Bulletin of Insectology ***61*** *(2): 251-276, 2008*
ISSN 1721-8861

Fauna and associations of aphid parasitoids in an up-dated farmland area (Czech Republic)

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Abstract

A structural analysis of the parasitoid-aphid-plant associations related to their occurrence in different habitats and periods of the season in a model area (Pacov and environs, Czech Republic) is presented. The information was obtained between 1958-2007 and it was derived from aphid/plant samples taken in the field and reared for parasitoids in the laboratory. Three periods, in the course of 1958-2007 (1958-1990, 1991-1999, 2000-2007), were compared, but no significant differences in the native tritrophic structures of associations were determined. However, apparent changes were found due to the impact of some invasive plant and aphid species (listed) and subsequent interactions in the communities. The results are discussed in relation to the environmentally friendly approaches to the landscape management.

Key words: aphids, Hymenoptera, Braconidae, Aphidiinae, parasitoids, associations, reservoirs, agroecosystems, management.

Introduction

The biodiversification of the cultivated landscape has been a research trend in many countries of the world (Altieri, 1991; Altieri *et al*., 1993; Bianchi *et al*., 2006; Collins and Qualset, 1999; Duelli, 1997; Ferron and Deguine, 2005; LaSalle and Gauld, 1991; Olfert *et al*., 2002; Roschewitz *et al*., 2005). Hedges have been found of key importance; natural vegetation around crop fields harbours alternate hosts or preys for natural enemies, thus providing seasonal resources to bridge gaps in the life cycles of entomophagous insects and crop pests (Altieri and Whitcomb, 1979; Athanassiou, 2007; Bennewicz *et al*., 2001; Burgio *et al*., 2004). Strategies of maintenance and management of ecological infrastructures (ecological compensation areas) are considered crucial in enhancing functional biodiversity for pest supression. These strategies have become a basic aspect for application of conservation biological control (Bugg, 1992; Burgio *et al*., 2004).

Managing the non-crop habitat of a farm to improve conservation biological control requires detailed basic knowledge of trophic relationships among non-crop plants, phytophages and beneficials (Burgio *et al*., 2004). The evidence by Müller *et al*. (1999) documented how richly the aphid-parasitoid associations may develop even in an abandoned field.

Also, some crops themselves (alfalfa) were classified as valuable and fundamentally contributing to the long-term sustainability of agricultural systems and to improved wildlife habitat (Němec and Starý, 1986; Putnam, 1998; Starý, 1978b).

Brewer (2007) summarized the research situation (in cereal aphid parasitoids) in that farm-scale diversity had a greater effect on parasitoid prevalence than regional-scale plant diversity (Thies *et al*., 2005), the dominating farm-scale for cereal aphid parasitoids was clear in work done in Germany, England and North America; in the latter case, regional-scale issues were also relevant.

Interactions within the same and/or different (agro) ecosystems through the aphids and their parasitoids and classification of various parasitoid reservoirs were emphasized by Starý (1962; 1964; 1968; 1970b; 1972; 1974b; 1978a; 1978b; 1982; 1983; 1986a; 1986b; 1991), Starý and Lyon (1980), Starý and Němec (1986), Barczak (1993b; 1996), Tomanović et Brajković (2001), Pons and Starý (2003), Tomanović *et al*. (2006; 2008b).

A number of authors contributed to an over-all research trend on the biodiversification of the farmland, also considering the aphid parasitoids. The management efforts or contributions pertained to the same crop, its ecotones, and the interactions of crop-systems and the non-crops in individual localities up to the landscape and regional scale (Athanassiou, 2007; Barczak, 1991a; 1991b; 1992; 1993b; 1993c; Barczak *et al*., 1992; 1999; Brewer, 2007; Brewer and Elliott, 2004; Cameron *et al*., 1984; Cardinale *et al*., 2003; Dabrowska-Prot, 1995; Debek-Jankowska and Barczak, 2006; Duelli *et al*., 1990; Eikenbary and Rogers, 1973; Feraru and Mustata, 2005; Frere and Hance, 2001; Glen, 2000; Gonzalez and Michelena, 1987; Hart *et al*., 1994; Höller, 1990; Langer, 2001; Legrand *et al*., 2001; Lexie *et al*., 2001; Lumbierres *et al*., 2007; Micha *et al*., 2000; Pankanin-Franczyk, 1987; Powell and Wright, 1988; Powell *et al*., 1986; Schmidt *et al*., 2003; Starý, 1970a; Stern *et al*., 1964; Thies *et al*., 2005; Thomas and Wratten, 1990; Tomanović and Brajković, 2001; Vickermann, 1982; Völkl and Stechmann, 1988; Vorley, 1986; Vorley and Wratten, 1987; Wratten and Powell, 1990).

Less frequently, there are respective studies on tritrophic associations in non crop-communities. Starý (1986b; 1986c; 1987b) and Winiarska (1958) dealt with the role of *Cirsium arvense* weeds as the reservoir of parasitoids, a similar approach to *Philadelphus coronarius* was followed by Starý (1991). Barczak (1996) mentioned the role of *Chenopodium* weeds within poppy fields to *Aphis fabae* and its parasitoids and *A. fabae* and *Aphis sambuci* in the midfield thickets

(Barczak *et al*., 1999; Bennewicz *et al*., 2001), Pike *et al*. (1997) analysed an *Artemisia* community, and Tomanović *et al*. (2008b) the *Hieracium* - associations. Parasitoids of genus *Uroleucon* - aphids on weed plants were studied by Völkl and Starý (1988) and Barczak (1993a). Feraru *et al*. (2005) and Debek-Jankowska and Barczak (2006) centered aphids and parasitoids on wild grassy plants in agroecosystems. Müller *et al*. (1999) and van Veen *et al*. (2008) analysed, even quantitatively, the trophic relationships between the aphids, parasitoids and secondary parasitoids in an abandoned field which manifested a surprising species richness in communities. Parasitoid associations in urban environments were dealt with by Starý (1987a), Barczak and Blazejewska (1992), Werstak and Wiackowski (1998), Lumbierres *et al*. (2004). Feraru *et al*. (2005), Kavallieratos *et al*. (2008a) analysed parasitoid complexes in orchards, and Feraru *et al*. (2005) on herbs in farmland.

Changes in the species composition of parasitoid complexes and species abundance within the complexes affected by obligatory host plant alternation by aphids (in a mild climate) were determined by Hodek *et al*. (1962; 1966), Starý (1964; 2006) and later, with some variation, the evidence was supplemented by Barczak (1990; 1991a; 1991b), *A. fabae* being exemplified. Some different results were, however, obtained by Tomanović and Brajkovic (2001), Barnea *et al*. (2005).

