UDK 630* 453 (001)

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 1–2 (2014): 293–300

OUTBREAK OF THE SPRUCE WEB-SPINNING SAWFLY *Cephalcia arvensis* (HYMENOPTERA: PAMPHILIIDAE) IN SLOVENIA

GRADACIJA SMREKINE OSE PREDIVICE *Cephalcia arvensis* (HYMENOPTERA: PAMPHILIIDAE) U SLOVENIJI

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Summary

The first local outbreak of the field web-spinning sawfly (*Cephalcia arvensis*) appeared in 2009 on one location on 106 ha in the northern part of Slovenia in a stand of 60-90-year-old *Picea abies* and on 600-800 m a. s. l. In the period from 2009 to 2011 the density of the prepupae, bio-ecology and defoliation of the trees were studied.

The density of the population of prepupae of *Cephalcia* species was studied on the six plots in the soil samples (25 x 25 x 20 cm). In 2009 it was high (average = 595 individuals/m^2 of soil), while in 2010 the average number of prepupae was lower for 68%. The collected data of soil and air temperatures indicate their impact on the beginning of the emergence of *Cephalcia* species in 2011; we found that it had started in large number when the average daily temperature was 14.7 °C and the average soil temperature was 8.7 °C.

In the autumn of 2009, six circular plots (50 x 50 m each) were defined where the defoliation of the crowns of 88 conifer trees with the breast height over 10 cm was estimated. The defoliation of *P. abies* has grown over two years; in 2009, the average defoliation was 28%, and in 2010 it was 32%.

KEY WORDS: *Cephalcia arvensis,* temperature, defoliation, outbreak, Norway spruce, Slovenia.

INTRODUCTION
Uvod

Cephalcia spp. are Holarctic species, inhabiting Eurasia and North America. In Europe, more than 10 species are known. *Cephalcia* spp. can cause extensive defoliation of conifers within the family Pinaceae, especially the species of the genera *Picea*, *Pinus*, and *Larix*, and occasionally *Cedrus* and *Abies*. The causes underlying the growing populations of the different species vary but include the presence of tree species more susceptible to attack due to weakening by different biotic and abiotic factors, appropriate ecological conditions for the development of *Cephalcia* spp. (higher temperatures and dry and hot weather), and a lack of natural enemies and pathogens of *Cephalcia* in the environment. Damage is caused by larvae that eat needles, and the defoliation of needles over multi-year periods weakens the host trees, reducing their growth and making those trees even more susceptible to damage from other biotic and abiotic factors (Jurc 2009). In north east Italy possible predominate causes of the outbreaks of *C. arvensis* were climatic and soil factors. In the years before outbreaks, the climate was hot

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and dry. This had effect on lower mortality and faster development of the insect and also on the increase of food quality as a consenquence of the water stress suffered by the trees, according to the soil and stand characteristics (Marchisio et al. 1994). In Europe, common outbreaks of the species *Cephalcia abietis* (Linnaeus, 1758) last several years (Martinek 1980); other species, including *Cephalcia alpina* (Klug, 1808), *Cephalcia annulicornis* (Hartig, 1837) and *Cephalcia arvensis* (Panzer, 1805), rarely occur in outbreaks (Battisti 1993; Martinek 1991, 1992; Battisti et al. 1998). The first record of the outbreak of *C. arvensis* was recorded on 400 ha on the late 19th century, between the years 1868 and 1874 (Escherich 1942). In the 20th century, outbreaks have been found in Sweden between 1916–1919 (Escherich 1942), in Denmark between 1927-1931 (Escherich 1942), in the Czech Republic between 1981–1986, 1982–1988 and 1996- 1999 (Křístek and Švestka 1986; Liška et al. 2001), in Italy between 1985–1993 (Battisti et al. 2000) and in Poland between 1982–1996 (Jachym 2003). In Slovenia, no records of growing populations of the species within the genus *Cephalcia* have been recorded until 2009. In 2009, damage appeared in a 106-ha, old stand of *Picea abies* (L.) Karst. located in the northern part of Slovenia (Jurc et al. 2010) caused by the species *C. arvensis* (Jurc 2012).

