Bulletin of Insectology ***69*** *(2): 263-269, 2016*
ISSN 1721-8861

Local predators attack exotic aphid *Brachycaudus divaricatae* in Lithuania

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Abstract

Cherry plum (*Prunus cerasifera* Ehrhart) and domestic plum (*Prunus domestica* L.) trees were monitored in Vilnius and Elektrėnai regions of Lithuania in 2014. An exotic aphid species *Brachycaudus divaricatae* Shaposhnikov was the most common on cherry plum and the native species *Hyalopterus pruni* (Geoffroy) was the most abundant on domestic plum. Out of 23 aphidophagous insect species belonging to 5 families, the most common were *Aphidoletes aphidimyza* (Rondani) (Diptera Cecidomyiidae), *Adalia bipunctata* (L.) (Coleoptera Coccinellidae), *Praon volucre* (Haliday) (Hymenoptera Braconidae Aphidiinae), *Syrphus ribesii* (L.) (Diptera Syrphidae) and *Leucopis annulipes* Zetterstedt (Diptera Chamaemyiidae). Species richness, diversity and abundance of aphidophagous insects complex in the colonies of *B. divaricatae* were lower than those in colonies of native aphid species *H. pruni*. *B. divaricatae* is expected to stabilise population dynamics of the native pest aphid species on plums, because numerous populations of the invasive aphid species serve as an important reservoir for the local aphidophagous species.

Key words: *Prunus*, Aphids, *Brachycaudus divaricatae*, *Hyalopterus pruni*, Coccinellidae, Cecidomyiidae, Syrphidae, Chamaemyiidae, Aphidiinae.

Introduction

During the last decade, several aphid species (Hemiptera Aphididae) appeared in the Eastern Baltic region of Europe (Osiadacz and Hałaj, 2012). Out of them, *Brachycaudus (Acaudus) divaricatae* Shaposhnikov has substantially expanded its original distribution area from the easternmost Europe (Crimea, northern Caucasus) and Middle East (Transcaucasia, Turkmenia, Iran, Turkey). Since 2002, it has already been reported from Belarus, Latvia, Lithuania, Poland, Czech Republic and is for now the most numerous aphid species inhabiting cherry plum (*Prunus cerasifera* Ehrhart) in central Europe (Rakauskas and Cichocka, 2005; Bašilova *et al*., 2012). Recently, it was also found in Estonia, Slovakia, Romania, Bulgaria and Denmark (Rakauskas *et al*., 2015). Thus, *B. divaricatae* might be taken for an invasive species based on the criterion of Estoup and Guillemaud (2010) which consider an invasive species as one that has been introduced into a new area, in which it has established, increased in numbers and spread geographically. Yet another important criterion of invasivity should be also considered. Namely, 'invasive exotic species' means an exotic species whose introduction or spread has been found to threaten or adversely impact biodiversity and related ecosystem services (Regulation EU No 1143/2014). A comparison of plum-inhabiting aphid guild structure before and after the emergence of species *B. divaricatae* suggested a minor impact of the latter on the local plum aphid species community in Lithuania (Rakauskas *et al*., 2015). The explanation was that *B. divaricatae* mostly inhabited an exotic plum species - the cherry plum (*P. cerasifera*), which had been underexploited by the local aphid species in Lithuania. When pondering on the possible impact of an exotic species on the local biodiversity it is important to evaluate the capability of local predators and parasitoids to regulate the population densities of the exotic species. For the present, nothing is known about the aphidophages of *B. divaricatae* neither in its native nor in invasive areas of distribution. This paper is the first report concerning the association of local aphid predators with *B. divaricatae* in its invasive area.

Materials and methods

Research was performed in 2014 from the beginning of April until the end of July in Vilnius town (four localities) and Elektrėnai district (five localities) of Lithuania. Research sites are located 50 km aside each other in the South - Eastern Lithuania (table 1). Each week, 52 trees of cherry plum and 25 of domestic plum (*Prunus domestica* L.) were monitored for the presence of aphids and aphidophages. Taxonomic key of Rakauskas and Cichocka (2005) was used for aphid identification in the field. The scaling method (Heathcote, 1972) was applied when recording aphid populations on plum trees. Degree of infestation was evaluated by assigning one of the four infestation levels, the fourth level being the heaviest one (Rakauskas, 1980). All visible aphidophagous insects were counted, photographed and sampled for rearing (larval stages and parasitoid mummies) and subsequent identification (imaginal stages fixed in ethanol).