Starý (1972; 1978a; 1978b) attempted, for the first time, to determine the seasonal relationships of semi-perennial Legumes (alfalfa, red clover) and annual cereals (wheat, barley) on grounds of the host-specificity of parasitoids and aphids, respectively. Starý and González (1991) and Barczak (1992) evaluated the role of the dominant *Chenopodium* - weed as a reservoir of parasitoids in agroecosystems, and (Barczak, 1966; 1993b) that of poppy (including *Chenopodium* - weeds) and beans as best crop reservoirs of parasitoids, wild shrubs being also considered. Tomanović and Brajković (2001) determined the relationships between crops/crops, crops/non-crops in an overall agroecosystem area. Pons and Starý (2003) classified the interactions of wheat and maize referred to differences between aphids and parasitoids.

Invasive plant-aphid associations were also targeted in this respect. Starý (1995) emphasized the role of invasive and specific aphid *Aphis spiraephaga* - *Spirea* as an important alternative host of local (and introduced) parasitoids in gardens. Occurrence of *Macrosiphum albifrons* and adaptation of native parasitoids was described by Starý and Havelka (1991). Invasion of *Diuraphis noxia* and adaptation of native parasitoids in Central Europe was determined by Starý (1999) and Starý *et al*. (2003). Tomanović *et al*. (2004) classified the invasive *Aphis oenotherae* - *Oenothera biennis* as a potential reservoir of local parasitioids in agroecosystem in Serbia. Pons *et al*. (2006) and Havelka and Starý (2007) centered the invasive *Myzocallis walshii* and adaptation of native parasitoids on the red oak in Spain and the Czech Republic. Starý (2006) listed the aphid-parasitoid associations on the invasive exotic *Impatiens glandulifera*; of them, the adapted local *A. fabae* developed powerful reservoirs of the aphid and associated parasitoid populations in course of the critical periods (late summer, early autumn) of the season in the Czech Republic.

Adaptation and interactions of introduced parasitoids in Europe were studied in *Lysiphlebus testaceipes* (Kavallieratos *et al*., 2002; Starý, 2006; Starý *et al*., 1988) and *Aphidius colemani* (Adisu *et al*., 2002; Starý, 2006).

The biosystematical research level, together with the knowledge of the host range of the participating parasitoid species (Kavallieratos *et al*., 2002) have doubtlessly improved the ecological studies.

There is an over-all increase of research on interactions between the crops and allied non-crop communities centering the evaluation of parasitoid reservoirs (Barczak *et al*., 1999; Kavallieratos *et al*., 2002).

Up-dated research on the biocorridors and plant-aphid-parasitoids associations has been on-going in several countries (Athanassiou, 2007; Kavallieratos *et al*., 2002; Rakhshani *et al*., 2007; 2008b; Tomanović *et al*., 2006; 2008a; 2008b). Doubtlessly, it also represents initial structural studies contributing to the over-all increase of ecological optimization studies.

As everywhere in Central Europe, the transformation of native ecosystems into cultivated land is of old date. The model area selected in the Czech Republic thus manifests a prevailing matrix of agroecosystems, managed forests, aquatic environments, the so-called non-crops habitats, and the settlement systems. Relatively up-dated (politically introduced) changes affected partially adversely the biodiversity in the crops and nearby habitats. The development of the farmland started from small and different smaller crop fields separated by field banks, organic fertilizers being applied; the floral and faunal composition of the banks was rather diverse and species numerous. The politically introduced Cooperative system resulted in the extensive monoculture crop areas and a wide, often even over-use of herbicides and prevailingly anorganic fertilizers with respective destruction of the former banks together with a decrease of the flora and fauna in the surviving ones. Also, farm roadsides and many smaller meadows and sites remained uncut seasonally. Drainage system and newly introduced ditches affected the wetlands and, simultaneously, the channels provided a composition of mostly-weed or undesirable self-sown plant volunteers. Some attempts to regenerate the farmland ecologically have been in progress.

The present account is an attempt to analyse, at least structurally the role of aphid parasitoids (a part of the aphid antagonists) as one of the model groups which centers the plant protection related to ecological optimization in a broader farmland area. A similar study was carried out in Serbia (Tomanović and Brajković, 2001). It is rather emphasized that the achieved results are specific for the parasitoids-aphid-plant associations and the area.

Materials and methods

Area

The model sites were restricted to an area of about 30-40 km east of Tabor, at about the borders of Central Bohemia, South Bohemia and the Highlands (= Vyso-

čina) districts, situated between the towns of Chýnov, Pacov, Ml. Vožice, Načeradec, Lukavec and their environs. The research centre was at Těchobuz village near Pacov, which is at 537 m above sea level, 49° 30' 48" N, 14° 55' 51" E. The area is climatically moderately wet and warm, belonging to the border of the so-called "Czech Siberia". Faunal grids: 6355, 6454, 6455, 6554, 6555. Annual year mean temperatures are 5-8 °C (mean temperatures in July 16 °C, in January –4 °C), annual mean precipitations 550-900 mm. Altitudes a.s.l. are between 450-650 metres. Agricultural production is of potato-growing type. The area is hilly, with some plateaus, with numerous, often patchy, managed forests. Roads are prevailingly bordered by various trees, with herbal undergrowth. Ponds, streams, rivers and wetlands are also common. Main production crops are potatoes, wheat, barley, rye, oat, maize, rape, red clover, to a lesser degree alfalfa, poppy, beet and flax. The acreage of the individual crops has been largely affected by the market.

Habitats

According to the interpretation manual "Catalogue of habitats of of the Czech Republic" (Chytrý *et al*., 2001) all the localities belong to habitats affected or created by man, namely to X2: Intensively managed fields, X3: Extensively managed fields, X5: Intensively managed meadows, X7: herbaceous ruderal vegetation outside human settlements, X9: Forest plantations of allochtonous trees, and X13: Woody vegetation outside forest and human settlements. Apart this, there are remaining parts of original habitats, e.g., T15: Wet *Cirsium* meadows as well.

All the types of the main habitats in the model area were sampled, but the field habitats (crop fields, roadsides, field banks) were gradually more preferred due to individual research targets which pertain to the farmland. In 2007, the interest was still somewhat modified, yet considering the system of "diversified" field banks newly introduced and initially launched in the area.

Period

The information was partially derived from research realized between 1958-2007 within a framework of determination of aphid parasitoid fauna and its host and habitat associations in the Czech Republic (Starý, 2006). However, special interest was paid to the model area scoping the farmland features and, as well, supplementary subsequent research was still launched in 2007. Simultaneously, some aphid and plant species (invaders) associations were targeted sometimes more intensively compared with the routine approaches. Also, an over-all research intensity in the model area somewhat varied in the sucessive years. In general, the whole research period was subdivided into three periods because of comparison possibilities. The first period covered 1958-1990 (443 samples), the period in between (1991-1999) included prevailingly occasional and/or species-targeting samples (50), and the last period (2000-2007) yielded 188 samples. In total, 631 samples were taken, 596 of which yielded parasitoids.