C. arvensis is considered particularly variable from a phenological and morphological point of view (Battisti 1993). The emergence period of this species takes place from the end of April until the end of August. Spring and summer forms can be identified based on the time of emergence. Both forms also have differences in morphological and behavioural features (Křístek and Švestka 1986; Battisti 1993). Females lay eggs on the one-year needles found in the upper and middle parts of the crown. Eggs are laid throughout the entire lifetime of the female, with a maximum number laid in the first week. The larvae hatch after 12-20 days and are isolated inside shelters, which are connected with a silk tube to the spruce needles by several silk threads. The falling period of the larvae takes place from July until the end of August. As the mature larvae reach the soil surface, they immediately begin to penetrate into the soil, where they build oval earth-walled chambers. Prepupae develop into pronymphs or enter into prolonged diapause as eonymphs. Only pronymphs develop into pupae and then into adults the following spring (Battisti 1993; Battisti et al. 2000).

The aim of this study was to identify the dominant species of web-spinning sawfly that entered an outbreak phase in 2009 at one location in the northern part of Slovenia in a *Picea abies* stand, Also, some bio-ecological characteristics like cardinal temperatures (soil and air temperature during the adult emergence period) were assessed along with the defoliation intensity and its impact on the tree health status.

MATERIALS AND METHODS
Materijal i metode

Description of the research area – Područje istraživanja

The affected area was located on the slope of Riflov vrh (coordinates: x = 492607, y = 155471), which is located over Prevalje near the Austrian border.

The infested area comprised a 106 ha region of a stand of 60-90-year-old *Picea abies* that was located on a northern slope with a 20% slope incline, 600-800 m a.s.l. The growing stock varied between 321 m^3/ha and 408 m^3/ha, and the proportion of Norway spruce in the growing stock was over 70%, with individual admixtures of *Fagus sylvatica*, *Acer pseudoplatanus*, *Fraxinus excelsior*, *Pinus sylvestris* and *Larix decidua*. Naturally, these sites are part of the acid beech forest, and the forest community is *Omphalodo – Fagetum* (Forestry Service of Slovenia 2009).

Sampling of prepupae and adults – Uzorkovanje pretkukuljica i imaga

In 2009, soil samples (25 x 25 x 20 cm) were taken from the plots under the crowns, on six plots located along the slopes covering the entire area. We counted prepupae (eonymph/pronymph) of the different species of *Cephalcia* that were present and we photographed them, so that they could be identified (NIKON D 200, Tokyo, Japan, objective AF-S NIKKOR 105 mm). In total, 147 specimens were photographed and identified (Zanocco and Battisti 1995; Battisti and Sun 1996).

In 2010 we repeated this method and the number of prepupae in each sample were counted.

In spring 2012 we caught along the entire slope, with the entomological nets, 85 adults and identified them (Beneš 1976; Pschorn-Walcher 1982; Schwenke 1982; Achteberg and Aartsen 1986, Escherich 1942). The identities of the adults that were caught were confirmed at the University of Padova by Prof. Andrea Battisti, Ph.D.

Climatic factors – soil and air temperature – Klimatski čimbenici – temperature tla i zraka

Air and soil temperature data were obtained from the Slovenian Agency for the environment (ARSO) for the Šmartno pri Slovenj Gradcu meteorological station over the period between 2007 and 2010 (average max., min., and year temperature) for each year in this period. Soil temperature was measured at a depth of 20 cm, and air temperature at a height 2 meters above ground.

For each day in the year 2010 we also measured the temperature of the soil at a depth of 20 cm on location Prevalje. Soil temperature was measured with 'T-button' thermom-

eters (T-buttons, Dallas Semioconductor, USA; accuracy 0.1°C, 0.1%), which record the soil temperature every 30 minutes.

