THE FIRST RECORD OF *IPS DUPLICATUS* (COLEOPTERA: CURCULIONIDAE, SCOLYTINAE) INFESTATIONS IN CENTRAL EUROPEAN INNER MOUNTAINS*

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The natural distribution of the double-spined spruce bark beetle, *Ips duplicatus*, includes the Palearctic stretching from Scandinavia across NE and Central Europe to NE Asia. The first outbreak of I. duplicatus in Central Europe probably occurred in the early 1990s in North Moravia and Silesia, where the beetle still infests spruces at elevations < 600 m a.s.l. This species, which prefers elevations < 600 m a.s.l., has not been previously found within large mountain ranges. The present study, however, deals with I. duplicatus occurrence at ca. 600 m a.s.l. in two large mountain ranges – the Moravskoslezské Beskydy Mts. and the Hrubý Jeseník Mts. In both the regions, the beetle was detected in the terminal parts of closed valleys, approximately 20 km south of the infested sites at 400 m a.s.l. The new infestations at 600 m a.s.l. probably result from the increased abundance of the beetle in the lowlands of the closed valleys. The only defence currently known is to identify and harvest (destroy) the infested trees before offspring mature and overwinter in the litter. Occurrence of I. duplicatus within large mountain ranges constitutes a new risk for spruce stands in the mountains, at least in the Abieto-Fagetum forest vegetation (altitudinal) zone.

bark beetle; occurrence; infestation; spruce; Czech Republic

INTRODUCTION

The double-spined spruce bark beetle, *Ips duplicatus* (Sahlberg, 1836) (Coleoptera: Curculionidae, Scolytinae), is naturally distributed over the Palearctic stretching from Scandinavia across some parts of NE and Central Europe to NE Asia (Wood, Bright, 1992; Pfeffer, 1995). Until the 20th century, the southernmost occurrence of *I. duplicatus* in Europe was in the Bialowieza Primeval Forest in today's northern Poland. In the first half of the 20th century, however, *I. duplicatus* began to spread southwards into artificially established spruce stands both in lowlands and uplands (Pfeffer, Knížek, 1995). The first record of *I. duplicatus* in Central Europe came from southern Poland (Tredl, 1907; Karpiński, 1925, 1926). In the Czech Republic it was firstly recorded in the eastern parts (Wanka, 1927), its first occurrence in Slovakia was reported almost simultaneously (Roubal, 1941). In northern Austria the first observations of *I. duplicatus* fall within the 1980s (Holzschuh, 1989).

By the end of the 1990s, *I. duplicatus* became widespread both in Slovakia (Turčáni et al., 2001) and the Czech Republic (Holuša et al., 2010). Since 2005, the beetle' main occurrence shifted from the east south- and westwards into the central part of Bohemia (Holuša et al., 2010). The southern border of its central European distribution is likely to be in southern Slovakia (Zúbrik et al., 2006).

Pfeffer, Knížek (1995) stated that the first serious outbreak of *I. duplicatus* probably occurred in North Moravia and Silesia in the early 1990s. At that time, several hundreds of thousands of cubic metres of wood were harvested because of the beetle infestation. The volume of infested wood continued to increase because of the continuing effects of drought and *Armillaria* infestation (Knížek, 1998; Holuša, Liška, 2002). A similar *I. duplicatus* outbreak was recorded simultaneously in southern Poland (Grodzki, 1999).

Today, pheromone monitoring regularly detects *I. duplicatus* in highlands with elevations under 600 m a.s.l. (Holuša et al., 2006), and flying beetles are detected only exceptionally at higher elevations of the exterior ranges of the Western Carpathians (Holuša, 2004).

Currently no occurrence of *I. duplicatus*-infested trees is known in the interior parts of high mountain ranges, i.e., mountains exceeding 1,000 m a.s.l. (e.g.

