

Preimaginal development of *Cephalcia lariciphila* during an outbreak in the Czech Republic

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Abstract

An outbreak of *Cephalcia lariciphila* (Wachtl) (Hymenoptera Pamphiliidae) occurred in a mature spruce-larch forests near the village of Větrný Jeníkov (15°30'E, 49°28'N) between 2001 and 2004, when there were from 122.2 ± 118.8 (mean \pm SD) to 276.6 ± 141.8 prepupae per m² of soil. The prepupae density declined to $23.0 \pm 21.2/m^2$ by the spring of 2006 and continued to decline to undetectable levels in 2007-2009. From 2002-2006, the percentage of larvae that were still conymphs in the autumn and spring ranged from 18 to 50%, and the percentage of prepupae parasitized by the wasps *Notopygus bicarinatus* Teunissen and *Ctenopelma lucifer* (Gravenhorst) (Hymenoptera Ichneumonidae) ranged from 4.5 to 10.5%. The number of eggs detected was similar in upper, middle, and lower parts of the tree crown. The average number of eggs per twig (length ca. 30 cm) was always < 1 . In the forest, the first larvae were observed on 15 May and the last on 10 June. In the laboratory at 20 °C, females laid 32.3 ± 7.6 eggs, most eggs hatched 8 days after oviposition, and no egg parasitoid was detected. Examination of larvae that developed in the laboratory and those found in the forest indicated the existence of four instars for males and five instars for females. Larvae live individually and spin and live in their own webs. At 20 °C, the duration of individual instars was shortest for L1 (3.2 ± 1.0 days) and gradually increased with each successive stage (3.4 ± 1.0 for L2; 4.3 ± 1.6 for L3; 4.8 ± 1.2 for L4; and 4.0 ± 0.0 for L5). The duration for entire larval development was ca. 16 days in the laboratory and ca. 20 days in nature. The period during which larvae were evident in the forest lasted about 25 days.

Key words: *Cephalcia lariciphila*, soil samples, density, larval development, parasitism, IPM.

Introduction

Web-spinning sawflies in the genus *Cephalcia* (Hymenoptera Pamphiliidae) are important forest pests in Europe. They have caused severe damage in Austria, the Czech Republic, Denmark, Germany, Poland, Switzerland, and the United Kingdom (Huflejt, 1984; Jensen, 1988; Pschorn-Walcher, 1982). In the Czech Republic, web-spinning sawflies have damaged more than 100,000 ha of spruce forests in recent years (Liška *et al.*, 1991; Liška and Holuša, 2006; Martinek, 1980; 1991; 1992). Although the spruce-feeding *Cephalcia abietis* (L.), *Cephalcia alpina* (Klug), and *Cephalcia arvensis* Panzer are the most abundant species in central Europe (Liška *et al.*, 1991), the larch specialist *Cephalcia lariciphila* (Wachtl) can also reach outbreak levels. This species has become a serious forest pest, with several outbreaks observed in the last 150 years in Europe (summarized by Pschorn-Walcher, 1982).

In 2000, a *C. lariciphila* outbreak near the village of Větrný Jeníkov resulted in total defoliation of larch trees over a 4-ha area and large reductions in radial increment (Vejpustková and Holuša, 2006). *C. lariciphila* thus represents a potentially significant pest that merits not only monitoring (Holuša and Kuras, 2009) but also integrated control under expert guidance. Because the data regarding *C. lariciphila* flight activity collected during this outbreak differed from previously published data (Holuša and Kuras, 2009), the present study was conducted to clarify the ecology of this species and incorporate the information into IPM. The specific objectives were to (i) define the length of *C. lariciphila* embryonic development; (ii) compare the intensity of oviposition in different sections of the crown; (iii) quantify the length

of larval development, the number of instars, and the percentage of larvae that become flying adults; and (iv) quantify the level of parasitism and identify the species of parasitoids.

Materials and methods

Study area and plots

The study area was located near the village of Větrný Jeníkov (15°30'E, 49°28'N and 650 m a.s.l.) in the central part of the Czech Republic. The larch (*Larix decidua* Mill.) trees in this area were growing in mono-specific patches or groups within an 80- to 100-year-old spruce [*Picea abies* (L.) Karst.] plantation. The vegetation zone is the *Abieti-fagetum oligotrophicum* association (Plíva, 1991). The climate of the area is moderately warm and dry (Culek, 1996). According to data for 1955-2001 from the nearest weather station (at Přebyslav, 15°45'45"E, 49°34'58"N; 530 m a.s.l.), the annual mean temperature was 6.8 °C, the mean temperature during the May-September growing season was 12.8 °C, the mean annual total precipitation was 691.2 mm, and the mean sum of precipitation during the growing season was 442.6 mm. Weather in 2002 is described in figure 1.

Quantification of *C. lariciphila* larvae in soil beneath larch trees and parasitism by ichneumonids

In the forest stand, eight isolated groups of larches, approximately 50-100 m apart, were selected; the diameter of the trees was about 30 cm. Five soil plots (0.5 x 0.5 m each) were sampled in each of the eight groups of larches. The plots were located beneath the tree crowns, along a contour line, at intervals of 5-10 m.