Monitoring of the emergence of the web-spinning sawfly in year 2011 – Praćenje pojave imaga smrekine ose predivice u 2011. godini

After 10th of April 2011, we began with a detailed inspection of the stand, with the aim to identify the beginning of the emergence of web-spinning sawfly adults. By the scrutiny of the ground vegetation and trees, we determinate the start date of the emergence of *Cephalcia*. Monitoring was carried out till the last third of May, when *Cephalcia* adults were no longer observed. For each day in this period the average daily air temperature at a height of 2 meters above the ground, and the temperature of the soil at a depth of 20 cm was determinate. Soil temperature was measured with 'T-button' thermometers (T-buttons, Dallas Semioconductor, USA; accuracy 0.1°C, 0.1%), which record the soil temperature every 30 minutes.

Evaluation of crown defoliation – Procjena defolijacije u krošnjama

In the autumn of 2009, six circular plots (50 x 50 m each) were defined within the most highly infested area. On each of the plots, tree species whose diameter at breast height was over 10 cm were inventoried. The defoliation of the crowns of conifer trees was then estimated, which is a basic indicator for assessing the vitality of trees. This indicator expresses a visually estimated proportion of the missing assimilation organs of the selected tree compared with individuals of the same species and social class that were found on the same site but exhibited normal foliage (Kovač et al. 2007). The evaluation of crown defoliation was repeated in 2010.

RESULTS
Rezultati

In 2012, we identified the species *C. arvensis*. Males were dominant, as they comprised 89% of the total. Comparing specimens caught in Slovenia with specimens caught in Italy, we observed a difference in colour; the population from Slovenia had markedly darker patterns compared to the population from Italy (Figure 1, 2, 3).

Darker coloration also occurs in the species *C. alpina* and *C. annulicornis*, but, with precise identification, the presence of these two species was excluded. It might be that *C. arvensis* was the dominant species at the Prevalje location. Due to the damages and characteristics of the older larvae and prepupae, we could conclude that *C. abietis* was also present. Molecular study would give more data concerning the identification of *Cephalcia* species. Problem is, that in the base of sequences (GenBank base), there is no reference sequence down to the species level.

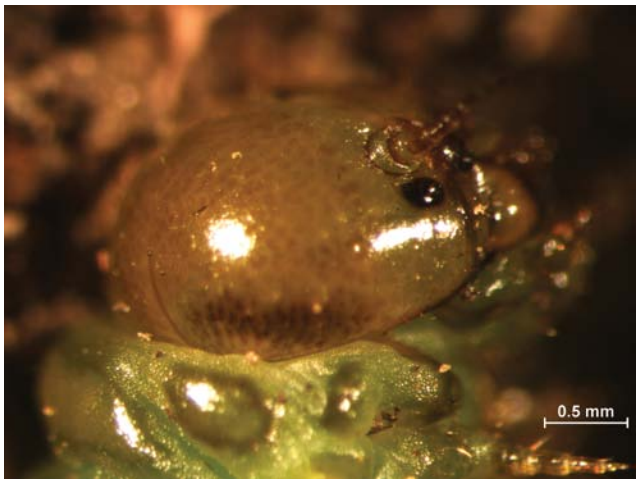

Figure 1, 2, 3: *Cephalcia arvensis* (Panzer, 1805): larvae, a head of young prepupa and adult specimen (Photo: M. Jurc, M. Jurc, D. Jurc)
Slika 1, 2, 3: *Cephalcia arvensis* (Panzer, 1805), larva, glava mlade pretkukuljice i imago (Foto: M. Jurc, M. Jurc, D. Jurc)

Species determination on the basis of prepupae was performed on 147 specimens. Of the sample, 71% matched the description of the prepupae of *C. arvensis*; the remaining 29% represented other species of the genus *Cephalcia* or the species could not be determined due to unclear patterns.