Sampling

The same methodology was followed throughout the whole research efforts. Parts of aphid-infestedplants were gently cut with scissors and transferred into translucent plastic containers (25-50 cm size) covered with nylon mesh. A representative part of aphid individuals was put in 7% ethanol for later identification. Plants were identified prevailingly at the spot or, less frequently, they were taken as a herbarium for later closer identification. The cages were mostly kept in transportable plastic frigs when in the car, and they were then transferred in the laboratory where they were maintained in 18-22 °C, about 70% RH and 18 hours photoperiod (fluorescent light). The samples were checked almost daily for parasitoid emergence. The parasitoids were sampled in 70% ethanol and later identified. Results of identification of plants, aphids and parasitoids (and habitats) were synthetized in a database of tritrophic associations.

Identification

The aphid material was identified by J. Holman (Inst. of Entomology, ASCR), P. Starý and J. Havelka. Parasitoid material was identified by P. Starý and it is preserved in his collection (České Budějovice).

Review of aphids and parasitoid species

The tritrophic associations parasitoid-aphid-plant and respective combinations are listed in tables 1, 2 and 3. The absence of parasitoids in the individual aphid species pertains prevailingly to the model area, whereas broader evidence can be found in the other areas of the Czech Republic (Starý, 2006).

Nomenclature used in aphids follows Havelka (2004), Eastop and Hille Ris Lambers (1976), Remaudiere and Remaudiere (1997), and that of the parasitoids Starý (2006).

References

Merely the references exemplifying various situations or information were cited. Many situations can be compared with these from other countries. Supplementing information on the seasonal history of the key parasitoid species and their aphid hosts can be found in the contributions by Starý (1966; 1974a; 1976; 1978b; 2006).

Results

Databases of associations

Information on the parasitoid species, aphid species, plant species, habitats and month of sampling are included, the records being alphabetically listed (table 1). Of course, the occurrence of some plant species can be overlapping in the individual habitats. The key-plant species sampled and their associations are mentioned in table 2, and for the aphid-parasitoid-plant associations in table 3, respectively. In some cases, no parasitoid evidence is presented, but the respective associations can be presumed to be found if more samples are taken (Starý, 2006).

Table 1. A list of parasitoid species, host aphid species, plants, habitats and months of sampling. [Habitats: 1 = Forests (managed forests: coniferous, mixed, decidous), parks, clearings, margins, undergrowth; 2 = Orchards, gardens, urban agglomerations (villages, cities); 3 = Wetlands (marshes, ponds, streams, rivers, drainage ditches and their sides); 4 = Meadows, pasture meadows; 5 = Fields (crops, including weeds and ecotones); 6 = Roadsides (grassy roadsides with some trees); 7 = Field banks (grassy, sometimes with some trees and shrubs hedges; also, anti-erosion banks); X = presence of a parasitoid species in a a sample].

Parasitoids	Aphids	Plants	Habitats							Months
			1	2	3	4	5	6	7	
Adialytus salicaphis (Fitch)	*Chaitophorus* sp.	*Populus tremula*	X					X	X	7 8
Aphidius absinthii Marshall	*Macrosiphoniella millefolii*	*Achillea millefolium*						X	X	7 8 9
Aphidius aquilus Mackauer	*Betulaphis brevipilosa*	*Betula* sp.	X							7
"	*Kallistaphis* sp.	"	X							8
Aphidius colemani Viereck	*Aphis viburni*	*Viburnum opulus*	X							5 6
"	*Brachycorynella asparagi*	*Asparagus officinalis*		X						8
"	*Cavariella* sp.	*Salix* sp.		X						7
"	*Diuraphis noxia*	*Hordeum vulgare*					X			7 8
Aphidius eadyi Starý,Gonzalez et Hall	*Acyrthosiphon pisum*	*Trifolium pratense*					X			5 6
"	"	*Pisum sativum*					X			7 8
"	"	*Medicago sativa*					X			8
"	"	*Vicia faba*					X			7
Aphidius ervi Haliday	*Acyrthosiphon pisum*	*Cytisus scoparius*				X				7
"	"	*Medicago sativa*					X			7
"	"	*Melilotus albus*		X						7
"	"	*Trifolium pratense*					X			6 7 8
"	"	*Vicia faba*					X			6 7
"	*Diuraphis noxia*	*Hordeum vulgare*					X			10
"	*Macrosiphum albifrons*	*Lupinus polyphyllus*	X					X		7
"	*Myzus persicae*	*Solanum tuberosum*					X			7
"	*Schizaphis graminum*	*Triticum aestivum*						X		7
"	*Sitobion avenae*	*Avena sativa*					X			7 8
"	"	*Hordeum vulgare*					X			6 7 8
"	"	*Secale cereale*					X			7
"	"	*Triticum aestivum*					X			6 7 8
Aphidius funebris Mackauer	*Uroleucon murale*	*Mycelis muralis*	X							8
"	*Uroleucon* sp.	*Carduus* sp.		X						7
"	"	*Centaurea* sp.				X		X	X	7 8
"	"	*Cirsium palustre*			X					7
"	"	*Crepis* sp.		X				X		8
Aphidius hieraciorum Starý	*Nasonovia nigra*	*Hieracium murorum*	X							6 7 8
"	*Nasonovia* sp.	"	X							8
Aphidius matricariae Haliday	*Brachycaudus* sp.	*Matricaria perforata*						X		8
"	*Capitophorus* sp.	*Cirsium arvense*						X		7
Aphidius microlophii Pennacchio et Tremblay	*Microlophium carnosum*	*Urtica dioica*	X	X	X			X	X	7 8
Aphidius phalangomyzi Starý	*Macrosiphoniella oblonga*	*Artemisia vulgaris*						X		8
Aphidius picipes (Nees) (=*avenae* Haliday)	*Acyrthosiphon pisum*	*Medicago sativa*					X			8
"	"	*Pisum sativum*					X			7
"	"	*Trifolium pratense*					X			5
"	*Microlophium carnosum*	*Urtica dioica*							X	7
"	*Sitobion avenae*	*Avena sativa*					X			8
"	"	*Secale cereale*					X			7
"	"	*Triticum aestivum*					X			6 7
Aphidius rhopalosiphi de Stefani-Perez	*Schizaphis graminum*	"						X		6 7
"	*Sitobion avenae*	*Secale cereale*					X			7
"	"	*Triticum aestivum*					X			7
Aphidius ribis Haliday	*Cryptomyzus galeopsidis*	*Galeopsis* sp.	X							7
Aphidius rosae Haliday	*Macrosiphum rosae*	*Rosa* sp.	X		X			X		7
Aphidius salicis Haliday	*Cavariella* sp.	*Daucus* sp.						X		8