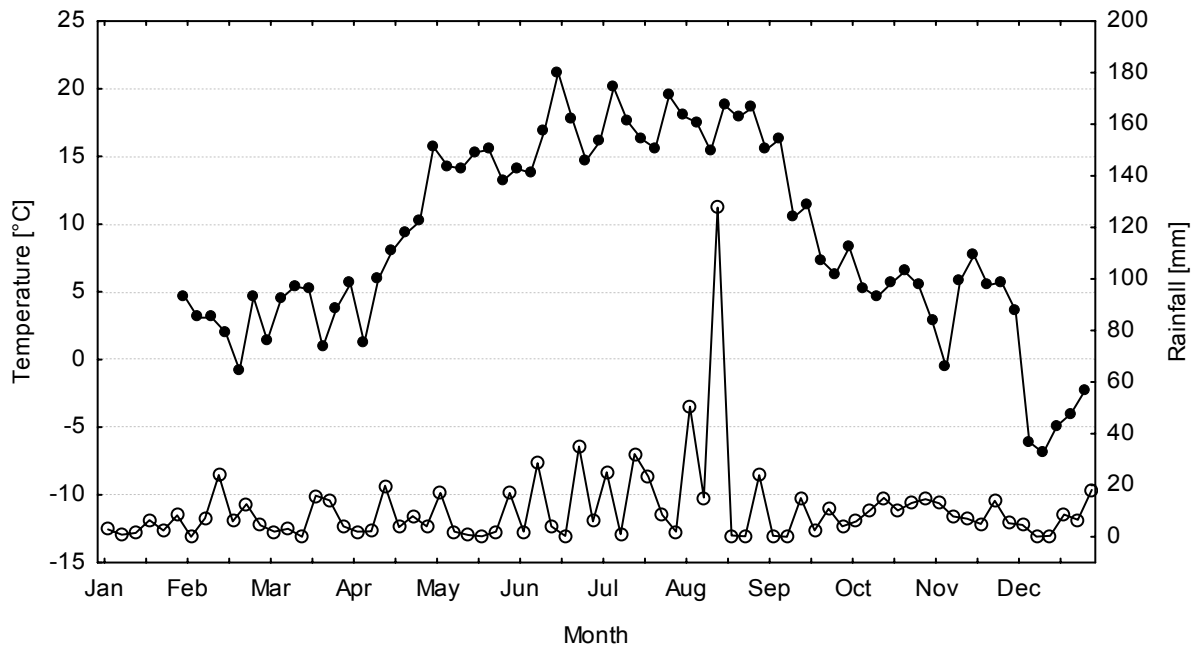


Figure 1. Mean daily temperature (filled circles) and total precipitation (empty circles) for 5-day intervals at the Pribyslav hydrometeorological station in 2002. (www.worldclimate.com)

From 2002 to 2009, litter (ca. 15 cm deep) and the upper layer of soil (the Ah horizon to a depth of 5 cm) were collected separately in the spring of each year (in March or April, depending on the accessibility of the terrain) and also in October in some years; different plots were designated and sampled each year. In the laboratory, both samples (litter and soil) were placed on a coarse sieve with 10 x 10 mm openings, and the material that passed through the sieve was examined for *C. lariciphila* prepupae. The prepupae were identified to species based on Wiitassari (2002). The prepupae were counted and determined to be eonymphs or pronymphs depending on the presence/absence of the pupal eye. *C. lariciphila* prepupae with adhering cocoons of ichneumonids (only the head capsule and rolled skin of parasitized prepupae remained) were considered to be parasitized by ichneumonids. For identification of ichneumonids, the cocoons were placed in 10-cm-diameter Petri dishes (one dish per plot per year) with forest litter. The dishes, which were regularly moistened and were covered with monofilament mesh with openings of 1 mm so that emerging wasps could not escape, were kept at 20 °C and with 16 h of daylight until the adults emerged. The wasps were identified according to Yu *et al.* (2005). All material was collected by the Forestry and Game Management Research Institute, and wasp determinations were made by J. Šedivý for material from 2003 and by K. Holý for material from 2004 to 2006.

Quantification of *C. lariciphila* eggs and larvae in larch trees

At one plot in the centre of the study area, one sample larch was felled on 15, 25, 31 May and 10 June 2002. Ten branches from each of the upper, middle, and lower sections of the crown were taken from each sample tree. The number of brachyblasts with needles and the num-

ber of *C. lariciphila* eggs and larvae were counted on 30-cm segments of these branches. *Cephalcia* eggs were assumed to be those of *C. lariciphila*, and larvae were identified according Lorenz and Kraus (1957). Older larvae (from sample trees felled 25 May and 31 May 2002) were taken to the laboratory, and their head capsule widths were measured to obtain information about numbers of instar stages.

Fecundity and development times in the laboratory

Fecundity, the length of egg and larval development, and the width of heads capsule for different instars were determined in the laboratory. Adults were captured on the ground in the study area on 27 April 2002 and 30 April 2003. One male and one female were reared together in one Drigalski dish (10 cm in diameter and 2 cm high). They were temporarily fed from a small cotton ball (0.5 cm diameter) that was saturated with sugar water. One larch twig with two opening buds was placed in the dish. The cut end of the twig was wrapped with wet padding to prevent rapid wilting of the foliage. At the end of each day, the twig with deposited eggs was removed and replaced with a fresh twig until the adults died. There were 42 replicate dishes in 2002 and 31 replicate dishes in 2003, and the dishes were kept at 20 °C and with a 16/8 h light/dark photoperiod. The number of eggs produced by each female was determined.