For the morphological identification of aphidophagous insects (imaginal stages), respective specialized identification keys were used: Hodek (1973), Pileckis and Monsevičius (1997) for identification of the ladybird species (Coleoptera Coccinellidae); Stackelberg (1970), Rotheray (1993), Stubbs and Falk (2002) for hoverflies (Diptera Syrphidae); Mamaeva (1964), Mamaev (1969), Mamaev and Krivosheina (1965) for predatory gall midges (Diptera Cecidomyiidae); Tanasijchuk (1970)

Table 1. Plum species (amount of individual trees) monitored in 9 localities of Lithuania on weekly basis from April 3 till July 31, 2014.

District	Location	Coordinates	*Prunus cerasifera*	*Prunus domestica*
Elektrėnai	Geibonys (north-east)	54°45'14.28"N 24°42'30"E	2	1
	Geibonys (south-east)	54°45'7.34"N 24°42'15.82"E	1	2
	Geibonys (north-west)	54°45'22.1"N 24°41'55.06"E	1	2
	Geibonys (south-west)	54°45'5.55"N 24°41'59.07"E	2	17
	Pastrėvys	54°43'2.52"N 24°40'14.28"E	5	1
Vilnius	Naujamiestis	54°40'40.04"N 25°14'53.21"E	18	2
	Vingio parkas	54°40'57.4"N 25°14'37.94"E	5	
	Žvėrynas (west)	54°41'29.17"N 25°14'36.47"E	13	
	Žvėrynas (east)	54°41'29.3"N 25°15'29.74"E	5	
		Total	52	25

for silver flies (Diptera Chamaemyiidae); Kavallieratos *et al*. (2005) for primary aphid parasitoids (Hymenoptera Braconidae Aphidiinae). Preimaginal stages were not identified to species, numbers of larval stages being counted separately from the imaginal ones. Lacewings (Neuroptera Chrysopidae Hemerobiidae) were mostly available as larvae and were identified to the family level (Fraser, 1959).

Aphid guild structure was evaluated by calculating the percentage of infestation for every aphid species on each host (cherry plum and domestic plum) during the April - July. Constancy index C = (q/Q) × 100 (q = number of samples in which species occurred, Q = number of analysed samples) (Szujecki, 1980) was used to evaluate the stability of aphid and aphidophagous species occurrence. Significance of the differences between constancy indices was checked by means of χ^2 test of independence (R software version 2.3.2).

Diversity of aphidophagous insect communities was evaluated by means of reciprocal Simpson's index $D = 1/\Sigma (n/N)^2$ where n = number of individuals of particular species and N = total number of individuals (Begon *et al*., 1986).

Results

Seven aphid species were registered on plum trees in monitored regions of Lithuania in 2014: *Aphis (Aphis) pomi* De Geer, *B. divaricatae*, *Brachycaudus (Prunaphis) cardui* (L.), *Brachycaudus (Brachycaudus) helichrysi* (Kaltenbach), *Hyalopterus pruni* (Geoffroy), *Phorodon (Phorodon) humuli* (Schrank), *Rhopalosiphum nymphaeae* (L.). *B. helichrysi* was found on domestic plum only; *B. divaricatae* and *A. pomi* - only on cherry plum. *H. pruni* and *P. humuli* were more frequent on domestic plum (χ^2 = 168.92; p = 0.000 and χ^2 = 52.08; p = 0.000 respectively); *R. nymphaeae* was most frequent on cherry plum (χ^2 = 6.44; p = 0.011). The predominant aphid species on cherry plum was *B. divaricatae*, followed by *P. humuli*, *H. pruni* and *B. cardui* (figure 1A). *B. divaricatae* was the most abundant aphid species on cherry plum during the entire evaluation period (figure 2A). The predominant aphid species inhabiting domestic plum was *H. pruni*, followed by *P. humuli* and *B. cardui* (figure 1B). *H. pruni* was available on domestic plum from the mid-May till the end of July, whilst other aphid species emigrated for summer host plants by the end of June (figure 2B).