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Kula, Ząbecki, 2001, 2002a, b). The present study focused on the determination of the current distribution of *I. duplicatus* in the eastern part of the Czech Republic in order to ascertain whether the beetle still occurs only at the foot of the mountains or whether the spruces in the interior parts of the Moravskoslezské Beskydy Mts. and the Hrubý Jeseník Mts. are also endangered.

MATERIAL AND METHODS

Characteristics of the study areas

Infested trees were studied at two localities in the Czech Republic (indicated by stars in Fig. 1):

(1) **Čeladná**, **Umučený** (49°27′24.712″N, 18°20′50.947″E; 660 m a.s.l.). Čeladná is located in the Moravskoslezské Beskydy Mts. (Outer Western Carpathians) and has an area of 623 km^2 and elevations between 508–1,323 m a.s.l. This locality supports the *Abies-Fagus*, *Picea-Fagus*, and *Fagus-Picea* forest vegetation (altitudinal) zones (for definitions, see Viewegh et al., 2003), with a dominance of the *Abies-Fagus* forest vegetation zone (Holuša, 2004). Spruce dominates the woody plants and represents ca. 80 % of the tree community mainly on non-original stands. Seven spruce (*Picea abies* L. (Karst.)) trees (38 m tall) were examined at this locality on August 15, 2012.

(2) **Adolfovice**, at the foot of Bezový Mt. (50°11′47.425″N, 17°9′22.939″E; 691 m a.s.l.). The locality is in the Hrubý Jeseník Mts. (Sudeten subprovince) and has an area of 530 km² and elevations between ca. 400–1,492 m a.s.l. The *Picea-Fagus* forest vegetation zone is dominant (covering 37 % of the area), and at higher elevations *Fagus-Picea* and *Picea* zones are abundant, covering 22 and 12 % of the area. The *Abies-Fagus* zone occupies 27 % of the lower boundaries of the area. Spruce stands of uniform age currently dominate the locality (occupying ca. 80% of the area), and a few stands have a substantial number of broadleaf trees, mainly beech (Culek 1996). Fifteen spruce trees (32 m tall) were examined at this locality on July 29, 2012.

Detection of *I. duplicatus*

In mature forest spruce stands at each study locality, spruce trees 25–35 cm in diameter (at chest height), older than 100 years, and with beetle infestation were cut down just above soil level. For assessment of bark beetle abundance, the entire trunk of each tree was debarked, and the extent of beetle infestation was assessed for each of the 1 m long sections. The width of each section (along the radial tree axis) was equal to half of the section's circumference. Beetles were considered abundant if there were more than 10 entrance holes per 0.1 m^2, and beetles were considered sparse if there were fewer than 9 entrance holes per 0.1 m^2. Stages of bark beetles were recorded, and bark beetles were identified to species based on adult morphology.

RESULTS AND DISCUSSION

I. duplicatus was detected at both localities. At Čeladná, all seven trees were infested with the bark beetles *Ips typographus* (L. 1758) and *Pityogenes chalcographus* (L. 1758). Two trees were abundantly infested (> 10 entrance holes per 0.1 m^2) with *I. duplicatus*. Abundant infestation of the trunks from Čeladná extended from the height of 12.5 ± 0.7 m to 24.5 ± 0.7 m; the stems had developed galleries that contained L2–L3 larvae and maternal beetles. At Adolfovice, all 15 trees were infested with *I. duplicatus*, *I. typographus*, and *P. chalcographus*, but infestations of the latter two species were sparse. Abundant infestation of the trunks with *I. duplicatus* extended from the height of 8.8 ± 0.7 m to 27.9 ± 2.3 m; stems had developed galleries that contained L2–L3 larvae and maternal beetles.

Both localities were similarly situated, in the closed part the valley, ca. 600 m a.s.l., and were ca. 20 km south of the already infested sites at 400 m a.s.l. in the respective valleys (Fig. 1). The developmental stages of *I. duplicatus* detected were the same along the trunks at both localities.