After the eggs on the twigs were counted, each twig with eggs was placed in one Drigalski dish at 20 °C and with a 16/8 h light/dark photoperiod. The time required for hatch was determined for 614 eggs.

When the eggs hatched, the larvae were kept in groups of two or three for 7 days but were subsequently kept as individuals in Drigalski dishes at 20 °C and with a 16/8 h light/dark photoperiod. For food, one larch twig was placed in each dish. New shoots were given to the

larvae after they had consumed most of the old shoots or if the shoots had wilted or decayed. Each larva ($n = 71$) was examined daily. In 2002 and 2003, the number of days required for the larvae ($n = 38$ in 2002 and 33 in 2003) to develop into adults was determined. The width of the head capsule was also measured in 2002. When the larvae were nearly mature, their colour changed from greenish grey colour with dark stripes to yellow, and soil was added to the dishes.

Statistical analyses

The numbers of larvae in litter and soil were compared among sample dates with the Kruskal-Wallis test. The numbers of eggs and larvae on single twigs in different parts of the tree crown were compared using one-way ANOVA. Development times determined in the laboratory were compared for 2002 and 2003 by a two-sample t -test. Statistica 8.0 was used for statistical analysis.

Results

Quantification of *C. lariciphila* larvae in soil beneath larch trees and parasitism by ichneumonids

From spring 2002 to spring 2004, the mean number of prepupae per m^2 of soil ranged from 122.2 ± 118.8 to 276.6 ± 141.8 (the differences were not statistically significant; $\chi^2 = 23.03$; $p > 0.01$) (table 1). From autumn 2004 to autumn 2005, the means were lower and ranged from 43.2 ± 37.6 to 78.9 ± 67.2 (the differences were not statistically significant; $\chi^2 = 10.28$; $p > 0.01$). From spring 2006 to spring 2009, the means ranged from 0 to 23.0 ± 21.2 (the differences were not statistically significant; $\chi^2 = 42.27$; $p > 0.01$). From 18% to 50% of the prepupae were still eonymphs from spring 2002 to autumn 2006 (table 1).

The ichneumonids that hatched from the cocoons were identified as *Notopygus bicarinatus* Teunissen and *Ctenopelma lucifer* (Gravenhorst). The percentage of larvae parasitized by *N. bicarinatus* and *C. lucifer* ranged from 4.5 to 10.5% between 2002 and 2009 (table 1).

Quantification of *C. lariciphila* eggs and larvae in larch trees

In 2002, eggs on a felled sample tree were detected only on 15 May. The average number of eggs on one twig (ca. 30 cm long) was always < 1 . No significant difference ($F = 1.15$; $p > 0.10$) was detected for numbers of eggs and larvae per twig in the lower, middle, and upper sections of the crown (table 2, total number of observed eggs was 275 and larvae was 162). None of the eggs had a dark hue, i.e., none was parasitized by chalcid wasps of the genus *Trichogramma* Westwood; all were a light green (which is their colour when they are laid) or grey (which is their colour before hatching) ($n = 117$). A significant difference was detected between the numbers of eggs and larvae per twig during individual examinations. Fewer numbers of eggs and larvae were detected on 25 May 2002 than on 15 May 2002 but numbers were similar on 25 May 2002 and 31 May 2002 [$F(3, 108) = 45.23$, $p < 0.0001$] (table 2). Only a single larva was discovered on 10 June 2002.

Table 1. Number (mean \pm SD) of *C. lariciphila* prepupae, eonymphs, and prepupae and eonymphs with parasitoid cocoons per m^2 of soil. Prepupae and eonymphs columns include individuals with parasitoid cocoons.

	Stage and presence of parasitoids		
	Prepupae	Eonymphs	Parasitoid cocoons
Spring 2002	177.4 ± 131.5	62.7 ± 63.0	16.8 ± 11.4
Autumn 2002	276.6 ± 141.8	80.0 ± 42.8	16.4 ± 12.8
Spring 2003	154.2 ± 125.0	60.0 ± 62.4	9.7 ± 16.0
Autumn 2003	122.2 ± 118.8	30.2 ± 47.4	7.9 ± 10.2
Spring 2004	216.0 ± 199.7	102.6 ± 97.1	18.1 ± 23.4
Autumn 2004	43.2 ± 37.6	7.8 ± 12.2	1.7 ± 2.4
Spring 2005	78.9 ± 67.2	36.2 ± 31.1	2.1 ± 3.2
Autumn 2005	57.0 ± 47.3	15.0 ± 15.0	2.6 ± 3.1
Spring 2006	23.0 ± 21.2	12.2 ± 12.5	2.2 ± 2.5
Autumn 2006	5.8 ± 9.7	2.9 ± 5.2	0.5 ± 1.8
Spring 2007	13.6 ± 9.2	0	0
Autumn 2007	0	0	0
Spring 2008	0	0	0
Autumn 2008	0	0	0
Spring 2009	0	0	0

Table 2. Number (mean \pm SD) of eggs and larvae per twig (30 cm long) in different crown sections in 2002 [$F(6, 108) = 0.86$, $p > 0.50$].