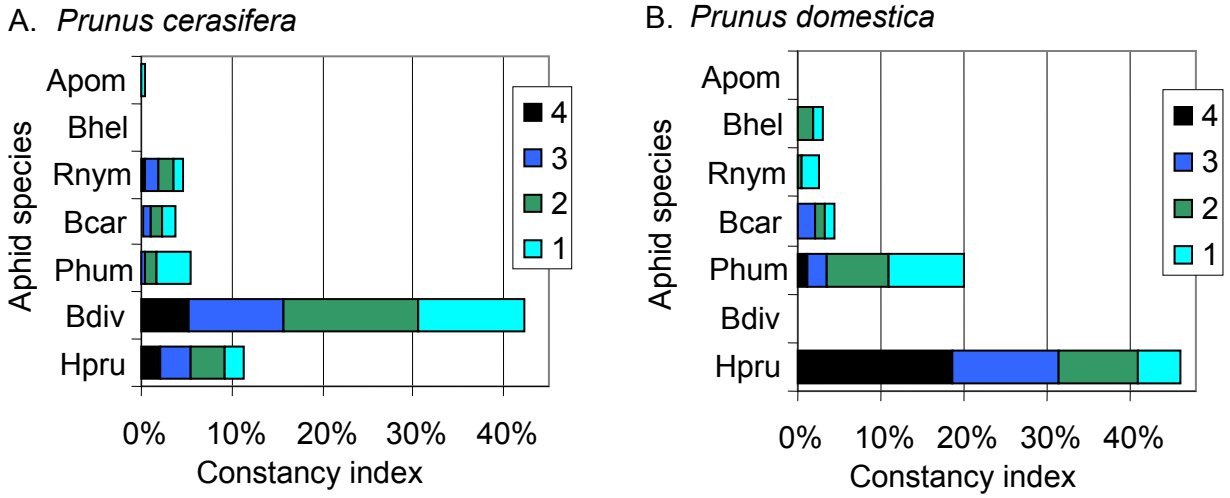

Figure 1. Occurrence of aphid colonies at different infestation levels on two plum species in Elektrėnai region and Vilnius during 2014. Abbreviations: Apom - *Aphis pomi*, Bhel - *Brachycaudus helichrysi*, Rnym - *Rhopalosiphum nymphaeae*, Bcar - *Brachycaudus cardui*, Phum - *Phorodon humuli*, Bdiv - *Brachycaudus divaricatae*, Hpru - *Hyalopterus pruni*. 1-4, infestation levels.

