Chilocorus renipustulatus (Coleoptera: Coccinellidae) dominates predatory ladybird assemblages on Sorbus aucuparia (Rosales: Rosaceae)

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Key words. Coccinellidae, Chilocorus renipustulatus, scale insect, mountain ash, Sorbus aucuparia, abundance, phenology, melanism

Abstract. Fourteen predatory species of ladybirds (Coleoptera: Coccinellidae) were collected from May to October 2008 from mountain ash (Sorbus aucuparia) infested with the scale insect Chionaspis salicis at 31 localities in the Ore Mountains, northern Bohemia, Czech Republic. Chilocorus renipustulatus, usually a rare species, made up 85% of the individuals collected (1690). Other abundant species were Coccinella septempunctata, Calvia quatuordecimguttata, Adalia bipunctata and Adalia decempunctata. The invasive alien Harmonia axyridis was present but made up less than one per cent of the individuals collected. Niche overlap between pairs of ladybird species measured in terms of the coefficient of community, Morisita’s index and cluster analysis showed that microhabitat preferences were similar and hence the possibility of competition was high in two pairs of congeneric species (Chilocorus and Calvia). Larvae of Ch. renipustulatus were abundant from mid-June through August and were still present in October.

INTRODUCTION

Mountain ash (Sorbus aucuparia Linnaeus) has become an important substitute woody plant in stands growing in seriously air-polluted locations at higher elevations of the Krušné hory Mts (Ore Mountains) at the north-western border of the Czech Republic (Balcar et al., 2008). This tree species is relatively resistant to sulphur dioxide, grows fast and forms a local environment with leaf litter improving soil conditions (Kubelka, 1993, Ulbrichová & Podrážský, 2002). The attractiveness of this woody plant for forest animals (browsing, deer de-barking) is a disadvantage for the plant itself (Sloup, 2008). The weakened trees are exposed to subsequent attack by insect pests and fungal pathogens (Kula et al., 2009).

Important leaf chewing pests of mountain ash include weevils (Urban, 1999, Kula & Šimon, 2007). Further, heavy defoliation of mountain ash is caused by the chrysolomelid Goniocenta (Goniomena) quinquemaculata (Fabr.) (Urban, 1998, Kula, 1999). In addition, caterpillars of 84 species of Lepidoptera have been obtained from mountain ash (Kula et al., 2009). Important sap sucking insects on mountain ash in Central Europe include the scale insects Diaspidiotus ostreaeformis (Curtis), Diaspidiotus perniciosus (Comstock), Diaspidiotus pyri (Lichtenstein), Lepidosaphes ulmi (L.), Parlatoria oleae (Colvée) and Pseudaulacaspis pentagona (Targioni Tozzetti) (Watson, 2005). Chionaspis salicis (Linnaeus) was reported from mountain ash in Germany (Lemme, 2010).

Potentially detrimental hemipterans and some chrysomelid eggs and larvae are preyed upon by several species of ladybird beetles. This paper presents the results of a survey of beneficial predatory ladybird beetles on mountain ash in the stressful conditions of the Ore Mountains. We discuss their species composition, abundance, phenology and niche overlap. Among these species, prevalence of coccidophagous ladybirds was expected due to infestation of the observed trees by scale insects, which was demonstrated by the unusual dominance of the relatively rare ladybird Chilocorus renipustulatus (Scriba).

MATERIAL AND METHODS

The study area was situated in northern Bohemia, in the Czech Republic. The area included 31 localities situated in the “Děčínská vrchovina” Uplands (50°47´N, 14°07´E – localities 1–3) and the eastern part of the Ore Mountains to Mount St. Sebastian (50°30´N, 13°16´E – localities 4–31; Table 1, Fig. 1). Altitudes sampled ranged from about 500 to 900 meters a.s.l. Seven samples were collected, two in May and five at monthly intervals from 14 June to 15 October 2008 (Table 2). Mountain ash (S. aucuparia) aged 15–60 years infested with Ch. salicis was studied at each locality. To obtain a representative sample, ladybirds were collected from five different trees on each occasion. At the time of the first sample (7 May 2008), the phenological stage of the trees differed among the localities, from stands with unfolded leaves to fully expanded leaves.