Crown section	15 May	25 May	31 May	10 June
Lower	0.31 ± 0.16	0.11 ± 0.11	0.13 ± 0.13	0.01
Middle	0.21 ± 0.15	0.04 ± 0.03	0.11 ± 0.09	0
Upper	0.25 ± 0.07	0.02 ± 0.03	0.08 ± 0.05	0

The distribution of head capsule measurements for larvae collected in the field (and for larvae reared in the laboratory) indicated the existence of five instars for *C. lariciphila*: L1, 0.70-0.80 mm; L2, 0.90-1.10 mm; L3, 1.20-1.60 mm; L4, 1.70-2.10 mm; and L5, 2.2 mm (figure 2).

On 15 May 2002 in the forest, larvae had already begun to hatch; of the total number of eggs, 7.8% had hatched in the lower section of the crown, 13.5% in the middle section, and 10.4% in the upper section ($n = 308$). On 25 May 2002, eggs were no longer detected. On this date, the proportion of larvae in L1 was very small (2%), while older larvae predominated: 13% were L2, 70% were L3, and 15% were L4 ($n = 59$). On 31 May 2002, no L1 larvae was found, the proportion of larvae of L2 was very small (2%), and L3 dominated (62% were L3 and 36% were L4; $n = 69$). On 10 June, only one larva was detected, indicating that the development of the entire population was complete and had lasted ca. 25 days. If the last larvae hatched between 15 and 25 May, it can be assumed that the development of a single larva in the field required fewer than 20 days.

On 22 May 2003, eggs were collected in the field, and most were grey. The field-collected eggs hatched after 3.1 ± 1.5 days ($n = 112$), indicating that they had undergone a substantial part of their embryonic development

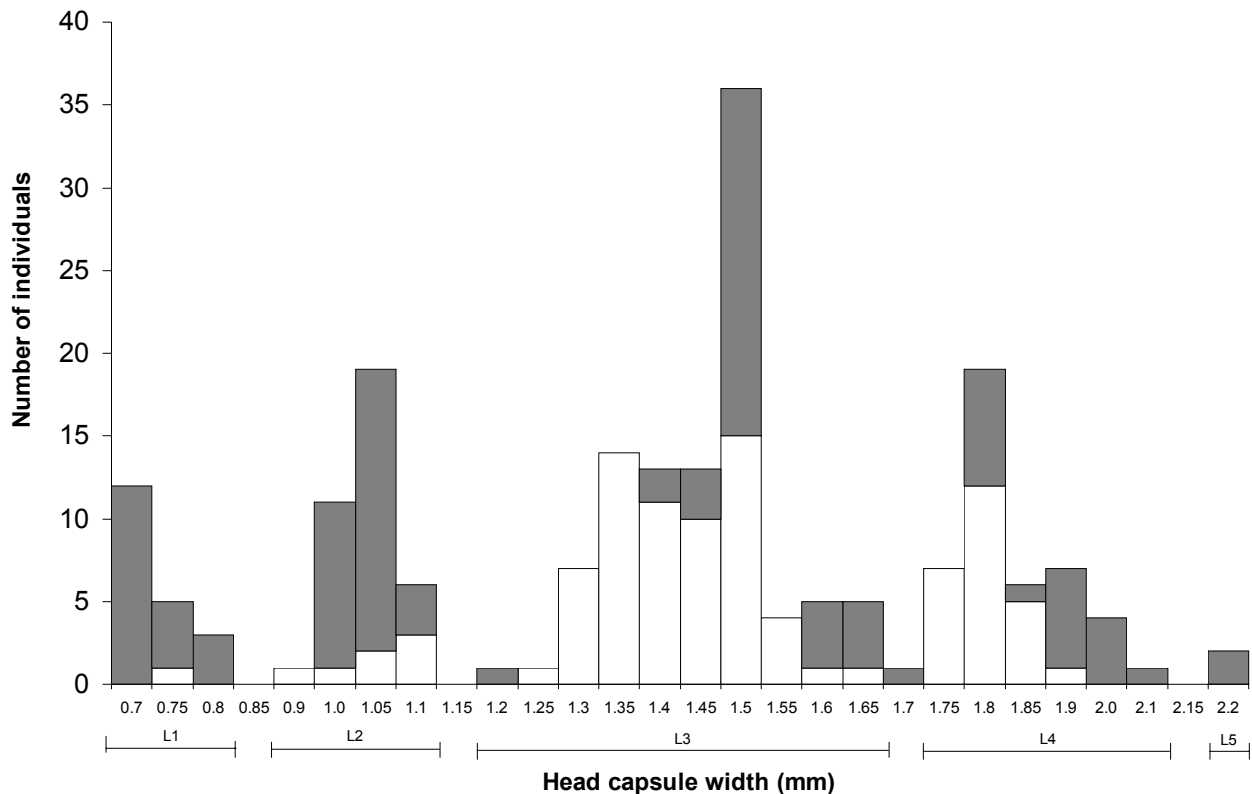


Figure 2. Width of head capsules of *C. lariciphila* larvae in 2002 (grey bars: larvae reared in the laboratory; white bars: larvae from the forest).

in nature. No parasitoid was detected on the larvae that developed from these field-collected (the number of surviving larvae was 29).

Fecundity and development times in the laboratory

In the laboratory at 20 °C, the average number of eggs laid by an individual female (n = 17) was 32.3 ± 7.6 (SD). The females laid eggs immediately after enclosure for rearing. Embryonic development lasted 8.5 ± 0.9 days (n = 138).