The number of prepupae, in the year 2009, found in the 25 x 25 x 20 cm soil samples taken from the middle of the circular plots varied from 10 to 59 individuals/sample, or, calculated per m² of soil, from 160 to 944 individuals/m² of soil, while in 2010 the number of prepupae varied from 4 to 20 individuals/sample, from 64 to 320 individuals/m² of soil. The average number of prepupae on the plot ranged from 37 ± 16,8 to 595 ± 269,5 individuals/m² of soil in 2009, while in 2010 the average number of prepupae on the plot ranged from 12 ± 5,5 to 189 ± 87,3 individuals/m² of soil. The average number of prepupae in the soil in 2010 was lower for 68%, according to the number of prepupae in the soil in 2009.

Soil and air temperature are important factors that affect the bionomy of *Cephalcia* spp. The duration of the development of *Cephalcia* spp. depends on the temperature of the soil and the temperature in the crowns of the trees. Table 1 present general temperature conditions (average max., min., and year soil and air temperature) for a wider area of the research location Prevalje over the period 2007–2010. For the air and soil temperature the data were obtained from ARSO, from the meteorological station Šmartno pri Slovenj Gradcu over the period 2007–2010, however for the year 2010, the data about the average max. and min. soil temperature were not available, because the method of measuring was changed. For the year 2010, soil temperatures were measured with 'T-button' thermometers on the location Prevalje.

If we look air and soil temperature through period 2007 -2010, there are differences in average max., min. and year temperature. These temperatures play an important role in eclosion of adults.

The influence of air and soil temperature on the time of occurrence of adult forms of the *C. arvensis* in 2011 is shown on Figure 4.

Figure 4 shows the average daily air temperature and average soil temperature (measured with 'T-button' thermometers) at a depth of 20 cm over the period from 19.4.2011 to 19.5.2011. In 2011, the emergence of *Cephalcia* was noted in large number on the 23rd of April (Figure 4), when the average daily air temperature at a height of 2 meters above the ground was 14.7 °C, the temperature of the soil at a depth of 20 cm was 8.7 °C, and the weather was clear and sunny. The emergence of *Cephalcia* was strong until the 9th of May, when the weather was clear to moderately cloudy, with an average daily air temperature between 7 to 14 °C and an average soil temperature between 8 to 10 °C. After this date, only individual *Cephalcia* adults were observed until the 19th of May, when they were no longer observed.

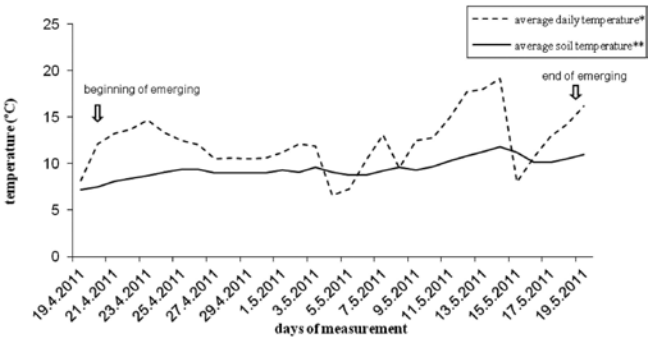

Figure 4: Average daily temperature* and average daily soil temperature at a depth of 20 cm over the period between 19.4.2011 and 19.5.2011 (*data obtained from ARSO, **own measures with 'T-button' thermometers)

Slika 4: Prosječna dnevna temperature zraka* i prosječna dnevna temperature tla** na dubini 20 cm u periodu između 19.4. 2011 i 19.5.2011 (*podaci ARSO, **vlastita mjerjenja sa 'T-button' mjernim uređajima)

The average defoliation of the trees found in the selected sample plots was 28% in the autumn of 2009, 32% in the autumn of 2010. Our study has shown, that tree defoliation increased within the two years of monitoring (Figure 5).