The insects were sampled by shaking them from the crowns of the trees by means of 4 kg heavy hammer blows to the trunks of the trees. Two pieces of canvas, each 2 × 2 m in size, were placed on the ground under the crowns of the trees to catch the insects. Samples from the five trees were pooled. The insects, including immature individuals, were killed and preserved in 75% ethanol. Larvae were identified using the field key of Savoiskaya & Klausnitzer (1973). Eggs of ladybird beetles are tightly attached to the substrate and cannot be sampled by beating. Pupae can be sampled with only limited efficiency.
The number of individuals of each species in each sample (for a particular locality and day) was expressed in terms of the relative proportion (p) of the total catch for the entire year, independent of the other species (Σp = 1 for each species). Niche overlap was then determined using the coefficient of community \( S_1 = \Sigma \min (p_i, q_i) \) and Morisita’s index \( S_2 = 2 \Sigma (p_i q_i) / \Sigma (p_i^2 + q_i^2) \). The Weighted pair-group average method after Jaccard similarity was applied for analysis. RESULTS

Altogether 1690 individuals of 14 predatory species of ladybirds (Table 2), including adults, pupae and larvae were collected. The single species Chilocorus renipustulatus made up 85\% of all individuals. The second most abundant species was Coccinella septempunctata Linnaeus (4\%), the next Calvia quatuordecimguttata (Linnaeus) (3\%) and two more species, Adalia bipunctata (Linnaeus) and A. decempunctata (Linnaeus), each made up over 1\%. The mycophagous ladybird Halyzia sedecimguttata (Linnaeus) was not included in the results and analyses. The abundance of Ch. renipustulatus differed among the localities, ranging from 1 to 217 individuals over the entire season, with a median of 38 and mean of 46 individuals per site. Abundance was not correlated with the geographical position of a particular locality (that is: there was no north-south or west-east gradient), or with the altitude of the sites.

The seasonal trend in abundance of Ch. renipustulatus was biphasic, with a ten-fold increase between mid-June and early July, due to a massive emergence of larvae of the new generation, and with adult emergence in August to September (Table 2, Fig. 2). All the other species together showed a more gradual change in abundance with a minimum in late May and maximum in early September. The highest increase was between July and August, when many aphidophagous ladybirds enter diapause.

The first larvae of Ch. renipustulatus were collected in mid June (43\% of the individuals collected), and were most abundant in early July, when 96\% of the population comprised immature individuals. Larvae occurred at most localities. The first pupae were recorded in early July and were most common in early August, when 52\% of the population were immature individuals. The number of larvae and pupae decreased in September (10\%), but a few individuals (1\%) were still present in early October. Calvia quatuordecimguttata also reproduced on these trees as larvae were present in June (Table 2). A few larvae of Calvia decempunctata (Linnaeus) were found in June and July and a single larva of Aphidecta obliterata

Table 1. Localities at which the mountain ash Sorbus aucuparia was sampled. Altitude, coordinates, grid-map square number, total abundance of predatory ladybirds and of Chilocorus renipustulatus (in parentheses) are presented.