(continued)

(Table 1 continued)

Parasitoids	Aphids	Plants	Habitats							Months
			1	2	3	4	5	6	7	
Aphidius salicis Haliday	*Cavariella* sp.	*Umbelliferae* sp.	X					X		8
Aphidius transcaspicus Telenga	*Hyalopterus pruni*	*Phragmites communis*			X					9
Aphidius urticae Haliday	*Microlophium carnosum*	*Urtica dioica*	X	X	X			X	X	7
"	*Rhopalomyzus lonicerae*	*Phalaris* sp.			X					7
Aphidius uzbekistanicus Luzhetzki	*Sitobion avenae*	*Avena sativa*					X			7
"	"	*Gramineae* sp.				X				7
"	"	*Holcus lanatus*				X				7
"	"	*Hordeum vulgare*				X				7
"	"	*Triticum aestivum*				X				7 8
Areopraon silvestre (Starý)	*Periphyllus testudinaceus*	*Acer pseudoplatanus*	X							5
"	*Periphyllus* sp.	"	X							10
Binodoxys acalephae (Marshall)	*Aphis craccae*	*Vicia cracca*						X		8
"	*Aphis fabae*	*Carduus* sp.		X						7
"	"	*Chenopodium* sp.		X				X		7 8
"	"	*Cirsium arvense*	X	X		X	X	X	X	7 8
"	"	*Euonymus europaea*		X						6
"	"	*Galium* sp.	X							6
"	"	*Impatiens noli-tangere*	X							9
"	"	*Rumex* sp.						X		7
"	"	*Vicia faba*					X			8
Binodoxys angelicae (Haliday)	*Aphis fabae*	*Cirsium arvense*					X	X		7
"	*Aphis hederae*	*Hedera helix*		X						7
"	"	*Spirea vanhoutei*		X						6
"	*Aphis viburni*	*Viburnum opulus*	X							5 6
"	*Aphis* sp.	*Vicia sp.*							X	8
"	*Brachycaudus* sp.	*Carduus* sp.		X						7
Binodoxys centaureae (Haliday)	*Uroleucon murale*	*Mycelis muralis*	X							8
"	*Uroleucon* sp.	*Carduus* sp.		X					X	8
"	"	*Centaurea* sp.				X				7
"	"	*Crepis* sp.				X				8
Diaeretiella rapae (M'Intosh)	*Aphis fabae*	*Chenopodium* sp.					X			8
"	*Brevicoryne brassicae*	*Brassica napus*					X	X	X	6 7 8 9
"	"	*Sinapis arvensis*					X			7 8
"	*Diuraphis noxia*	*Hordeum vulgare*					X			7
"	*Hayhurstia atriplicis*	*Chenopodium* sp.		X			X			7 8
"	*Schizaphis graminum*	*Triticum aestivum*						X		7
Diaeretus leucopterus (Haliday)	*Eulachnus agilis*	*Pinus sylvestris*	X							7
Dyscritulus planiceps (Marshall)	*Drepanosiphum platanoidis*	*Acer pseudoplatanus*	X							7 8 9
Ephedrus brevis Stelfox	unknown	unknown	X							8
Ephedrus helleni Mackauer	*Cavariella* sp.	*Umbelliferae* sp.						X		8
Ephedrus lacertosus (Haliday)	*Impatientinum balsamines*	*Impatiens noli-tangere*	X							7 9
Ephedrus nacheri Quilis	*Hayhurstia atriplicis*	*Chenopodium* sp.					X			7 8
"	*Lipaphis erysimi*	*Thlaspi arvense*						X		6
Ephedrus niger Gautier, Bonnamour et Gaumont	*Macrosiphoniella millefolii*	*Achillea millefolium*							X	8
Ephedrus persicae Froggatt	*Dysaphis sorbi*	*Sorbus aucuparia*	X							6
Ephedrus plagiator (Nees)	*Aphis fabae*	*Beta vulgaris*					X			7
"	"	*Chenopodium* sp.					X			8
"	"	*Cirsium arvense*		X						7
"	"	*Euonymus europaea*		X						6
"	"	*Impatiens noli-tangere*	X							8
"	"	*Rumex* sp.	X							8
"	*Aphis hederae*	*Hedera helix*	X							7
"	*Brachycorynella asparagi*	*Asparagus officinalis*		X						8
"	*Hyalopterus pruni*	*Phragmites communis*			X					9

(continued)

(Table 1 continued)