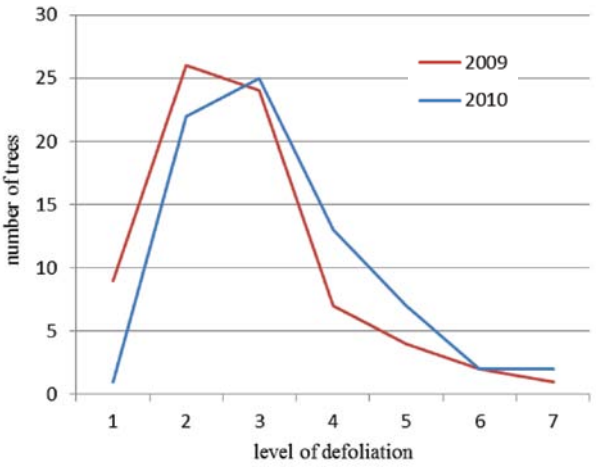

Figure 5: Comparison of defoliation of the crowns of spruce trees in the autumn of 2009 and 2010

Slika 5: Usporedba defoliacija smrekovih krošanja u jesen 2009. i 2010. godine

Table 1: Average max., min., year soil and air temperature over in the period 2007–2010

Tabela 1: Prosječna max., min., godišnja temperatura tla i zraka u razdoblju 2007–2010

Year Godina	Soil temperature (0 C) Temperatura tla			Air temperature (0 C) Temperatura zraka		
	max.	min.	year	max.	min.	year
2007	14,7	8,2	11,2	15,7	4,1	9,4
2008	15,0	7,9	11,3	15,1	4,9	9,6
2009	14,6	7,8	11,1	15,2	4,5	9,5
2010	10,9*	5,5*	8,1*	13,9	3,9	8,7

* Temperature measured with 'T-button' thermometers

* Temperatura mjerena s "T-button" mjernim uređajima

During the 2009 – 2010 assessment period, the number of trees, classified as belonging to the first (0-10%) and second (10-20%) level of defoliation, decreased; in all of the other defoliation classes defoliation increased, with a maximum increase in the trees belonging to the fourth (30–40%) and fifth (40–50%) level of defoliation, which indicates, that tree health declined.

DISCUSSION
Rasprava

At the Prevalje location, where, according to the data available in Slovenia, visible damage of the Norway spruce stand first appeared, the species *C. arvensis* was dominant. *C. arvensis* is considered the most variable species from both a morphological and biological standpoint (Battisti 1993). Comparisons of specimens caught in Slovenia and Italy revealed a difference in the colour of the specimens; the population in Slovenia had darker patterns compared to the population from Italy. The large number of *C. arvensis* males in 2012 was most likely due to the time they were caught (the end of April). Battisti (1993) showed that males are always the first to emerge, preceding the females by approximately one week. It is known that, of all the European species of the genus *Cephalcia*, this species is the first to emerge and does so at the end of April, while the other species emerge later (Battisti 1993). Past identification of the prepupae found in 2009 showed a 71% occurrence of *C. arvensis* (Klepec 2013), and, according to the damage and characteristics of older larvae and prepupae, we can assume that *C. abietis* was also present. Cescati and Battisti (1992), in their research on the distribution of species of the genus *Cephalcia* in non-outbreak areas of Trentino in northern Italy, noted that *C. arvensis* is a dominant species of the genus *Cephalcia*. Jensen (1988) also reported similar findings in his research of the distribution of species of the genus *Cephalcia* in Danish spruce forests. In the research of the outbreak of the species *C. arvensis* in the Czech Republic between 1997 and 1999, the presence of three other species, *C. abietis, C. annulicornis* and *C. alpina,* was recorded but they comprised less than 2% of the population (Liška et al. 2001).