<table>
<thead>
<tr>
<th>No.</th>
<th>Settlement</th>
<th>m</th>
<th>N</th>
<th>E</th>
<th>Square</th>
<th>Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sněžník</td>
<td>713</td>
<td>50°47’40”</td>
<td>14°05’55”</td>
<td>5150</td>
<td>30 (17)</td>
</tr>
<tr>
<td>2</td>
<td>Sněžník</td>
<td>598</td>
<td>50°47’03”</td>
<td>14°05’17”</td>
<td>5150</td>
<td>69 (58)</td>
</tr>
<tr>
<td>3</td>
<td>Rájec</td>
<td>526</td>
<td>50°47’59”</td>
<td>14°01’10”</td>
<td>5250</td>
<td>22 (7)</td>
</tr>
<tr>
<td>4</td>
<td>Krásný les</td>
<td>672</td>
<td>50°45’38”</td>
<td>13°58’28”</td>
<td>5250</td>
<td>74 (70)</td>
</tr>
<tr>
<td>5</td>
<td>Krásný les</td>
<td>734</td>
<td>50°45’05”</td>
<td>13°57’16”</td>
<td>5250</td>
<td>34 (27)</td>
</tr>
<tr>
<td>6</td>
<td>Adolfořov</td>
<td>703</td>
<td>50°45’11”</td>
<td>13°54’51”</td>
<td>5249</td>
<td>19 (12)</td>
</tr>
<tr>
<td>7</td>
<td>Adolfořov</td>
<td>756</td>
<td>50°44’02”</td>
<td>13°54’21”</td>
<td>5249</td>
<td>228 (217)</td>
</tr>
<tr>
<td>8</td>
<td>Fojtovice</td>
<td>762</td>
<td>50°42’32”</td>
<td>13°51’04”</td>
<td>5249</td>
<td>99 (94)</td>
</tr>
<tr>
<td>9</td>
<td>Fojtovice</td>
<td>770</td>
<td>50°43’16”</td>
<td>13°49’56”</td>
<td>5249</td>
<td>26 (15)</td>
</tr>
<tr>
<td>10</td>
<td>Činevec</td>
<td>868</td>
<td>50°43’36”</td>
<td>13°45’44”</td>
<td>5248</td>
<td>22 (13)</td>
</tr>
<tr>
<td>11</td>
<td>Nové Město</td>
<td>832</td>
<td>50°41’51”</td>
<td>13°43’20”</td>
<td>5348</td>
<td>15 (13)</td>
</tr>
<tr>
<td>12</td>
<td>Nové Město</td>
<td>862</td>
<td>50°42’16”</td>
<td>13°41’31”</td>
<td>5348</td>
<td>47 (44)</td>
</tr>
<tr>
<td>13</td>
<td>Fláje</td>
<td>782</td>
<td>50°41’49”</td>
<td>13°37’03”</td>
<td>5347</td>
<td>59 (51)</td>
</tr>
<tr>
<td>14</td>
<td>Fláje</td>
<td>664</td>
<td>50°41’45”</td>
<td>13°34’03”</td>
<td>5347</td>
<td>36 (32)</td>
</tr>
<tr>
<td>15</td>
<td>Dlouhá louka</td>
<td>800</td>
<td>50°41’31”</td>
<td>13°38’32”</td>
<td>5347</td>
<td>53 (46)</td>
</tr>
<tr>
<td>16</td>
<td>Dlouhá louka</td>
<td>863</td>
<td>50°39’17”</td>
<td>13°38’37”</td>
<td>5347</td>
<td>114 (107)</td>
</tr>
<tr>
<td>17</td>
<td>Buttersteig</td>
<td>742</td>
<td>50°38’08”</td>
<td>13°36’54”</td>
<td>5347</td>
<td>44 (34)</td>
</tr>
<tr>
<td>18</td>
<td>Litivínov</td>
<td>496</td>
<td>50°37’05”</td>
<td>13°37’19”</td>
<td>5446</td>
<td>25 (1)</td>
</tr>
<tr>
<td>19</td>
<td>Boleboř</td>
<td>855</td>
<td>50°32’33”</td>
<td>13°23’03”</td>
<td>5446</td>
<td>59 (50)</td>
</tr>
<tr>
<td>20</td>
<td>Boleboř</td>
<td>810</td>
<td>50°32’59”</td>
<td>13°23’16”</td>
<td>5446</td>
<td>39 (23)</td>
</tr>
<tr>
<td>21</td>
<td>Boleboř</td>
<td>722</td>
<td>50°32’40”</td>
<td>13°23’51”</td>
<td>5446</td>
<td>42 (38)</td>
</tr>
<tr>
<td>22</td>
<td>Jedlička</td>
<td>870</td>
<td>50°34’50”</td>
<td>13°25’33”</td>
<td>5446</td>
<td>68 (60)</td>
</tr>
<tr>
<td>23</td>
<td>Malý háj</td>
<td>821</td>
<td>50°34’54”</td>
<td>13°24’47”</td>
<td>5446</td>
<td>17 (16)</td>
</tr>
<tr>
<td>24</td>
<td>Svahová</td>
<td>800</td>
<td>50°33’35”</td>
<td>13°24’25”</td>
<td>5446</td>
<td>68 (49)</td>
</tr>
<tr>
<td>25</td>
<td>Svahová</td>
<td>798</td>
<td>50°33’01”</td>
<td>13°24’07”</td>
<td>5446</td>
<td>21 (12)</td>
</tr>
<tr>
<td>26</td>
<td>Orasín</td>
<td>562</td>
<td>50°31’58”</td>
<td>13°23’44”</td>
<td>5446</td>
<td>90 (80)</td>
</tr>
<tr>
<td>27</td>
<td>Mezihoří</td>
<td>686</td>
<td>50°32’05”</td>
<td>13°21’44”</td>
<td>5446</td>
<td>96 (87)</td>
</tr>
<tr>
<td>28</td>
<td>Kálek</td>
<td>714</td>
<td>50°34’40”</td>
<td>13°18’12”</td>
<td>5445</td>
<td>48 (45)</td>
</tr>
<tr>
<td>29</td>
<td>Hora sv. Šebestiána</td>
<td>842</td>
<td>50°31’28”</td>
<td>13°14’09”</td>
<td>5445</td>
<td>79 (78)</td>
</tr>
<tr>
<td>30</td>
<td>Hora sv. Šebestiána</td>
<td>837</td>
<td>50°30’41”</td>
<td>13°16’21”</td>
<td>5445</td>
<td>36 (28)</td>
</tr>
<tr>
<td>31</td>
<td>Celná-Místo</td>
<td>745</td>
<td>50°28’38”</td>
<td>13°16’35”</td>
<td>5545</td>
<td>18 (13)</td>
</tr>
</tbody>
</table>
(Linnaeus) in July. Three larvae of *Harmonia axyridis* (Pallas) were recorded in June and October. The other species were not found reproducing on these trees.

