

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

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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 & Podrázský, 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 chrysomelid *Gonioctena* (*Goniomena*) *quinquepunctata* (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.

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.

No.	Settlement	m	N	E	Square	Individuals
1	Sněžník	713	50°47'40"	14°05'55"	5150	30 (17)
2	Sněžník	598	50°47'03"	14°05'17"	5150	69 (58)
3	Rájec	526	50°47'59"	14°01'10"	5250	22 (7)
4	Krásný les	672	50°45'38"	13°58'28"	5250	74 (70)
5	Krásný les	734	50°45'05"	13°57'16"	5250	34 (27)
6	Adolfov	703	50°45'11"	13°54'51"	5249	19 (12)
7	Adolfov	756	50°44'02"	13°54'21"	5249	228 (217)
8	Fojtovice	762	50°42'32"	13°51'04"	5249	99 (94)
9	Fojtovice	770	50°43'16"	13°49'56"	5249	26 (15)
10	Cínovec	868	50°43'36"	13°45'44"	5248	22 (13)
11	Nové Město	832	50°41'51"	13°43'20"	5348	15 (13)
12	Nové Město	862	50°42'16"	13°41'31"	5348	47 (44)
13	Fláje	782	50°41'49"	13°37'03"	5347	59 (51)
14	Fláje	664	50°41'45"	13°34'03"	5347	36 (32)
15	Dlouhá louka	800	50°41'31"	13°38'32"	5347	53 (46)
16	Dlouhá louka	863	50°39'17"	13°38'37"	5347	114 (107)
17	Buttersteig	742	50°38'08"	13°36'54"	5347	44 (34)
18	Litvínov	496	50°37'05"	13°37'19"	5446	25 (1)
19	Boleboř	855	50°33'18"	13°23'03"	5446	59 (50)
20	Boleboř	810	50°32'59"	13°23'16"	5446	39 (23)
21	Boleboř	722	50°32'40"	13°23'51"	5446	42 (38)
22	Jedlák	870	50°34'50"	13°25'33"	5446	68 (60)
23	Malý háj	821	50°34'54"	13°24'47"	5446	17 (16)
24	Svahová	800	50°33'35"	13°24'25"	5446	68 (49)
25	Svahová	798	50°33'01"	13°24'07"	5446	21 (12)
26	Orasín	562	50°31'58"	13°23'44"	5446	90 (80)
27	Mezihoří	686	50°32'05"	13°21'44"	5446	96 (87)
28	Kálek	714	50°34'40"	13°18'12"	5445	48 (45)
29	Hora sv. Šebestiána	842	50°31'28"	13°14'09"	5445	79 (78)
30	Hora sv. Šebestiána	837	50°30'41"	13°16'21"	5445	36 (28)
31	Celná-Místo	745	50°28'38"	13°16'35"	5545	18 (13)

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_i) of the total catch for the entire year, independent of the other species ($\Sigma p_i = 1$ for each species). Niche overlap was then determined using the coefficient of community [$S1 = \Sigma \min(p_i, q_i)$] and Morisita's index [$S2 = 2\Sigma(p_i \cdot q_i) / (\Sigma p_i^2 + \Sigma q_i^2)$]. The Weighted pair-group average method after applying 1-Pearson r measure of similarity was used for cluster 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 *Halysia sedecimguttata* (Linnaeus) (7 individuals) 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 oblitterata*