In soil samples taken from the Prevalje location, we found in 2009, 994 eonymphs/pronymphs per m^2 of soil. As a result, we could very reliably expect outbreaks of *Cephalcia* spp. in the coming years (Jurc and Mlinšek 2009). Battisti and Rodeghiero (1988) reported that harmful defoliation starts with an abundance of 20 pronymphs/m^2 of soil or 14.26 adults/yellow sticky trap. The number of prepupae found in the soil in 2010 was lower, but still large; in some parts of the studied area, we found up to 320 specimens/m^2 of soil. For the outbreak of *C. arvensis* in the Czech Republic between 1997 and 1999, the average number of prepupae in the soil was between 200 and 300 specimens/m^2; the highest recorded density was in 1998 and was 1.300 specimens/m^2 of soil (Liška et al. 2001). The number of prepupae at the Prevalje location even in 2010 was ten times higher, compared to the number of prepupae in the soil in the year when the harmful defoliation started.

Temperature is a natural factor that significantly affects the development, time of emergence and abundance of the species of the genus *Cephalcia*. In boreal spruce forests and forest boundary areas of the Alps, where the temperatures are lower, development proceeds more slowly, and *C. arvensis* does not pass into outbreak. This species can be harmful in warmer areas, such as in the Italian pre-Alps and at lower altitudes in central Europe (Martinek 1991; Battisti 1993).

The temperature of the air is particularly important for the beginning of emergence and the existence of imago in spring and at the same time also presents the temperature threshold at which larvae from the crowns of the trees fall on the ground and penetrates into the soil (Battisti and Cescatti 1994).

Studies in Italy have shown that the emergence of *C. arvensis* takes place from May until June, when the air temperature is approximately 12 °C. In Slovenia in 2011, the emergence of a larger number of *Cephalcia* spp. was observed on the 23rd of April, when the average daily temperature was 14.7 °C. Individual imagos were observed on the 20th of April, when the average daily air temperature was over 12 °C, and the emergence ended after 30 days. The slightly earlier emergence of this species (before May) was also noted by Martinek (1991) when researching the outbreak of *C. arvensis* between 1982 – 1988 in the Czech Republic, where this species was emerging during the second half of April.

The air temperature should be the most important factor affecting the temperature of the soil (Spurr and Barnes 1980 cit. after Battisti 1994). The temperature of the soil is important in understanding the ecology of species of the genus *Cephalcia* because they spend most of their lifetimes in the soil. Battisti (1994) has shown that temperature conditions are important for larvae, both when they are entering into the soil and when they live in the soil as eonymphs/pronymphs. Soil temperature has an effect on the timing of the development of the different developmental forms. If the soil temperature is above 12 °C when the larvae are migrating into the soil, the larvae immediately change into pronymphs, and adults will occur the next spring. If the temperature of the soil is below 12 °C, the larvae will change into eonymphs and then into pronymps the following summer (Battisti 1994). The development can last for two years, in which case diapause is extended.

Consequently, soil temperature has an effect on the dynamics of the population. Long-lasting soil temperatures below 0 °C may result in higher mortality of the prepupae found

in the soil (Battisti 1994). But in our study, soil temperature didn't had effect on mortality of the prepupae, because there were no days, when the temperature was below 0 °C (min. 0,0 °C) and the period of low temperatures lasted short time. Other reason for reduction of the abundance of prepupae is the presence of species from family Soricidae, which food are insects and whose traces were noticed in the whole area. On the prepupae from the soil we also noticed the presence of entomopathogenic fungi, which is also one of the reasons of the reduction of the abundance of prepupae, but we didn't research them.

The consequences of larvae eating needles that were one or more years old was reflected in the defoliation of the crowns.

The average defoliation of the crowns of conifer trees on the research plots was 28% in 2009 and 32% in 2010, the health status of the evaluated trees according to the defoliation declined.. If we compare the average defoliation of conifers located on the research plots with the average defoliation of conifers found throughout the Republic of Slovenia in 2009, we can see that, at 26%, the average defoliation throughout Slovenia was 2% lower, while the average defoliation of conifer trees throughout members of the EU was 19, 9% (Fischer et al. 2010). Weakened trees are more susceptible to damage from other biotic and abiotic factors, in a case from Carpathians, where the outbreak took 10 years, the resistance of the trees fell significantly. These trees died due to infections with species of fungi from the genus *Armillaria* and because of the colonisation of weakened trees with bark beetles; increased numbers of events like this can be expected in Slovenia in the coming years.