All individuals of *A. obliterata* belonged to the pale morph and either had or lacked semilunar black markings on their elytra. Of the *Adalia bipunctata*, 24 were the typical pale morph, four the four-spotted melanic morph (*quadrimaculata*) and one the six-spotted melanic morph (*sexpustulata*). Of the *A. decempunctata*, six were the typical pale morph, 12 the chequered form (*decempustulata*) and five melanic (*bimaculata*). All the individuals of *H. axyridis* were the pale spotted *succinea* morph.

Niche overlap between pairs of ladybird species based on the coefficient of community ranged from 0 to 0.288 and on Morisita’s index from 0 to 0.320. These values group together those species that tend to occur simultaneously. The following pairs of species had values of both indices over 0.20: *Coccinella septempunctata* and *Adalia bipunctata*; *Calvia quatuordecimguttata* and *C. decempunctata*; *C. septempunctata* and *C. quatuordecimguttata*; *A. decempunctata* and *Anatis ocellata* (Linnaeus). Cluster analysis indicated similar groupings (Fig. 3) with the addition of *Ch. renipustulatus* and *Ch. bipustulatus* (Linnaeus).

**Table 2.** Number of individuals of all developmental stages (and number of immature individuals in parentheses) of fourteen ladybird species sampled on seven sampling days during the course of a season.