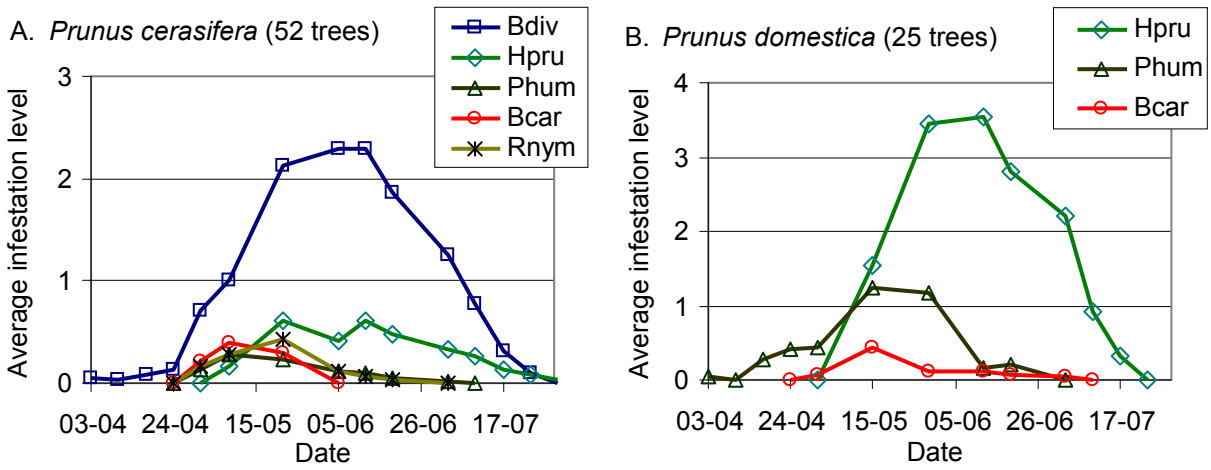

Figure 2. Seasonal dynamics of the most common aphid species on monitored plum trees in Vilnius and Elektrėnai region in 2014. Abbreviations: Bdiv - *Brachycaudus divaricatae*, Hpru - *Hyalopterus pruni*, Phum - *Phorodon humuli*, Bcar - *Brachycaudus cardui*, Rnym - *Rhopalosiphum nymphaeae*.

Table 2. Aphidophagous insect species registered in the aphid colonies on two plum species in 9 localities of Lithuania from April 3 till July 31, 2014.

Family - Species	*Prunus cerasifera* (52 trees)	*Prunus domestica* (25 trees)	Total
Coccinellidae			
Adalia (Adalia) bipunctata (L. 1758)	518	172	690
Coccinella (Coccinella) septempunctata L. 1758	17	22	39*
Propylea quatuordecimpunctata (L. 1758)	7	27	34
Adalia (Adalia) decempunctata (L. 1758)	23	9	32
Exochomus (Exochomus) quadripustulatus L. 1758		5	5*
Oenopia conglobata (L. 1758)		5	5*
Calvia quatuordecimguttata L. 1758	2	3	5*
Harmonia axyridis (Pallas 1773)	3		3**
Anatis ocellata (L. 1758)		1	1*
Coccinula quatuordecimpustulata (L. 1758)	1		1*
Unidentified preimaginal stages altogether	391	248	639
Cecidomyiidae			
Aphidoletes aphidimyza (Rondani 1847)	137	311	448
Unidentified preimaginal stages altogether	39	103	142
Chamaemyiidae			
Leucopis (Leucopis) annulipes Zetterstedt 1848	14	107	121
Unidentified preimaginal stages altogether	3	16	19
Syrphidae			
Syrphus ribesii (L. 1758)	54	155	209
Episyrphus balteatus (De Geer 1776)	14	26	40
Epistrophe eligans (Harris 1780)	6	4	10
Meligramma triangulifera (Zetterstedt 1843)	1	3	4*
Eupeodes corollae (Fabricius 1794)		2	2*
Meliscaeva cinctella (Zetterstedt 1843)		2	2*
Scaeva pyrastri (L. 1758)		1	1*
Unidentified preimaginal stages altogether	44	103	147
Braconidae			
Praon volucre (Haliday 1833)	27	198	225
Ephedrus plagiator (Nees 1811)	2	43	45
Lysiphlebus fabarum (Marshall 1896)	11	3	14
Monoctonus mali van Achterberg 1989		3	3*
Unidentified preimaginal stages altogether	16	54	70
Neuroptera			
Chrysopidae	12	55	67
Hemerobiidae	7	34	41

(*) species observed in Elektrėnai district only; (**) species observed in Vilnius only.

Table 3. Species richness, diversity and evenness of communities of predatory insects in the aphid colonies on two plum species in 9 localities of Lithuania from April 3 until July 31, 2014.

Indices/aphid and plum species	*Brachycaudus divaricatae* (*Prunus cerasifera*)	*Hyalopterus pruni* (*Prunus domestica*)
Number of observations	233	119
Number of individuals	475	810
Average number of individuals per observation	2.04	6.81
Number of species	8	19
Simpson‘s diversity index (D)	1.81	5.75
Simpson‘s index of evenness (E)	0.23	0.30

Twenty-three aphidophagous species of Coleoptera (Coccinellidae 10 species), Diptera (Syrphidae 7, Chamaemyiidae 1, Cecidomyiidae 1), and Hymenoptera (Braconidae Aphidiinae 4 species) were found in aphid colonies on cherry and domestic plums (table 2). *Harmonia axyridis* (Pallas), an invasive ladybird species, was recorded feeding on aphids in Lithuania for the first time (for details see Havelka *et al*., 2015). The aphid parasitoid *Monoctonus mali* van Achterberg was registered in Lithuania for the first time. Ladybirds *Coccinella septempunctata* L. and *Coccinula quatuordecimpustulata* (L.), hoverfly *Meligramma triangulifera* (Zetterstedt), and parasitoid *Ephedrus plagiator* (Nees) were observed in Elektrėnai district only; ladybird *H. axyridis* only in Vilnius.