In laboratory-reared larvae, four instars were detected most often but five instars occurred for two individuals (five instars required 17 days of larval development) and three instars occurred for one individual (three instars required 13 days of larval development). The larvae were solitary, and each spun and lived in its own web. The duration of the first instar L1 was shortest (n = 38; 3.2 ± 1.0 days) and increased slightly with each subsequent stage: 3.4 ± 1.0 days for L2 (n = 34); 4.3 ± 1.6 days for L3 (n = 22); 4.8 ± 1.2 days for L4 (n = 10); and 4.0 ± 0.0 days for L5 (n = 2). The average duration of the entire larval development in the laboratory was 15.6 ± 1.3 days in 2002 (n = 12) and 16.2 ± 3.1 days in 2003 (n = 33) (the difference was not significant; $t = 0.77$; $p > 0.10$). As noted earlier, the distribution of head capsule measurements for larvae reared in the laboratory indicated the existence of five instars (figure 2).

Discussion

C. lariciphila is the only species of *Cephalcia* that is a larch specialist in Europe (Pschorn-Walcher, 1982). There were only very old records of *C. lariciphila* outbreaks in the Czech Republic before 2000 (Wiehl, 1896; 1897), when an outbreak of the insect occurred around the village of Větrný Jeníkov (Kapitola and Liška, 2001; Holuša and Drápela, 2004). It is possible, however, that an outbreak occurred near Větrný Jeníkov in 1996 (Vejpustková and Holuša, 2006). In 2001, there were 200-500 prepupae/m² of soil in the outbreak area (Kapitola and Liška, 2001). According to the present study, the number remained high (150-300 prepupae/m²) through the spring of 2004. These values fall within the range of values (57-650 prepupae/m²) reported by Pschorn-Walcher (1982), even though the values in that study related to young forests (sapling and pole stages) in which the population of sawflies caused total defoliation. Based on the numbers of prepupae, we conclude that an outbreak of *C. lariciphila* species occurred near Větrný Jeníkov from 2000 to 2004 and ended in the autumn of 2005; since 2005, the population has been in decline. Some outbreaks of *C. lariciphila* have been shorter (summarized by Pschorn-Walcher, 1982 and Ozaki *et al.*, 2004), but an outbreak that lasted longer than 4 years was documented in the United Kingdom (Billany and Brown, 1980). For the entire period, the outbreak near Větrný Jeníkov was restricted to 4 ha of

spruce-larch forest and did not expand, even though larch forests are also present in the surrounding area. In this case, site quality, which depends on the type, structure, and quality of the soil, may have greatly affected sawfly outbreaks. Trees growing in poor sites are often physiologically stressed, resulting in increased food quality for sawflies (McMillin and Wagner, 1993).

C. lariciphila is a univoltine species that overwinters as a prepupa either in eonymph (extended diapause) or pronymph (annual development) form (Pschorn-Walcher, 1982). Part of the population remains in the eonymph phase longer than one winter, and adults of a single generation can emerge at three or four different times (Luitjes and Minderman, 1959). The observed percentage of individuals with prolonged diapause (from 18 to 50%) during the Czech outbreak is broadly within the range of previous data (31-44%, reported by Pschorn-Walcher, 1982), although the percentage can also be much lower (Billany and Brown, 1980).

Factors influencing population dynamics of *C. lariciphila* are not known. However, a strong bottom-up effect can be assumed to trigger outbreaks of this species in part because strong bottom-up effects are thought to cause eruptive outbreaks in tenthredinids and diprionids sawflies on conifers (Price *et al.*, 2005). Larch appears to be particularly favourable for tenthredinid sawflies as these species evolve to use conifers rather than angiosperms as hosts (Price *et al.*, 2005). Larch is an unusual conifer, being both deciduous and having indeterminate growth of leading shoots (Kozłowski, 1964; Haack and Mattson, 1993). Thus, it resembles angiosperms more than other conifers and has been colonized relatively frequently by tenthredinid sawflies (Price *et al.*, 2005). Our results suggest that parasitism and mortality during hatching do not affect population dynamics in that the level of parasitism by wasps was approximately the same during outbreak and non-outbreak years. Population dynamics are probably affected by specialized predators such as insectivores and possibly nematodes but not by rodents (Holuša and Turčáni, 2007). Although a decline in *C. lariciphila* in the United Kingdom was attributed to the larval parasitoid *Olesicampe monticola* Hedwig, which parasitized over 90% of the prepupae (Billany and Brown, 1980), population control by ichneumonids seems unlikely. Eichhorn (1990) concluded that larval parasites have no regulatory effect on *C. abietis* populations, and Battisti *et al.* (2000) concluded that natural enemies are unable to keep *C. arvensis* populations at an endemic level.

In a previous study of the same outbreak reported here, adult sawflies started to emerge from the ground in the middle of April or during the last 10 days of April (Holuša and Kuras, 2009). All or most sawflies had emerged by the end of April, and only a small proportion emerged later. The flight activity was continuous and reached its peak at the end of April or the beginning of May. The last ones had emerged by the beginning or middle of May (Holuša and Kuras, 2009).