<table>
<thead>
<tr>
<th>Species</th>
<th>07–05</th>
<th>26–05</th>
<th>15–06</th>
<th>05–07</th>
<th>05–08</th>
<th>05–09</th>
<th>09–10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Exocharomus quadripustulatus</em></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>Chilocorus renipustulatus</em></td>
<td>25</td>
<td>20</td>
<td>44 (18)</td>
<td>392 (376)</td>
<td>299 (170)</td>
<td>334 (35)</td>
<td>323 (3)</td>
<td>1437 (602)</td>
</tr>
<tr>
<td><em>Chilocorus bipustulatus</em></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td><em>Calvia quatuordecimguttata</em></td>
<td>6</td>
<td>0</td>
<td>15 (11)</td>
<td>4</td>
<td>9</td>
<td>11</td>
<td>9</td>
<td>54 (11)</td>
</tr>
<tr>
<td><em>Calvia decempunctata</em></td>
<td>0</td>
<td>0</td>
<td>2 (1)</td>
<td>3 (3)</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>11 (4)</td>
</tr>
<tr>
<td><em>Propylea quatuordecimpunctata</em></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><em>Coccinella septempunctata</em></td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>18</td>
<td>26</td>
<td>11</td>
<td>69</td>
</tr>
<tr>
<td><em>Adalia bipunctata</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>15</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td><em>Adalia decempunctata</em></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td><em>Harmonia axyridis</em></td>
<td>0</td>
<td>1</td>
<td>2 (2)</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>3 (1)</td>
<td>16 (3)</td>
</tr>
<tr>
<td><em>Anatis ocellata</em></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td><em>Aphidecta obliterata</em></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2 (1)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>11 (1)</td>
</tr>
<tr>
<td><em>Hippodamia septemmaculata</em></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><em>Hippodamia variegata</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>43</td>
<td>23</td>
<td>65 (32)</td>
<td>425 (380)</td>
<td>361 (170)</td>
<td>411 (35)</td>
<td>362 (4)</td>
<td>1690 (621)</td>
</tr>
</tbody>
</table>
DISCUSSION

Species dominance

The dominant ladybird on most sites in the study area with mountain ash Sorbus aucuparia was the coccidio-

phagous Chilocorus renipustulatus, which is rarely com-

mon. In a previous survey over a period of four years in

the Czech Republic (Nedvěd, 1989), only two individuals

of this species were encountered in 5,222 ladybirds col-

lected. In a long term survey over 25 years on several tree

species (unpublished data) we found 34 individuals of

Ch. renipustulatus among 14,435 coccinellids. This spe-

cies was not found at all in several other surveys made in

orchards in Europe, including the Czech Republic (Hodek

& Hončík, 1996). In orchards in the Leningrad (= St.
Petersburg) region it was the seventh most common spe-

cies, after Adalia bipunctata, Coccinella septempunctata,

Calvia quatuordecimguttata, C. quinquepunctata Lin-

naeus, Propylea quatuordecimpunctata (Linnaeus) and

A. decempunctata, with a few species less common

(Semyanov, 1965). Klausnitzer (1994) classified

Ch. renipustulatus as frequent and widespread in

Thuringia (Germany). It is likely that Ch. renipustulatus

is often common on ash, but nobody, hereto, has studied

ladybirds on mountain ash in tensively. Simple visual

observations during other years, however, did not record

conspicuously high abundances of Ch. renipustulatus.

Prey relations

The abundance and dominance of Ch. renipustulatus

recorded in this study was associated with abundance of

its prey, the scale insect, Chionaspis salicis. It was not

possible, however, to quantify the abundance of the prey

species because it lives high in the crowns of the trees and

the individuals cannot be collected by shaking the trees.