Eight predatory insect species were registered in the colonies of *B. divaricatae*. Species richness of aphidophagous insects in colonies of a native aphid species *H. pruni* was higher - 19 species (table 3, figure 3). Both diversity and abundance of aphidophages in the colonies of *B. divaricatae* were lower than those in the colonies of native aphid species. Noticeably, no aphid parasitoids were registered in the colonies of *B. divaricatae.* Out of aphidopage species with constancy index exceeding 10%, *Aphidoletes aphidimyza* (Rondani), *Syrphus ribesii* (L.) and *Episyrphus balteatus* (De Geer) were most frequent in colonies of *H. pruni* (χ^2 = 24.50; p = 0.000 and χ^2 = 36.02; p = 0.000 and χ^2 = 17.93 and p = 0.000 respectively); There was no significant difference between the frequencies of *Adalia bipunctata* (L.) in colonies of *B. divaricatae* and *H. pruni* (χ^2 = 0,04; p = 0.847). The most constant predator of *B. divaricatae* during the season was the ladybird *A. bipunctata*. The most constant aphidophagous species in the colonies of *H. pruni* were *A. bipunctata*, *Leucopis annulipes* Zetterstedt, *A. aphidimyza*, *Praon volucre* (Haliday) and *S. ribesii* (figure 3). These species of aphidophagous insects were available in the aphid colonies throughout the whole vegetation season (figure 4).

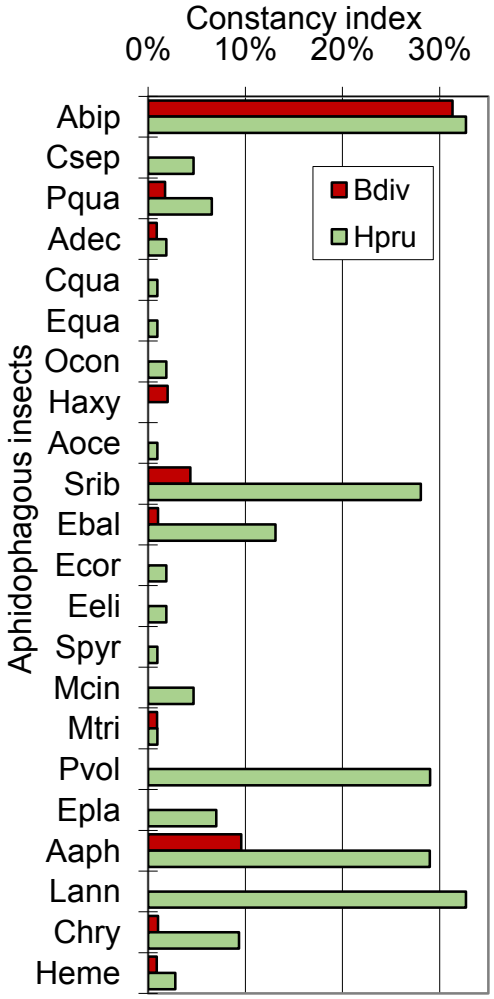

Figure 3. Occurence of aphidophages in pure and mixed colonies of the most common aphid species on monitored plum trees in Vilnius and Elektrėnai region in 2014. Abbreviations: Bdiv - *Brachycaudus divaricatae*; Hpru - *Hyalopterus pruni*; Abip - *Adalia bipunctata*; Csep - *Coccinella septempunctata*; Pqua - *Propylea quatuordecimpunctata*; Adec - *Adalia decempunctata*, Cqua - *Calvia quatuordecimguttata*; Equa - *Exochomus quadripustulatus*; Ocon - *Oenopia conglobata*; Haxy - *Harmonia axyridis*; Aoce - *Anatis ocellata*; Srib - *Syrphus ribesii*; Ebal - *Episyrphus balteatus*; Ecor - *Eupeodes corollae*; Eeli - *Epistrophe eligans*; Spyr - *Scaeva pyrastri*; Mcin - *Meliscaeva cinctella*; Mtri - *Meligramma triangulifera*; Pvol - *Praon volucre*; Epla - *Ephedrus plagiator*; Aaph - *Aphidoletes aphidimyza*; Lann - *Leucopis annulipes*; Chry - Chrysopidae; Heme - Hemerobiidae.