C. lariciphila fecundity in the current study (32.3 ± 7.6 eggs/female) was similar to the fecundity (25 eggs/female) reported for the Netherlands (Luitjes and Minderman, 1959) but was substantially lower than the

84 eggs/female reported by Pschorn-Walcher (1982). The latter value seems unreasonably high because the size of *C. lariciphila* adults is similar to that of *Cephalcia* species with lower fecundity, e.g., *C. arvensis* (Battisti and Stergulc, 1988; Battisti, 1993). Species with higher fecundity, like *C. abietis*, are much larger than *C. lariciphila* (Martinek 1980; Pschorn-Walcher, 1982). Females apparently laid less than 1 egg per twig in the forest but several dozens of eggs per twig in the laboratory (Billany and Brown, 1980; and the current study). The fertility of *C. abietis* females can be influenced by the temperature during swarming (Gruppe, 1998).

A previous report indicated that *C. lariciphila* females laid most eggs in the upper sections of the tree crown (Pschorn-Walcher, 1982), but in the present study the number of eggs did not differ in the lower, middle, and upper sections of the crown. The significant drop in abundance of larvae between 15 and 26 May 2002 (table 2) could be due merely to the selection of a sample tree with an originally lower number of eggs. The drop in abundance might also be explained by high mortality of larvae of the youngest instars.

If *C. lariciphila* swarming had culminated before the end of April and the larvae had hatched on 15 May 2002, then embryonic development lasted ca. 15-20 days in the forest. This agrees well with previous reports that embryonic development required 3-4 weeks (Roehrig, 1953) or 3.5-5.0 weeks (Luitjes and Minderman, 1959) in nature. In the current study, embryonic development of eggs maintained at 20 °C in the laboratory required only ca. 8 days, which corresponds to an earlier observation of a shorter duration of development (10-20 days) in the laboratory than in the field (Billany and Brown, 1980).

The observed total period of *C. lariciphila* larval development in the current study (15 days at 20 °C) also was significantly shorter than the 22-26 days at 16-20 °C and 28 days at 13-16 °C reported by Pschorn-Walcher (1982). Larval development of our population in the field was also faster than previously reported, i.e., development in the field required 2-3 weeks in the current study versus 3.5-5.0 weeks in Luitjes and Minderman (1959) and 4-5 weeks in Billany and Brown (1980). The last mature larvae were found on 10 June 2002, by which time the larches were already completely defoliated (Holuša and Drápela, 2004). In Schleswig-Holstein, most larvae were still in the third or fourth instar on 7 July and feeding extended into the second half of July (Roehrig, 1953). The shorter larval development times in the current study are surprising because the average temperature was higher in all previously studied localities and the weather was normal in 2002 in the current study (figure 1).

When *C. lariciphila* larvae were reared in the laboratory, three to five instars were recorded, which correspond to four (or three) for male larvae and five for females (see also Pschorn-Walcher, 1982). A different number of instars for males and females was unambiguously confirmed for *Cephalcia masuttii* Battisti et Boato (Battisti and Boato, 1998). The fifth instar was not detected in nature in the current study because sample trees were felled on 31 May and 10 June. That is to say,

if larvae hatched on 15 May and the entire larval development lasted 15-20 days, then larvae completed development between 31 May and 10 June. Thus, larvae of the fifth instar were probably present but undetected because of the time between sampling. The distribution of head capsule measurements for 3rd and 4th instar larvae shows two peaks, which could correspond to different values of head capsule measurements for male and female larvae.

Although no egg parasitoid of *C. lariciphila* has been reported (cf. also Pschorn-Walcher, 1982), we cannot exclude the possibility of egg parasitism, which can be as high as 90% for web-spinning sawflies of the genus *Cephalcia* (Martinek, 1980; Eichhorn, 1990). The level of larval parasitism over the years in the current study ranged from 4.5 to 10.5%, which was lower than previously recorded for ichneumonids on *C. lariciphila* (Pschorn-Walcher, 1982; Billany *et al.*, 1985) and on *C. abietis* (Bogenschutz and Eichhorn, 2000).

Larvae of *C. lariciphila* frequently cause complete defoliation on larch, which does not lead to tree death (Billany and Brown, 1980) but does reduce tree height and needle size (Billany and Brown, 1980) and radial growth (Vejpustková and Holuša, 2006). Because larvae of *C. lariciphila* cause economic losses, they require integrated pest management. A threshold value of 200 prepupae/m² indicates the risk of total defoliation (Holuša and Drápela, 2004). Although monitoring prepupae via soil counts is useful, sufficient numbers of samples must be collected to obtain reasonably accurate estimates (Holuša and Drápela, 2004). It is also possible to monitor the population by trapping imagos on yellow sticky panels (Holuša and Kuras, 2009). If chemical intervention with larvicides is considered necessary, this should be carried out when all females have emerged and laid their eggs (Holuša and Kuras, 2009). In the outbreak area of the current study, this would be in mid-May. Because larvae develop very rapidly, a later intervention date would fail to affect the majority of the larval population. In addition to chemical controls, soil applications of the entomopathogenic nematode *Steinernema feltiae* (Filipjev) have potential for biological control of sawfly prepupae (Georgis and Hague, 1988). This might represent a viable alternative to chemical control of *C. lariciphila* and other *Cephalcia* species (Battisti, 1994).

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References

BATTISTI A., 1993.- Bionomics of the spruce web-spinning sawfly *Cephalcia arvensis* Panzer (Hym., Pamphiliidae) in North-eastern Italy.- *Journal of Applied Entomology*, 115: 52-61.