Parasitoids	Aphids	Plants	Habitats							Months
			1	2	3	4	5	6	7	
Ephedrus plagiator (Nees)	*Impatientinum asiaticum*	*Impatiens parviflora*	X							8
"	*Impatientinum balsamines*	*Impatiens noli-tangere*	X							7 8 9
"	*Rhopalosiphum padi*	*Prunus padus*	X							5
"	*Sitobion avenae*	*Avena sativa*					X			7 8
"	"	*Gramineae* sp.	X							7
"	"	*Hordeum distichon*					X			7
"	"	*Secale cereale*					X			7
"	"	*Triticum aestivum*					X			7
Ephedrus prociphili Starý	*Prociphilus fraxini*	*Fraxinus excelsior*	X							6 7
Euaphidius cingulatus Ruthe	*Pterocomma* sp.	*Salix caprea*	X							10
"	"	*Salix* sp.	X							8
Falciconus pseudoplatani (Marshall)	*Drepanosiphum platanoidis*	*Acer pseudoplatanus*	X							6 7 8
Lysiphlebus cardui (Marshall)	*Aphis fabae*	*Chenopodium* sp.					X			7 8
"	"	*Cirsium arvense*					X	X	X	7 8
"	"	*Galium* sp.						X		6
Lysiphlebus confusus Tremblay et Eady	*Aphis farinosa*	*Salix caprea*		X						7 8
"	"	*Salix* sp.		X						8
Lysiphlebus confusus-group	*Aphis grossulariae*	*Ribes rubrum*		X						7
Lysiphlebus fabarum (Marshall)	*Aphis craccivora*	*Vicia* sp.						X		8
"	*Aphis fabae*	*Carduus* sp.				X				7
"	"	*Chenopodium* sp.					X			7 8
"	"	*Cirsium arvense*		X		X	X	X	X	7 8
"	"	*Cirsium* sp.					X			7
"	"	*Matricaria perforata*						X		8
"	*Aphis hederae*	*Hedera helix*	X							6
Lysiphlebus fritzmuelleri Mackauer	*Aphis craccae*	*Vicia cracca*							X	8
Lysiphlebus melandriicola Starý	*Brachycaudus lychnidis*	*Silene alba*						X		7
Metaphidius aterrimus (Fahringer)	*Cinara* sp.	*Pinus sylvestris*	X							7
Monoctonus crepidis (Haliday)	*Nasonovia nigra*	*Hieracium murorum*	X							7
Monoctonus nervosus (Haliday)	*Impatientinum balsamines*	*Impatiens noli-tangere*	X							7 8 9
Paramonoctonus angustivalvus Starý	*Nasonovia nigra*	*Hieracium murorum*	X							6 8
Pauesia abietis (Marshall)	*Cinara* sp.	*Larix decidua*	X							6 7 8
Pauesia infulata (Haliday)	*Cinara* sp.	*Picea abies*	X							7
Pauesia laricis (Haliday)	*Cinara* sp.	*Larix decidua*	X							7
"	"	*Pinus sylvestris*	X							7
Pauesia piceaecollis (Starý)	*Cinara* sp.	*Picea abies*	X							7
"	"	*Pinus sylvestris*	X							7
Pauesia pini (Haliday)	*Cinara* sp.	*Larix decidua*	X							7
"	"	*Pinus sylvestris*	X							7
Pauesia unilachni (Gahan)	*Schizolachnus pineti*	"	X							7
Praon abjectum (Haliday)	*Aphis spiraephaga*	*Spirea vanhoutei*		X						6
Praon absinthii Bignell	*Macrosiphoniella tanacetaria*	*Tanacetum vulgare*							X	8
Praon barbatum Mackauer	*Acyrthosiphon pisum*	*Pisum sativum*					X			5
"	"	*Trifolium pratense*					X			7
Praon bicolor Mackauer	*Eulachnus agilis*	*Pinus sylvestris*	X							6 7
Praon flavinode (Haliday)	*Euceraphis punctipenis*	*Betula* sp.	X							8
"	*Myzocallis coryli*	*Corylus avellana*	X							7
"	*Tuberculatus annulatus*	*Quercus* sp.	X							8
Praon gallicum Starý	*Schizaphis graminum*	*Triticum aestivum*						X		7
"	*Sitobion avenae*	*Hordeum distichon*					X			7 8
"	"	*Triticum aestivum*					X			6
Praon longicorne Marshall	*Impatientinum asiaticum*	*Impatiens parviflora*	X							9
"	*Impatientinum balsamines*	*Impatiens noli-tangere*	X							7 8 9
"	*Microlophium carnosum*	*Urtica dioica*	X							8

(continued)

(Table 1 continued)

Parasitoids	Aphids	Plants	Habitats							Months
			1	2	3	4	5	6	7	
Praon pubescens Starý	*Nasonovia nigra*	*Hieracium murorum*	X							6 7
Praon volucre (Haliday)	*Aphis fabae*	*Chenopodium* sp.					X			8
"	*Brachycaudus lychnidis*	*Silene alba*						X		6
"	*Corylobium avellanae*	*Corylus avellana*	X							7
"	*Hyalopterus pruni*	*Phragmites communis*			X					7 8 9 10
"	"	*Prunus domestica*		X						7 8
"	*Impatientinum asiaticum*	*Impatiens parviflora*	X					X		7 8 9
"	*Lipaphis erysimi*	*Thlaspi arvense*						X		6
"	*Macrosiphum rosae*	*Rosa* sp.						X		8
"	*Macrosiphum* sp.	*Euphorbia* sp.	X							8
"	*Microlophium carnosum*	*Urtica dioica*	X					X	X	7 8
"	*Rhopalosiphum padi*	*Prunus padus*	X							5
"	*Schizaphis graminum*	*Triticum aestivum*						X		7
"	*Sitobion avenae*	*Avena sativa*					X			7 8
"	"	*Hordeum distichon*					X			7
"	"	*Secale cereale*					X			7
"	"	*Triticum aestivum*					X			7
Praon yomenae Takada	*Uroleucon* sp.	*Centaurea* sp.						X		7
"	"	*Cirsium palustre*								7
"	"	*Crepis biennis*				X				7
Pseudopraon mindariphagum Starý	*Mindarus abietinus*	*Abies alba*	X							5 6
Trioxys auctus (Haliday)	*Rhopalosiphum padi*	*Triticum aestivum*					X			7
Trioxys betulae (Marshall)	*Symydobius oblongus*	*Betula* sp.	X							8
Trioxys cirsii Curtis	*Drepanosiphum platanoidis*	*Acer pseudoplatanus*	X							6 8
Trioxys curvicaudus Mackauer	*Myzocallis walshii*	*Quercus rubra*	X							7
"	*Tuberculatus* sp.	*Quercus* sp.	X							7
Trioxys falcatus Mackauer	*Periphyllus testudinaceus*	*Acer pseudoplatanus*	X							5
Trioxys pallidus (Haliday)	*Myzocallis carpini*	*Carpinus betulus*	X							7
"	*Myzocallis walshii*	*Quercus rubra*	X							7 9
"	*Tuberculatus annulatus*	*Quercus* sp.	X							6 7
Trioxys tenuicaudus Starý	*Eucallipterus tiliae*	*Tilia* sp.	X							7
"	*Myzocallis coryli*	*Corylus avellana*	X							7

F o r e s t s a n d p a r k s

The managed forests composition consists prevailingly of *Picea abies*, to a lesser degree of *Pinus sylvestris*, with a small percentage of *Abies alba*, *Larix europaea*, *Fagus sylvatica*, *Betula* spp., *Tilia* spp., *Quercus* spp., *Alnus glutinosa*, *Prunus padus*, *P. avium*, *Carpinus betulus*, *Corylus avellana*, *Crataegus oxyacantha*, *Fraxinus excelsior*, *Euonymus europaea*, *Populus tremula*, *P. nigra*, *Salix* spp., *Sorbus aucuparia*, *Ulmus* spp., *Viburnum opulus*. Undergrowth: *Rubus caesius*, *R. idaeus*, *Lonicera xylosteum*, *Hieracium murorum*, *Mycelis muralis*, *Senecio nemorensis*, *Impatiens parviflora*, *I. nolitangere*, *Prenanthes purpurea*, *Oxalis acetosella*, *Vaccinium myrtillus*, *Erica carnea*, *Lycopodium clavatum*, *Equisetum silvaticum*, grasses.

The parks manifest a rather similar tree/shrub species composition as the mixed forests, but some exotic species both in the shrub and tree layer can be found: *Pseudotsuga menziesii*, *Pinus* sp., *Abies* sp., rhododendrons and other ornamentals.