Discussion

The present study clearly indicates the availability of local species of aphidophagous insects in the colonies of the exotic aphid *B. divaricatae*. However, some of these local Lithuanian ladybird species also occur within the native area of *B. divaricatae*. Namely, the original distribution of *A. bipunctata* is Holarctic (Toda and Saku-

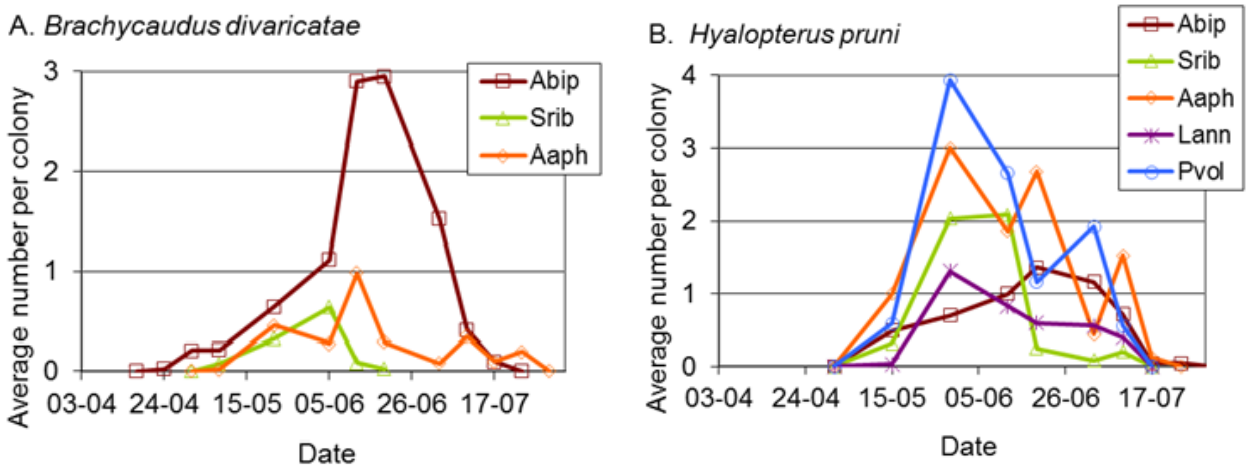

Figure 4. Seasonal dynamics of most common aphidophages in the colonies of *B. divaricatae* and *H. pruni* on monitored plums in Lithuania (Vilnius and Elektrėnai regions) in 2014. Abbreviations: Aaph - *Aphidoletes aphidimyza*; Abip - *Adalia bipunctata*; Lann - *Leucopis annulipes*; Pvol - *Praon volucre*; Srib - *Syrphus ribesii*.