- BATTISTI A., 1994.- Effects of entomopathogenic nematodes on the spruce web-spinning sawfly *Cephalcia arvensis* Panzer and its parasitoids in the field.- *Biocontrol Science and Technology*, 4: 95-102.
- BATTISTI A., BOATO A., 1998.- *Cephalcia masuttii* sp. n. (Hymenoptera: Pamphiliidae), a new web-spinning sawfly living on spruce.- *European Journal of Entomology*, 95: 251-262.
- BATTISTI A., STERGULC F., 1998.- Notizie preliminari su pullulazioni di *Cephalcia arvensis* Panzer (Hym. Pamphiliidae) in peccete delle Prealpi Orientali, pp 431-438. In: *Atti XV Congresso Nazionale Italiano di Entomologia*, L'Aquila, Italy, 13-17 June 1988.
- BATTISTI A., BOATO A., MASUTTI L., 2000.- Influence of silvicultural practices and population genetics on management of the spruce sawfly, *Cephalcia arvensis*.- *Forest Ecology and Management*, 128: 159-166.
- BILLANY D. J., BROWN R. M., 1980.- The web-spinning larch sawfly *Cephalcia lariciphila* Wachtl. (Hymenoptera: Pamphiliidae) a new pest of Larix in England and Wales.- *Forestry*, 53: 71-80.
- BILLANY D. J., WINTER T. G., GAULD I. D., 1985.- *Olesicampe monticola* (Hedwig) (Hymenoptera: Ichneumonidae) redescribed together with notes on its biology as a parasite of *Cephalcia lariciphila* (Wachtl.) (Hymenoptera: Pamphiliidae).- *Bulletin of Entomological Research*, 75: 267-274.
- CULEK M., 1996.- *Biogeografické členění České republiky*.- Enigma, Prague, Czech Republic.
- EICHHORN O., 1990.- Untersuchungen über die Fichtengespinstblattwespen *Cephalcia* spp. Panz. (Hym., Pamphiliidae) III. Populationsdynamische Faktoren und Gesamt-schau.- *Journal of Applied Entomology*, 110: 321-345.
- EICHHORN O., BOGENSCHUTZ H., 2000.- Untersuchungen über die Fichtengespinstblattwespen *Cephalcia* spp. Panz. (Hym., Pamphiliidae) IV. Massenwechsel von *Cephalcia abietis* L. im oberschwäbischen Forstrevier Erolzheim (Fbz. Ochsenhausen).- *Journal of Applied Entomology*, 124: 131-149.
- ESCHERICH K., 1942.- *Die Forstinsekten Mitteleuropas. Viertes Band. Hymenoptera (Hauflügler) und Diptera (Zweiflügler)*.- Verlag von Paul Parey, Berlin, Germany.
- GEORGIS R., HAGUE N. G. M., 1988.- Field evaluation of *Steinernema feltiae* against the web-spinning larch sawfly *Cephalcia lariciphila*.- *Journal of Nematology*, 20: 317-320.
- GRUPPE A., 1998.- Influence of genotype and temperature on the fitness of the webspinning sawfly *Cephalcia abietis* (Hymenoptera: Symphyta, Pamphiliidae), pp. 439-440. In: *Book of abstracts, 6th European Congress of Entomology* (BRUNNHOFER V., SOLDÁN T., Eds), České Budějovice, Czech Republic, 23-29 August 1998.
- HAACK R. A., MATTSON W. J., 1993.- Life history patterns of North American tree-feeding sawflies, pp. 503-545. In: *Sawfly life history adaptations to woody plants* (WAGNER M., RAFFA K. F., Eds).- Academic Press Inc., San Diego, USA.
- HOLUŠA J., DRÁPELA K., 2004.- Logistic regression approach to the forecast of tree defoliation caused by sawflies (Hymenoptera: Symphyta).- *Journal of Forestry Science*, 50: 284-291.
- HOLUŠA J., KURAS T., 2009.- Diurnal behavior of *Cephalcia lariciphila* (Hymenoptera: Pamphiliidae): relation to climatic factors and significance for monitoring.- *European Journal of Forest Research*, 129: 243-248.
- HOLUŠA J., TURČÁNI M., 2007.- Předběžná analýza faktorů ovlivňujících populační dynamiku ploskohřbetky *Cephalcia lariciphila* v okolí Větrného Jeníkova (Česká republika). In: *Zoologické dny Brno 2007. Sborník abstraktů z konference 8.-9. února 2007* (BRYJA J., ZUKAL J., ŘEHÁK Z., Eds). Ústav biologie obratlovců AV ČR, Brno: 67.