O r c h a r d s a n d g a r d e n s

Prevailingly a mix of fruit trees and shrubs in family gardens: *Prunus domestica* et var., *P. avium*, *Malus domestica*, *Pyrus communis*, *Juglans regia*, *Ribes rubrum*, *R. nigrum*, Grossularia. Rarely, remaining old *Prunus avium* orchards in the field. *Syringa* and *Spirea* ornamentals. *Hedera helix*, *Humulus lupulus* and *Sambucus nigra* in neglected sites, also *Cirsium arvense*, *Carduus*, and others. Gardens also manifest a widely variable set of ornamentals trees and shrubs such as *Picea abies*, *P. pungens*, *Chamaecyparis*, *Thuja*, *Abies grandis*, *A. concolor*, *A. koreana*, *Pinus sylvestris*, *P. nigra*, *Rhodondendron* spp., apart from ornamental herbs and rock garden plants.

W e t l a n d s

Numerous ponds can be found in the area, with *Caltha palustris*, *Phragmites communis*, *Phalaris arundinacea*, *Typha* spp. and often with *Betula*, *Alnus* on the banks. Wet meadows are remaining parts of original habitats. Wet *Cirsium* meadows (Atlantic and sub Atlantic humid meadows, alliance *Calthion palustris*), yield often *Caltha palustris*, *Cirsium palustre*, *C. oleraceum*, *C.*

heterophyllum, *Filipendula ulmaria*, *Agrostis canina*, *Alopecurus pratensis*, *Angelica sylvestris*, *Anthoxanthum odoratum*, *Bistorta major*, *Carex acuta*, *C. acutiformis*, *C. canescens*, *C. cespitosa*, *C. echinata*, *C. nigra*, *Deschampsia cespitosa*, *Festuca pratensis*, *Juncus effusus*, *Luzula campestris*, *Myosotis palustris*, *Poa pratensis*, *Potentilla erecta*, *Scirpus sylvaticus*, *Succisa pratensis*, *Valeriana dioica*, *Viola palustris*, with *Salix* spp., *Frangula alnus* and *Alnus glutinosa* hedges. Streams and rivers bordered commonly with *Alnus* and *Salix*, often *Prunus padus,* the herbal stratum - *Galium aparine*, *Urtica dioica*, *Impatiens glandulifera*, sometimes *Petasites hybridus.*

M e a d o w s a n d g r a s s f i e l d s

Pasture meadows are remaining parts of original habitats. Alluvial *Alopecurus* meadows (Moist or wet lowland eutrophic and mesotropic grassland, alliance *Alopecurion pratensis*), manifesting prevailingly a number of various grasses - *Alopecurus pratensis*, *Deschampsia cespitosa*, *Elytrigia repens*, *Festuca pratensis*, *Holcus lannatus*, *Poa pratensis*, mixed with *Taraxacum officinale*, *Glechoma hederacea*, *Lychnis flos-cuculi*, *Lysimachia nummularia*, *Rumex crispus*, *R. obtusifolius*, *Sanguisorba officinalis*, *Symphytum officinale* and *Trifolium hybridum.*

F i e l d s

The prevailing crops are *Avena sativa*, *Brassica napus*, *Hordeum vulgare*, *Medicago sativa*, *Pisum sativum*, *Secale cereale*, *Solanum tuberosum*, *Trifolium pratense*, *Triticum aestivum*, *Vicia faba*, less frequently *Beta vulgaris*, *Papaver somniferum*. *Phacelia tanacetifolia* is also grown as a honey-plant.

R o a d s i d e s

The district roads are prevailingly bordered by various road-line trees. *Acer platanoides*, *A. pseudoplatanus*, *Aesculus hippocastanus*, *Alnus glutinosa*, *Betula* spp., *Fraxinus excelsior*, *Quercus* spp., *Picea abies*, *Pinus sylvestris*, *Populus nigra*, *P. tremula*, *Prunus avium* (volunteer), *Salix* spp., *Sorbus aucuparia*, *S. nigra*, *Tilia* spp., and remnants of fruit tree groves such as *Prunus avium*, *Malus domestica*, *Prunus domestica* et var., *Pyrus communis*. Roadside herbs differ depending on the nearby habitats, namely forests and wetlands compared with the fields. Forests: *Cytisus scoparius*, *Hieracium murorum*, *Impatiens noli-tangere*, *I. glandulifera*, *I. parviflora*, *Lupinus polyphyllus*, *Petasites hybridus*, *Rubus idaeus*, *Rubus* spp., *Senecio nemorensis*, *Tussilago farfara*, *Urtica dioica* various *Daucaceae*. Wetlands: *Caltha palustris*, *Cirsium oleraceum*, *C. palustre*, *Echinops sphaerocephalus*, *Filipendula ulmaria*, *Galium aparine*, *Impatiens glandulifera*, *I. parviflora*, *Phalaris arundinacea*, *Phragmites communis*, *Urtica dioica*. Fields: *Aegopodium podagraria*, *Arctium* spp., *Brassica napus*, *Cirsium arvense*, *Geranium* spp., *Lathyrus* spp., *Plantago* spp., *Rubus idaeus*, *Silene alba*, *Sonchus oleraceus*, *Verathrum* spp.

The farm roads manifest also road-line associations of an older date such as *Prunus avium*, *P. domestica* et var., *Malus domestica*, *Pyrus communis*, *Betula* spp. Hedges of *Prunus spinosa*, *Rosa* spp., rarely of *Euonymus europaea* also occur.

Opposite to the earlier approaches, the newly planted road-line trees avoid the fruit trees, and they are generally ornamental and shade-trees (wind-breaks), *Populus* spp., *Fraxinus excelsior*, *Sorbus aucuparia*, and others.

The herbs include *Achillea millefolium*, *Artemisia vulgaris*, *Carduus* spp., *Centaurea* spp., *Chenopodium* spp., *Cirsium arvense*, *Crepis biennis*, *Cytisus scoparius*, *Daucus* sp., *Epilobium* spp., *Galium aparine*, *Poaceae* spp., *Heracleum sphondylium*, *Lathyrus* spp., *Lupinus polyphyllus*, *Matricaria perforata*, *Rumex* spp., *Silene alba*, *Sinapis arvensis*, *Sonchus oleraceus*, *Tanacetum vulgare*, *Taraxacum officinale*, *Urtica dioica*, *Vicia cracca*.

D r a i n a g e d i t c h e s

Some drainage programmes resulted also in the development of cement-block bordered ditches. These were gradually covered with a mixture of volunteer plant species and associated fauna originating partially from the wetlands (*Phragmites communis*, *Caltha palustris*, *Filipendula ulmaria*), fields (weeds - *Daucus*, *Chenopodium*, volunteer crops - *Brassica oleracea*), meadows (*Taraxacum officinale*). If not controlled, *Alnus glutinosa*, *Frangula alnus* and others contributed to the development of a successive hedge-like groves.

T r a d i t i o n a l t e r r a c e f i e l d b a n k s

The old-time terrace banks manifest a more or less numerous mix of volunteer shrubs and trees - *Prunus spinosa*, *Prunus domestica*, *Rosa* sp., *Picea abies*, *Corylus avellana*, *Sorbus aucuparia*, *Quercus robur*. Some of them, especially these closer to a village area are cut seasonally.