Before the present study, *I. duplicatus* has never been detected within large mountain ranges. Recently, infested trees have been detected in flat to rolling highlands at elevations up to ca. 600 m a.s.l. (Turčáni, 2000; Holuša et al., 2010; personal observations). Although infested trees have occasionally been found in the Moravskoslezské Beskydy Mts. at 800 m a.s.l. (Holuša, 2003), these were growing on slopes adjacent to a lowland area. Contrarily, the infested trees under the present study were situated in closed valleys of extensive mountain ranges with elevations exceeding 1,000 m a.s.l.

The occurrence of *I. duplicatus* within extensive mountain ranges is probably a consequence of its increased abundance in the lowlands (Holuša et al., 2010) and pressures of a growing population along the longitudinal axes of the interior valleys. Both Čeladná and Adolfovice are in forest districts where only ca. 100 overwintering beetles per pheromone trap were captured as recently as 2011 (Knížek, Modlinger, 2012). This, however, is the consequence of their location within mountainous areas where densities of *I. duplicatus* have historically been low. In both areas, the first bark beetle infestations occurred in 2011. A longer-term local bark beetle outbreak exists on the southern slope of Smrk Mt. in the Moravskoslezské Beskydy Mts.; this outbreak including *I. typographus* and *Ips amitinus* (Eichhoff, 1872), is at 1,200 m a.s.l.