- HOLUŠA J., LIŠKA J., ŠVESTKA M., 2004.- Listožravý a savý hmyz, pp. 40-49. In: *Výskyt lesních škodlivých činitelů v roce 2003 a jejich očekávaný stav v roce 2004* [Occurrence of forest damaging agents in Czechia in 2003 and forecast for 2004] (KAPITOLA P., KNÍŽEK M., BAŇAŘ P., Eds).- Zpravodaj Ochrany Lesa, Supplementum 2004.
- HUFLEJT T., 1984.- Zagrożenie drzewostanów swierkowych przez ważniejsze rosliniarki.- *Prace Instytutu Badawczego Lesnictwa B*, 1: 41-56.
- JENSEN T. S., 1988.- Phenology and spatial distribution of *Cephalcia* (Hym., Pamphiliidae) imagines in Danish spruce forests.- *Journal of Applied Entomology*, 106: 402-407.
- KAPITOLA P., LIŠKA J., 2001.- A local outbreak of *Cephalcia lariciphia* (Wachtl) in Czechia.- *Journal of Forest Science*, (Special issue) 47: 111-112.
- KOZŁOWSKI T. T., 1964.- Shoot growth in woody plants.- *Botanical Review*, 30: 335-392.
- LIŠKA J., HOLUŠA J., 2003.- Listožravý hmyz, pp. 24-31. In: *Výskyt lesních škodlivých činitelů v roce 2002 a jejich očekávaný stav v roce 2003* [Occurrence of forest damaging agents in Czechia in 2002 and forecast for 2003] (KAPITOLA P., KNÍŽEK M., Eds).- Zpravodaj Ochrany Lesa Supplementum 2003.
- LIŠKA J., PÍCHOVÁ V., KNÍŽEK M., HOCHMUT R., 1991.- Přehled výskytu lesních hmyzích škůdců v českých zemích.- *Lesnické průvodce*, 3: 1-37.
- LORENZ H., KRAUS M., 1957.- Die Larvensystematik der Blattwespen (Tenthredinoidea und Megalodontoidea). Akademie-Verlag, Berlin, Germany.
- LUITJES J., MINDERMAN G., 1959.- Die spinselbladwesp vande lariks.- *Nederlands Bosbouw Tijdschrift*, 31: 245-253.
- MARTINEK V., 1980.- Zum Problem der Übervermehrung der Gemeinen Fichtengespinstblattwespe (*Cephalcia abietis* L.) (Hym.: Pamphiliidae) in Bohmen.- *Rozpravy Československé Akademie Ved., Řada Matematicko-přírodovědných Věd*, 90: 1-165.
- MARTINEK V., 1991.- Přemnožení ploskohřbetky severské (*Cephalcia arvensis* Panz.) (Hym., Pamphiliidae) ve východních Čechách [An outbreak of the web-spinning sawfly *Cephalcia arvensis* Panz. (Hym., Pamphiliidae) in eastern Bohemia].- *Lesnictví (Prague)*, 37: 543-570.
- MARTINEK V., 1992.- Nový škůdce smrku, ploskohřbetka černá (*Cephalcia fallenii* Dalm.) (Hymenoptera, Pamphiliidae), v Orlických horách [The sawfly *Cephalcia fallenii* (Dalm.) (Hym., Pamphiliidae) as a new pest on spruce on the Orlicke hory Mts.].- *Lesnictví (Prague)*, 38: 205-220.
- MCMILLIN J. D., WAGNER M. R., 1993.- Influence of stand characteristics and site quality on sawfly population dynamics, pp. 333-361. In: *Sawfly life history adaptations to woody plants* (WAGNER M., RAFFA K. F., Eds).- Academic Press Inc., San Diego, USA.
- OZAKI K., FUKUYAMA K., ISONO M., TAKAO G., 2004.- Simultaneous outbreaks of three species of larch web-spinning sawflies: influences of weather and stand structure.- *Forest Ecology and Management*, 187: 75-84.
- PLÍVA K., 1991.- *Funkčně integrované lesní hospodářství – 1. díl, Přírodní podmínky v lesním plánování*.- ÚHÚL Brandýs nad Labem, Czech Republic.
- PRICE P. W., ROININEN H., OHGUSHI T., 2005.- Adaptive radiation into ecological niches with eruptive dynamics: a comparison of tenthredinid and diprionid sawflies.- *Journal of Animal Ecology*, 74: 397-408.
- PSCHORN-WALCHER H., 1982.- Unterordnung Symphyta, Pflanzenwespen, pp. 4-234. In: *Die Forstschädlinge Europas 4. Hautflügler und Zweiflügler* (SCHWENKE W., Ed.).- Parey, Hamburg, Berlin, Germany.
- ROEHRIG E., 1953.- Die Larchengespinstblattwespe *Cephalcia alpina* Klug. Untersuchungen bei einer Massenvermehrung in Schleswig-Holstein.- *Zeitschrift für Angewandte Entomologie*, 35: 207-245.
- VEJPUSTKOVÁ M., HOLUŠA J., 2006.- Impact of defoliation caused by web spinning sawfly *Cephalcia lariciphila* (Hymenoptera: Pamphiliidae) larvae on tree-ring formation of larch (*Larix decidua*) around Větrný Jeníkov, Czech Republic.- *European Journal of Forest Research*, 125: 391-396.
- WIEHL J., 1896.- Über das Auftreten einer neuen Lyda-art (Bemerkung).- *Verhandlungen der Forstwirte von Mahren und Schlesien*, 47: 458-459.
- WIEHL J., 1897.- Über das Auftreten einer neuen Lyda-art (Bemerkung).- *Verhandlungen der Forstwirte von Mahren und Schlesien*, 48: 363.
- WITASSARI M., 2002.- *Sawflies I*.- Tremex press Ltd., Helsinki, Finland.
- YU D. S., VAN ACHTERBERG C., HORSTMANN K., 2005.- *World Ichneumonoidea 2004. Taxonomy, biology, morphology and distribution (Ichneumonidae)*.- Taxapad 2005 (Scientific names for information management). Interactive electronic catalogue on DVD/CD-ROM, Taxapad, Vancouver, Canada.

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