These habitats possess a mixture of herbal elements such as *Achillea millefolium*, *Alchemilla vulgaris*, *Agrostis stolonifera*, *Anthriscus sylvestris*, *Artemisia vulgaris*, *Campanula rapunculus*, *Centaurea jacea*, *Cerastium arvense*, *Cirsium arvense*, *Convolvulus arvensis*, *Coronilla varia*, *Crepis biennis*, *Daucus carota*, *Dianthus deltoides*, *Echium vulgare*, *Epilobium angustifolium*, *Equisetum arvense*, *Fumaria officinalis*, *Galium mollugo*, *G. verum*, *Geranium robertianum*, *Heracleum sphondylium*, *Hypericum perforatum*, *Knautia arvensis*, *Leontodon hispidus*, *Linaria vulgaris*, *Matricaria maritima*, *Plantago lanceolata*, *P. media*, *Ranunculus bulbosus*, *Rubus idaeus*, *Rumex obtusifolius*, *Securigera varia*, *Silene alba*, *Tanacetum vulgare*, *Taraxacum officinale*, *Thymus serpyllum*, *Trifolium pratense*, *T. repens*, *Urtica dioica*, *Verbascum blattaria*, *Veronica chamaedrys*, *Vicia cracca*, various Poaceae species.

Of them, *Artemisia*, *Tanacetum* are associated with a specific aphid fauna, and the same is true for the parasitoids; these members do not have any relationships with the crops.

Cirsium arvense is important for often high populations of *A. fabae* (non-pest biotype) and associated parasitoids (*A. fabae* and other species). *Arctium* is a similar case, but the aphids usually manifest low parasitization.

Many species of Poaceae host the aphids and some of them are reservoirs of *S. avenae* (for cereal crops, the same for parasitoids).

Table 2. Plant-aphid-parasitoid associations in the model area. The associations are listed alphabeticaly. Also, associations where no aphid parasitoides were detected are included as parasitoids can be detected in the future (cf. Starý, 2006). Habitats can be derived from the parasitoid-aphid-plant list (table 1).

Plants	Aphids	Parasitoids
Abies alba	*Mindarus abietinus*	*Pseudopraon mindariphagum*
"	*Prociphilus fraxini*	–
Abies concolor	*Cinara curvipes*	–
Abies grandis	*Cinara curvipes*	–
"	*Prociphilus fraxini*	–
Abies koreana	*Prociphilus fraxini*	–
Acer platanoides	*Periphyllus* sp.	–
Acer pseudoplatanus	*Drepanosiphum platanoides*	*Dyscritulus planiceps*
"	"	*Falciconus pseudoplatani*
"	"	*Trioxys cirsii*
"	*Periphyllus testudinaceus*	*Areopraon silvestre*
"	"	*Trioxys falcatus*
"	*Periphyllus* sp.	*Areopraon silvestre*
Achillea millefolium	*Macrosiphoniella millefolii*	*Aphidius absinthii*
"	"	*Ephedrus niger*
Artemisia vulgaris	*Macrosiphoniella oblonga*	*Aphidius phalangomyzi*
Asparagus officinalis	*Brachycorynella asparagi*	*Aphidius colemani*
"	"	*Ephedrus plagiator*
Avena sativa	*Metopolophium dirhodum*	–
"	*Rhopalosiphum padi*	*Ephedrus plagiator*
Abies koreana	*Prociphilus fraxini*	–
Avena sativa	*Sitobion avenae*	*Aphidius ervi*
"	"	*Aphidius picipes*
"	"	*Aphidius uzbekistanicus*
"	"	*Praon volucre*
Beta vulgaris	*Aphis fabae*	*Ephedrus plagiator*
Betula sp.	*Betulaphis brevipilosa*	*Aphidius aquilus*
"	*Euceraphis punctipennis*	*Praon flavinode*
"	*Kallistaphis* sp.	*Aphidius aquilus*
"	*Symydobius oblongus*	*Trioxys betulae*
Brassica napus	*Brevicoryne brassicae*	*Diaeretiella rapae*
Carduus sp.	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Lysiphlebus fabarum*
"	*Brachycaudus* sp.	*Binodoxys angelicae*
"	*Uroleucon* sp.	*Aphidius funebris*
"	"	*Binodoxys centaureae*
Carpinus betulus	*Myzocallis carpini*	*Triopxys pallidus*
Centaurea sp.	*Uroleucon* sp.	*Aphidius funebris*
"	"	*Binodoxys centaureae*
"	"	*Praon yomenae*
Chenopodium sp.	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Diaeretiella rapae*
"	"	*Ephedrus plagiator*
"	"	*Lysiphlebus cardui*
"	"	*Lysiphlebus fabarum*
"	"	*Praon volucre*
"	*Hayhurstia atriplicis*	*Diaeretiella rapae*
"	"	*Ephedrus nacheri*
Cirsium arvense	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Binodoxys angelicae*
"	"	*Ephedrus plagiator*
"	"	*Lysiphlebus cardui*
"	"	*Lysiphlebus fabarum*

(continued)

(Table 2 continued)