All attacks in Europe have occurred in stands of Norway spruce, on sites where higher proportions of Norway spruce are naturally not present, especially in non-native stands. Because of the higher incidence of non-native pure stands of Norway spruce in Slovenia and the growing impact of changing climatic factors, such as reduced rainfall and increasing of temperatures, especially during oviposition, we can expect more frequent increases in the species of the genus *Cephalcia* in Slovenian forests.

ACKNOWLEDGMENTS
Zahvala

We are very grateful to Prof. Andrea Battisti, Ph.D. (Universita di Padova

DAFNAE-Entomologia, Italia) for reviewing *Cephalcia* identifications presented in this article. We also thank Gorazd Mlinšek (Forestry Service of Slovenia, KE Slovenj Gradec) for his help and assistance with the fieldwork. For financial support we are grateful to Pahernik foundation and Programme group P4-0059 Forest, forestry and renewable forest resources (1.1. 1999-31.12.2014).

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Sažetak

U Sloveniji je prvi jak napad ose predivice iz roda *Cephalcia* (Hymenoptera, Symphyta, Pamphilidae) zabilježen u srpnju 2009. godine na padini Riflov vrh (koordinate: x = 492607, y = 155471) iznad grada Prevalje u sjevernom dijelu Slovenije. Napadnuto područje prostiralo se na površini od 106 ha u 60–90 godina staroj sastojini obične smreke (*Picea abies*) smještenoj na sjevernoj padini s nagibom 20 % i nadmorskoj visini između 600 i 800 metara. Drvna zaliha varira između 321 m^3/ha i 408 m^3/ha, s udjelom smreke u drvnoj zalihi od 70% te s pojedinačnom primjesom obične bukve (*Fagus sylvatica*), gorskog javora (*Acer pseudoplatanus*), gorskog jasena (*Fraxinus excelsior*), običnog bora (*Pinus sylvestris*) i europskog ariša (*Larix decidua*). Ova staništa pripadaju kiselim bukovim šumama, s pripadnom šumskom zajednicom *Omphalodo-Fagetum*.

U Europi je poznato više od 10 vrsta roda *Cephalcia* koje uzrokuju defolijacije četinjača unutar porodice Pinaceae, posebno na vrstama roda *Picea, Pinus, Larix,* a povremeno i *Cedrus* i *Abies*. Štete uzrokuju ličinke koje se hrane iglicama i tako kroz višegodišnje defolijacije mogu oslabiti četinjače, smanjiti njihov prirast i stvoriti uvjete za dodatnu štetu zbog drugih biotskih i abiotskih čimbenika.

Cilj istraživanja bio je utvrditi dominirajuću vrstu roda *Cephalcia* koja je uzrokovala defolijaciju na sjeveru Slovenije i istražiti neka njena bioekološka obilježja (temperature aktivacije najvažnijih fenoloških razdoblja), brojnost pretkukuljica u tlu i utjecaj vrsta *Cephalcia* na defolijaciju drveća.

U 2009. i 2010. godini prikupljeni su uzorci tla (25 × 25 × 20 cm) s površina ispod krošanja na šest lokacija, raspoređenim uzduž cijele padine, a s namjerom taksonomske identifikacije i fotografiranja pretkukuljica različitih vrsta roda *Cephalcia*. Na taj je način ukupno fotografirano i identificirano 147 jedinki.

Broj pretkukuljica u uzorcima tla 2009. godine iznosio je od 160 do 944 jedinki/m^2 tla, dok je brojnost pretkukuljica iz 2010. godine bila manja, ali još uvijek visoka i iznosila je od 64 do 320 primjeraka/m^2 tla. Prema Battisti i Rodeghiero (1988), intenzitet defolijacije pri kojoj nastaje štetni učinak na smreci nastaje kada brojnost iznosi 20 pretkukuljica/m^2 tla. Na lokaciji Prevalje 2010. godine prosječan broj pretkukuljica iznosio je 189 jedinki/m^2 tla, što upućuje na posljedičnu defolijaciju.