ratani, 2006), overlapping with the native distribution of *B. divaricatae* (Transcaucasia, Turkmenia, Iran, Turkey; Blackman and Eastop, 2000). The same concerns ladybird species *C. septempunctata*, *Propylea quatuordecimpunctata* (L.) and *Oenopia conglobata* (L.), and some other species of aphidopahgous insects mentioned in the present study (*A. aphidimyza*, *L. annulipes*, *S. ribesii*, *E. balteatus*). Thus, feeding of these aphidophagous species on *B. divaricatae* in Lithuania can be expected. The spectrum of aphidophagous insects in the colonies of the most common native plum aphid, *H. pruni*, in Lithuania appeared rather similar before (Rakauskas, 1983) and after (this study) the arrival of *B. divaricatae*. Note that *A. bipunctata* was one of the most common ladybird species in the colonies of *H. pruni* in 1975-1980 (Rakauskas, 1983) and in 2014 (the present study). The same concerns the predatory gall midge *A. aphidimyza*, hoverfly *S. ribesii*, and hymenopterous parasitoid *P. volucre*. It is important to emphasize that the present study concerns just availability of aphidophages in aphid colonies. Their possible impact (prey preference, voracity, etc.) on the particular aphid species is a matter of additional sophisticated studies. One should be aware of the possibility of non-prey relationships between particular aphids and aphidophages available in the aphid colonies. For example, the ladybird *Exochomus quadripustulatus* (L.) is reported to prefer scale insects. Ladybird species *A. bipunctata* and *Adalia decempunctata* (L.) can prey not only on different aphid species, but also on psyllids, mites, coccids, and also larvae of Chrysomelidae (Hodek, 1973; Pileckis and Monsevičius, 1997). Yet the existence of numerous pupae of *A. bipunctata* in the colonies of *B. divaricatae* strongly suggests that *B. divaricatae* is highly acceptable prey for this ladybird in the studied areas. The same concerns aphidophagous species that have been reared from the larvae or pupae collected in the colonies of this aphid species (i.e., gall midges and hover flies). The presence of local aphidophagous species could suggest that they are capable of reducing population outbreaks of *B. divaricatae*. Firstly, the local complex of polyphagous insects and highly voracious aphidophages (ladybirds and lacewings) might possibly reduce aphid numbers when population densities of their prey are high (Grez *et al*., 2014; Canard, 2001). Secondly, hover flies and predatory gall midges are reported to be effective at medium or low population density of their prey. These species are characterized by numerical and functional responses to prey population density (Kuchlein, 1966; El Titi, 1974; Havelka, 1978).

Noticeably, *B. divaricatae* hatches early in the season in Lithuania (figure 2), coinciding with the bursting of leaf buds (green cone phase; Rakauskas and Turčinavičienė, 2006), reaching high population densities early in the season when local aphid species are not that numerous (Rakauskas *et al*., 2015). This provides a proper prey supply for local aphidophagous species immediately after their emergence from overwintering shelters. After having preyed on exotic aphid species early in the season, aphidophages receive local aphid species as subsequent additional food resources later in the season, when numbers of *B. divaricatae* decline. Therefore, exotic aphid species might serve as an additional resource enhancing the stability of the local complex of aphidophagous insects and thus enabling better control of local plum aphid species by the local natural enemies (von Berg *et al*., 2009; Takada and Nakamura, 2010). For broader discussion see subchapter "Provision of Resources for Natural Enemies" in Wratten *et al*., 2007. Yet the present data are just introductory ones; additional studies (more seasons and study sites) are necessary to confirm the above statement.

Note that *B. divaricatae* might be taken for exotic, but not invasive aphid species in Lithuania and the entire Eastern Baltic region of Europe. Firstly, incorporation of *B. divaricatae* into the plum aphid guild in the eastern Baltic region of Europe increased the stability of the guild by increasing the effectiveness of the use of local resources - invasive for the region cherry plum was underexploited by aphids before the invasion of the new aphid species (Rakauskas *et al*., 2015). Secondly, *B. di-*

varicatae seems to be an important additional resource for local aphid predators. The available data indicate a possible switch in the feeding habits of the common local ladybird species *A. bipunctata*, which was more abundant in the colonies of *B. divaricatae* when compared with the common local plum aphid species *H. pruni*.

Conclusions

Exotic aphid *B. divaricatae* was predominant on cherry plum and absent on domestic plum trees in Lithuania in 2014. A native aphid *H. pruni* was the most common aphid species on domestic plum. Local species of aphidophagous insects (six species of Coccinellidae, three of Syrphidae, one of Cecidomyiidae, also larvae of Chrysopidae and Hemerobiidae) were noted in colonies of *B. divaricatae* in 2014. The ladybird *A. bipunctata* was the most constant predator in the colonies of *B. divaricatae* and in the colonies of *H. pruni*. The highest aphidophagous guild species richness, diversity, and abundance were in the colonies of *H. pruni* when compared with *B. divaricatae*. The exotic *B. divaricatae* is expected to stabilize the population dynamics of the native aphid species on plum, because numerous populations of the invasive aphid species serve as an important reservoir for the aphid natural enemies.

Acknowledgements

This study was supported by a scientific practice grant (No. SMP14-11) awarded to J. Danilov from the Research Council of Lithuania. Our appreciation is also due to R. Ferenca (Kaunas, Lithuania) for checking our identification of ladybirds.

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Received January 21, 2016. Accepted June 14, 2016.