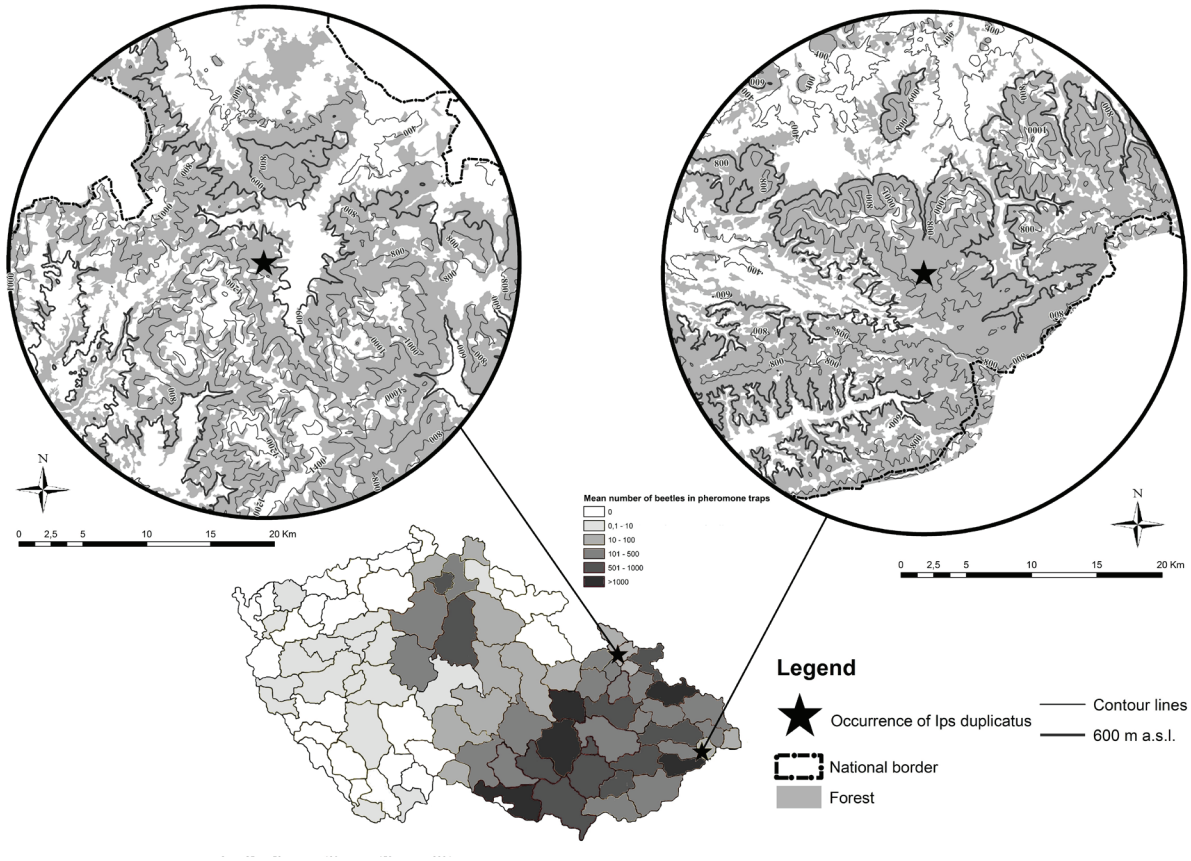

Fig. 1. Locations of Adolfovice (left) and Čeladná (right) (grey area – forest stands) in relation to pheromone monitoring of *Ips duplicatus* in the Czech Republic during 2011 (below, captures of the overwintering generation according to Knížek, Modlinger (2012))

and has been detected by trap trees (Lukášová, Holuša, 2011). The now infested standing trees were studied only in 2010, when infestation with *I. duplicatus* was not found (personal observation).

Both Čeladná and Adolfovice have elevations that only slightly exceed 600 m a.s.l., and detection of *I. duplicatus* at these localities is in accord with the beetle's preference for elevations ≤ 600 m a.s.l. (Grodzki, 2002, 2003; Vakula et al., 2011).

The rate at which *I. duplicatus* is multiplying and spreading in Central Europe indicates that this species has reacted positively to the moderate climate in Central Europe (Holuša et al., 2010). Although *I. duplicatus* is adapted to northern and possibly to mountain conditions, in response to higher temperatures it is capable of producing multiple generations per year. According to most authors, while this species annually produces one generation in the taiga and in northern Poland (Saalas, 1923; Karpiński, 1933; Pfeffer, 1955; Schnaider, Sierpiński, 1955), it produces up to three generations in Central Europe per year (Schnaider, Sierpiński, 1955; Grodzki, 1997; Holuša et al., 2003, 2006). Although *I. duplicatus* occurs at higher altitudes just sporadically (Grodzki, 2002, 2003; Holuša et al., 2010; Vakula et al., 2011), it resembles *I. typographus* here in producing only one generation per year (Holuša et al., 2006). At elevations like Čeladná and Adolfovice (600 m a.s.l.), *I. typographus* can produce 1–2 generations per year (Holuša et al., 2006). In the present study, the mature beetles detected were probably re-emerging maternal beetles (rather than a new generation of adults), which matches the general pattern observed at lower and medium elevations in Central Europe in 2012 (personal observation).

CONCLUSION

Although it has an extensive range, *I. duplicatus* is usually captured in pheromone traps at lower and medium elevations. In addition, the number of beetles captured in pheromone traps correlates with the number in infested trees (Holuša et al., 2010).

Control of *I. duplicatus* is complicated by several factors. First, *I. duplicatus* normally attacks scattered trees within a stand, and the invasion is concentrated in the tree crowns. Second, beetle development is often either completed or considerably advanced before change in needle colour is evident; i.e., infested

trees are recognized only late. Third, *I. duplicatus* only rarely invades trees lying on the ground, and therefore classical traps cannot be used for its control (Grodzki, 1997; Knížek, 1998, 2010; Holuša et al., 2006). The only defence is to identify and harvest (destroy) infested trees before offspring mature and overwinter in the litter.

The occurrence of the double-spined bark beetle, *I. duplicatus*, in the interior of mountain ranges constitutes a new threat for spruce stands in the mountains, at least in the *Abies–Fagus* zone. On the basis of these findings, the recommendation is to monitore *I. duplicatus* with pheromone traps within mountain ranges and at elevations up to ca. 600 m a.s.l. If *I. duplicatus* is captured at these locations, we recommend that trees infested with bark beetles be debarked and studied in detail to confirm *I. duplicatus* occurrence. If the species of *I. duplicatus* is confirmed, foresters must carefully examine other trees in the area to determine the extent of the infestation and to guide management decisions.

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