Determinacija vrsta na temelju prikupljenih pretkukuljica ukazala je na dominaciju vrste *C. arvensis* (71 %). Ostatak pretkukuljica pripadao je drugim vrstama roda *Cephalcia* ili ih se zbog nejasnih uzoraka nije moglo preciznije odrediti.

U proljeće 2012. godine s entomološkim mrežama hvatana su živa imaga i taksonomski identificirani. Sva imaga pripadala su vrsti *C. arvensis*. Identifikacije je potvrdio prof. dr. Andrea Battisti sa Sveučilišta u Padovi.

Temperature zraka i tla važni su čimbenici koji dominantno utječu na bionomiju vrsta roda *Cephalcia*. Podaci s meteorološke stanice Šmartno pri Slovenj Gradcu preuzeti su za razdoblje 2007–2010. od Agencije Republike Slovenije za okoliš (ARSO), dok su 2010. godine na lokaciji Prevalje izmjerene temperature tla na dubini 20 cm s digitalnim termometrima 'T-button' thermometers (T-buttons, Dallas Semiconductor, USA; preciznost 0,1 °C, 0,1 %).

Temperatura tla ima jak utjecaj na dinamiku populacije ovih osa pa primjerice temperatura ispod 0 °C kroz duže razdoblje može rezultirati povećanim mortalitetom pretkukuljica. U provedenom istraživanju temperatura tla nije imal utjecaja na njihov mortalitet s obzirom da se niti jednom nije spustila ispod 0 °C. Drugi razlozi za smanjenje brojnosti pretkukuljica su predatori iz porodice Soricidae, te entomopatogene gljive koje nisu bile predmet ovog istraživanja.

Fenološki važne temperaturne vrijednosti povezane s pojavom imaga *Cephalcia* vrsta utvrdili smo praćenjem početka pojave odraslih osa u travnju 2011. godine detaljnim pregledom prizemnog rašća i drveća sve do prestanka njihovog nalaza. Za svaki dan u ovom razdoblju utvrdili smo prosječnu dnevnu zračnu temperaturu na visini 2 m od tla i temperaturu tla na dubini 20 cm. Prva imaga pojavila su se 20. travnja, kada je prosječna dnevna temperatura iznosila iznad 12 °C, a u većem broju 23. travnja (prosječna dnevna temperatura 14,7 °C, temperatura tla 8,7 °C), sve do 9. svibnja. Nakon tog datuma pa sve do 19. svibnja pojava imaga je oslabila i nalažena su tek pojedinačne ose.

Brst smrekinh iglica i posljedični gubitak asimilacijskog aparata važan je indikator vitalnosti stabala te je rezultat utjecaja različitih biotskih i abiotskih čimbenika. Unutar područja najjače zahvaćenog defoliacijom, 2009. godine izabrali smo 6 površina (svaka 50 × 50 m), te svakom stablu iznad 10 cm prsnog promjera procijenili postotak defolijacije krošnje. Isti postupak ponovljen je 2010. godine. 2009. godine prosječna defolijacija krošanja na istraženim lokacijama iznosila je 26 %, a 2010 godine 32 %, što ukazuje na pogoršanje vitalnosti napadnutih smreka.

Sve gradacije *C. arvensis* u Europi dogodili su se u smrekovim sastojinama, naročito u smrekovim kulturama. Budući da u Sloveniji postoji mnogo ovakvih sastojina, a uslijed recentnih promjene klimatskih čimbenika, primjerice porasta temperature i smanjena količina oborina u razdoblju kada se smrekine ose predivice roje i ženke odlažu jaja, u šumama Slovenije možemo očekivati učestalija prenamnoženja populacija ovih štetnika.

KLJUČNE RIJEČI: *Cephalcia arvensis*, temperatura, defolijacija, gradacija, obična smreka, Slovenija