakened by removing or leaving the brushwood. The type of management had no impact on the population even on *P. chalcographus*. Zumr (1988) stated that the catches of *P. chalcographus* included an "insignificant number" of predators that were attracted to the pheromone components used such as kairomone (Heuer & Vité 1984) with the *N. elongatum* being the most numerous (accounting for 60.1% of all the trapped predators). In previous studies, other predator species have been noted such as *Nudobius lentus* (Gravenhorst, 1806) (Coleoptera: Staphylinidae), *Thanasimus formicarius* (Linnaues, 1758) (Coleoptera: Cleridae) and *Paromalus parallelepipedus* (Herbst, 1792) (Coleoptera: Tenebrionidae), but all of them predate various species of bark beetles. Zahradník (1988, 1995) also mentioned a number of other predators, including some specific to *P. chalcographus* such as *Corticeus linearis* (Fabricius, 1790) (Coleoptera: Tenebrionidae) or *Leptophloeus alternans* (Erichson, 1845) (Coleoptera: Laemophloeidae). Nevertheless, *N. elongatum* still provided the clear majority of the trapped predators and other beetles (excluding the target species): its ratios were 75% and 72% in the window traps (Theysohn and Chemika) and 43% in the tubular traps. In comparison, *P. chalcographus* only provided 0.25–3.94%; (0.89% on average) of the species caught in the Theysohn traps, 1.94% on average in the Chemika traps and 1.1% on average in the tubular traps. Baader and Vité (1986) reported a proportion of trapped *N. elongatum* of between 0.1–1.6%. Wegensteiner *et al.* (1989) captured a total of 1,175 *N. elongatum* specimens, 255 specimens of other beetle species and 339 specimens of non-target bark beetle species from a total of 650 492 trapped *P. chalcographus*.

It is evident that the percentage of *N. elongatum* to *P. chalcographus* in the catches is higher than the

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percentage of *Thanasimus formicarius* (Linnaeus, 1758) and *Thanasimus femoralis* (Zetterstedt, 1828) in the catches of the European spruce bark beetle (the most important pest of the spruce stands) which represent less than 0.01% (Novák 1981; Brutovský & Ulčáková 1982; Bakke 1985). In all of these cases, it was also shown that the beetles of the genus *Thanasimus* were also affected by the components of the synthetic pheromone, such as kairomone, used to attract *I. typographus* (Bakke & Kvamme 1979, 1981). The different proportions of the *Thanasimus* and *N. elongatum* beetles trapped in pheromone traps, which can be expressed in orders, may be a consequence of the different strategies of the olfactory perception employed by the families Cleridae and Trogossitidae as pointed out by Kohnle and Vité (1984). The proportions of the trapped *N. elongatum* were significant and the significance of their trapped numbers might exceed the significance of the number of caught *P. chalcographus* (Dippel 1996).

This field of research was poorly studied. The impact of the brushwood management on the *P. chalcographus* population density and predation has not yet been published.

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