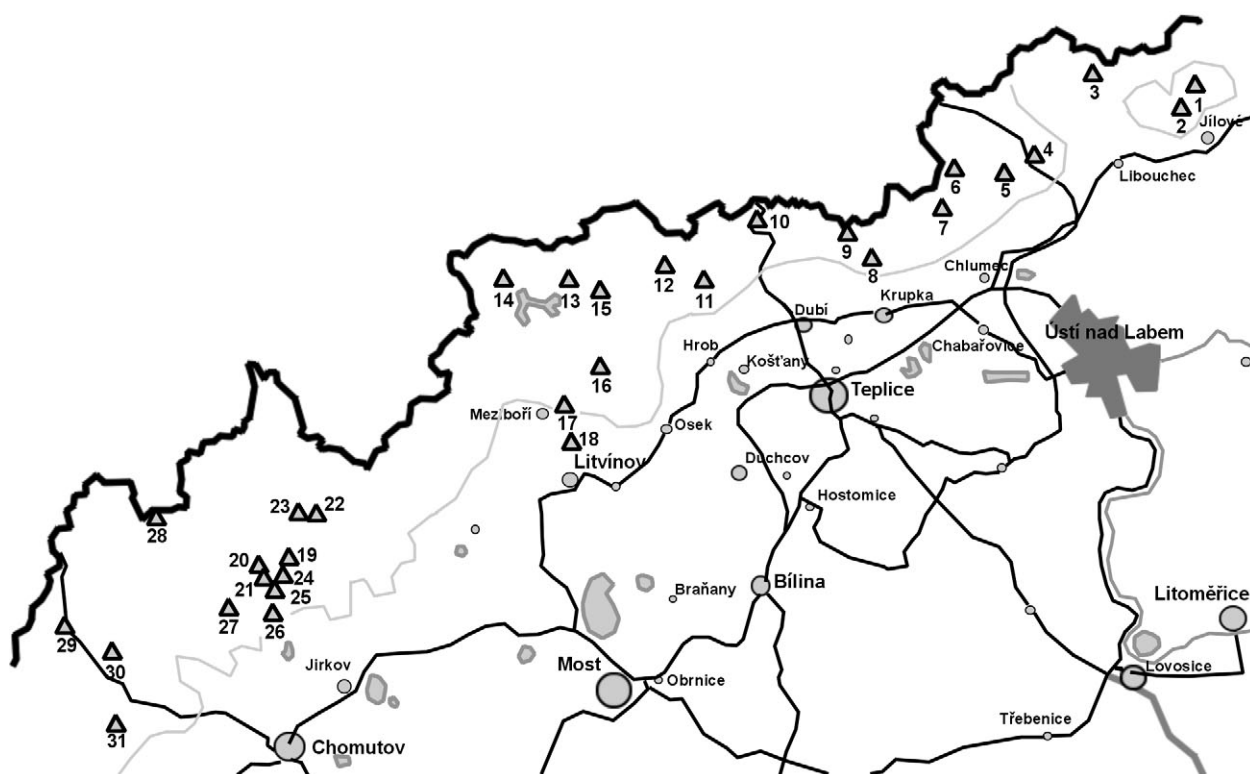


Fig. 1. Geographical distribution of the 31 localities studied in the north western part of the Czech Republic.

(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 (*sempustulata*). 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. decemguttata*; *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.

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

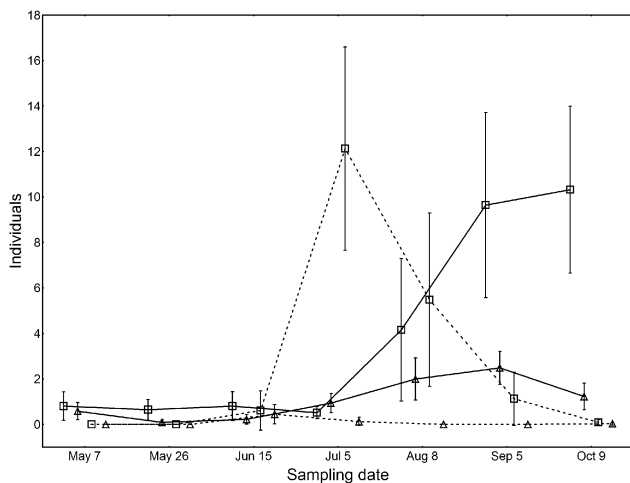


Fig. 2. Seasonal population dynamics of predatory ladybirds on mountain ash in 2008. Squares – *Chilocorus renipustulatus*; triangles – other species pooled; dashed lines – larvae and pupae; solid lines – adults. Plotted are means per sampling site \pm 95% confidential intervals.

DISCUSSION

Species dominance

The dominant ladybird on most sites in the study area with mountain ash *Sorbus aucuparia* was the coccidophagous *Chilocorus renipustulatus*, which is rarely common. 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 collected. 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 species was not found at all in several other surveys made in orchards in Europe, including the Czech Republic (Hodek & Honěk, 1996). In orchards in the Leningrad (= St. Petersburg) region it was the seventh most common species, after *Adalia bipunctata*, *Coccinella septempunctata*, *Calvia quatuordecimguttata*, *C. quinquepunctata* Linnaeus, *Propylea quatuordecimpunctata* (Linnaeus) and *A. decempunctata*, with a few species less common (Semyanov, 1996) and formed 2.7% of all ladybird individuals (Semjanov 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 intensively. 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-*

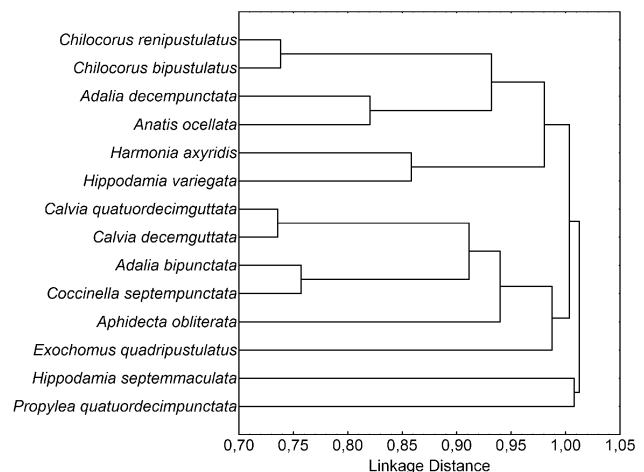


Fig. 3. Clustering of the ladybird species based on the weighted pair-group average method after applying 1-Pearson r measure of similarity of relative proportions of individuals (p_i , q_i) in each sample. Note the small groups (pairs of species) joined at short linkage distances: the main branching on the right of the graph has little importance.

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, 2005, 2008).

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 (Graora & Spasić, 2008), the newly introduced Japanese wax scale *Ceroplastes japonicus* Green, a pest of laurel in Croatia (Milek & Simala, 2008), the California scale *Q. perniciosus* in fruit-growing areas of Dagestan, Russia (Gamzaev, 2002) and the *Dictyospermum* scale *Chrysomphalus 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. axyridis* 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 generation 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

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 coccinellids. 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 interbreeding. 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*). *Chilocorus* was not recorded in that study, but the two species of *Calvia* clustered close to each other (together with *Oenopia conglobata* (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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