We estimated by visual observation that the infestation of

trees in 2008 was not exceptionally high. Ch. renipustu-

latus has also been reported feeding on Ch. salicis on

S. aucuparia in Germany (Lemme, 2010). In Britain, Ch.

renipustulatus is recorded feeding on coccids on willows

(Salix). Ch. renipustulatus is also associated with

Unaspis euonymi (Comstock), on spindle (Euonymus spp.) (Kirby,


There are several other ladybird beetles that specialize

on scale insects in central Europe, such as the congeneric

Ch. bipustulatus that was less abundant in our samples. In

southern Europe, the Mediterranean and the Middle East,

Ch. renipustulatus is replaced by other congeneric

species, namely Ch. bipustulatus (Rodas et al., 2006).

Populations of the scale Quadraspidiotus perniciosus

(Comstock) in apple and peach orchards are controlled by

both Ch. renipustulatus and Ch. bipustulatus in Romania

(Trandafirescu et al., 2004). Both species also prey upon

Pseudaulacaspis pentagona (Targioni Tozzetti) in Serbia

(Grora & Spasić, 2008), the newly introduced Japanese

wax scale Ceroplastes japonicus Green, a pest of laurel in

Croacia (Milek & Simala, 2008), the California scale

Q. perniciosus in fruit-growing areas of Dagestan, Russia

(Gamzaev, 2002) and the Dictyospermum scale Chrysom-

phalus dictyospermi (Morgan) in citrus groves in Georgia

(Chkhaidze & Yasnosh, 2001).

Aphids were rare on the mountain ash trees studied, and

larval development of most of the ladybird species

recorded on these trees was not observed. Both species of

Calvia might have fed on psyllids, the generalist H. axy-

ridis on psyllids, coccids, or non-prey food groups such

as fruit, fungi and pollen (Berkvens et al., 2010).

Phenology

Ch. renipustulatus probably only completed one gen-

eration during the entire season, but the reproductive

period extended into late summer and autumn, which is

unusual in comparison with other ladybirds in central

Europe (Hodek, 1996). Only the invasive H. axyridis is

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known to produce progeny (second or third generation) regularly in October (Adriaens et al., 2008). In Britain, the earliest record of a newly emerged adult of *Ch. renipustulatus* is June 18th, which is later than other coc-cinellids. Mating between males and females of the old and new generation has been observed (Majerus, 1994). In the Maikop district (Adygeya, southern Russia), *Ch. renipustulatus* has two generations a year, compared with one in St. Petersburg (northern Russia) (Pantyukhov, 1968). None of the ladybird species recorded here was present solely in the autumn but *C. septempunctata* and *A. bipunctata* reached highest numbers in September and thus are suggested as likely overwintering migrants.

**Niche overlap**

The cluster analysis and niche overlap indices indicated that several pairs of species of ladybirds usually occurred together, which might indicate that they have similar microhabitat preference. Although it can be argued that congeneric species simply share aspects of their biology by common descent, conversely it may be hypothesized that closely related, sympatric species may diverge, as a part of a speciation process, to avoid competition or inter-breeding. Interestingly, two pairs of congeneric species (*Chilocorus* and *Calvia*) clustered closely together. This co-occurrence suggests that interspecific competition has not structured particular ladybird assemblages (that is: related species did not substantially diverge) (Machac et al., 2011). On the other side, two *Adalia* species, (the most closely related of the congeners here) did not cluster together. The two *Hippodamia* species were too rare to show clear relationships. Niche overlap between the two *Chilocorus* species and the other ladybirds (Table 3) was overestimated, because the former occur mainly on the branches and trunk and the latter on the leaves, but they were sampled together. A previous cluster analysis of 22 species of ladybirds occurring on a wide diversity of plants over a wide area (Nedvěd, 1999) also included pairs of congeneric species (*Adalia, Scymnus*). *Chilo-corus* was not recorded in that study, but the two species of *Calvia* clustered close to each other (together with *Oenopia conglobrata* (Linnaeus)).

The invasive alien *Harmonia axyridis* overlapped only slightly with the other ladybirds in our study. It was first recognized in the Czech Republic in 2006 (Brown et al., 2008) but has not yet become an important threat to the biodiversity of beneficial predators on mountain ash.

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