Plants	Aphids	Parasitoids
Cirsium arvense	*Capitophorus* sp.	*Aphidius matricariae*
Cirsium palustre	*Uroleucon* sp.	*Aphidius funebris*
Cirsium sp.	*Aphis fabae*	*Lysiphlebus fabarum*
Corylus avellana	*Corylobium avellanae*	*Praon volucre*
"	*Myzocallis coryli*	*Praon flavinode*
"	"	*Trioxys tenuicaudus*
Crataegus oxyacantha	*Ovatus crataegarius*	–
Crepis biennis	*Uroleucon* sp.	*Praon yomenae*
Crepis sp.	*Uroleucon* sp.	*Aphidius funebris*
"	"	*Binodoxys centaureae*
Cytisus scoparius	*Acyrthosiphon pisum*	*Aphidius ervi*
Dactylis glomerata	*Sitobion avenae*	–
Daucus sp.	*Aphis fabae*	*Binodoxys acalephae*
Epilobium	*Aphis* sp.	–
Euonymus europaea	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Ephedrus plagiator*
Euphorbia sp.	*Macrosiphum* sp.	*Praon volucre*
Fagus sylvatica	*Phyllaphis fagi*	–
Filipendula ulmaria	*Macrosiphum cholodkowskyi*	–
Fraxinus excelsior	*Prociphilus* sp.	*Ephedrus prociphili*
Galeopsis sp.	*Cryptomyzus galeopsidis*	*Aphidius ribis*
Galium sp.	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Lysiphlebus cardui*
Gramineae sp.	*Sitobion avenae*	*Aphidius uzbekistanicus*
"	"	*Ephedrus plagiator*
Hedera helix	*Aphis hederae*	*Binodoxys angelicae*
"	"	*Ephedrus plagiator*
"	"	*Lysiphlebus fabarum*
Heracleum sphondylium	*Cavariella pastinacae*	–
Hieracium murorum	*Nasonovia nigra*	*Aphidius hieraciorum*
"	"	*Monoctonus crepidis*
"	"	*Paramonoctonus angustivalvus*
"	"	*Praon pubescens*
"	*Nasonovia* sp.	*Aphidius hieraciorum*
"	*Uroleucon* sp.	–
Holcus lanatus	*Sitobion avenae*	*Aphidius uzbekistanicus*
Hordeum vulgare	*Diuraphis noxia*	*Aphidius colemani*
"	"	*Aphidius ervi*
"	"	*Diaeretiella rapae*
"	*Sitobion avenae*	*Aphidius ervi*
"	"	*Aphidius uzbekistanicus*
"	"	*Ephedrus plagiator*
"	"	*Praon gallicum*
"	"	*Praon volucre*
Humulus lupulus	*Phorodon humuli*	–
Impatiens glandulifera	*Aphis fabae*	–
"	*Impatientinum asiaticum*	–
Impatiens noli-tangere	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Ephedrus plagiator*
"	"	*Praon* sp.
"	*Impatientinum balsamines*	*Ephedrus lacertosus*
"	"	*Ephedrus plagiator*
"	"	*Monoctonus nervosus*
"	"	*Praon longicorne*
Impatiens parviflora	*Impatientinum asiaticum*	*Ephedrus plagiator*

(continued)

(Table 2 continued)

Plants	Aphids	Parasitoids
Impatiens parviflora	*Impatientinum asiaticum*	*Praon longicorne*
"	"	*Praon volucre*
Juglans regia	*Chromaphis juglandis*	–
Larix decidua	*Adelges laricis*	–
"	*Adelges viridis*	–
"	*Cinara* sp.	*Pauesia abietis*
"	"	*Pauesia laricis*
"	"	*Pauesia pini*
Lathyrus sp.	*Acyrthosiphon pisum*	–
"	*Megoura viciae*	–
Lolium sp.	*Sitobion avenae*	–
Lupinus polyphyllus	*Acyrthosiphon pisum*	–
"	*Macrosiphum albifrons*	*Aphidius ervi*
Malus domestica	*Aphis pomi*	–
"	*Eriosoma lanigerum*	–
"	*Rhopalosiphum insertum*	–
Malva sp.	*Aphis umbrella*	–
Matricaria perforata	*Aphis fabae*	*Lysiphlebus fabarum*
"	*Brachycaudus* sp.	*Aphidius matricariae*
Medicago sativa	*Acyrthosiphon pisum*	*Aphidius eadyi*
"	"	*Aphidius ervi*
"	"	*Aphidius picipes*
Melilotus albus	*Acyrthosiphon pisum*	*Aphidius ervi*
Mycelis muralis	*Uroleucon murale*	*Binodoxys centaureae*
"	*Uroleucon obscurum*	*Aphidius funebris*
Papaver somniferum	*Aphis fabae*	–
Phalaris arundinacea	*Hyalopteroides humilis*	–
"	*Rhopalomyzus lonicerae*	*Aphidius urticae*
Phragmites communis	*Hyalopterus pruni*	*Aphidius trancaspicus*
"	"	*Ephedrus plagiator*
"	"	*Praon volucre*
Picea abies	*Adelges laricis*	–
"	*Adelges viridis*	–
"	*Cinara* sp.	*Pauesia infulata*
"	"	*Pauesia piceaecollis*
Pinus cembra	*Pineus cembrae*	–
Pinus sylvestris	*Eulachnus agilis*	*Diaeretus leucopterus*
"	"	*Praon bicolor*
"	*Cinara* sp.	*Metaphidius aterrimus*
"	"	*Pauesia laricis*
"	"	*Pauesia piceaecollis*
"	"	*Pauesia pini*
"	*Schizolachnus pineti*	*Pauesia unilachni*
Pisum sativum	*Acyrthosiphon pisum*	*Aphidius eadyi*
"	"	*Aphidius ervi*
"	"	*Praon barbatum*
Prunus avium	*Myzus cerasi*	–
Prunus domestica	*Hyalopterus pruni*	*Praon volucre*
Prunus padus	*Rhopalosiphum padi*	*Ephedrus plagiator*
"	"	*Praon volucre*
Populus tremula	*Chaitophorus* sp.	*Adialytus salicaphis*
Pseudotsuga menziesii	*Gilletteella cooleyi*	–
Quercus rubra	*Myzocallis walshii*	*Trioxys curvicaudus*
"	"	*Trioxys pallidus*
"	*Stomaphis quercus*	–

(continued)

(Table 2 continued)

Plants	Aphids	Parasitoids
Quercus rubra	*Thelaxes dryophila*	–
Quercus sp.	*Lachnus roboris*	–
"	*Tuberculatus annulatus*	*Praon flavinode*
"	"	*Trioxys pallidus*
"	*Tuberculatus* sp.	*Trioxys curvicaudus*
Ribes rubrum	*Aphis grossulariae*	*Lysiphlebus confusus-group*
Rosa sp.	*Macrosiphum rosae*	*Aphidius rosae*
"	"	*Praon volucre*
Ranunculus sp.	*Thelaxes dryophila*	–
Rubus caesius	*Macrosiphum funestum*	–
Rubus idaeus	*Aphis idaei*	–
Rumex sp.	*Aphis fabae*	*Binodoxys acalephae*
"	"	*Ephedrus plagiator*
Salix caprea	*Aphis farinosa*	*Lysiphlebus confusus*
"	*Pterocomma* sp.	*Euaphidius cingulatus*
Salix sp.	*Aphis farinosa*	*Lysiphlebus confusus*
"	*Cavariella* sp.	*Aphidius colemani*
"	*Pterocomma* sp.	*Euaphidius cingulatus*
Sambucus nigra	*Aphis sambuci*	–
Secale cereale	*Sitobion avenae*	*Aphidius ervi*
"	"	*Aphidius picipes*
"	"	*Aphidius rhopalosiphi*
"	"	*Ephedrus plagiator*
"	"	*Praon volucre*
Senecio nemorensis	*Aphis jacobaeae*	–
Silene alba	*Brachycaudus lychnidis*	*Lysiphlebus melandriicola*
"	"	*Praon volucre*
Sinapis arvensis	*Brevicoryne brassicae*	*Diaeretiella rapae*
Solanum tuberosum	*Myzus persicae*	*Aphidius ervi*
Sonchus oleraceus	*Hyperomyzus lactucae*	–
"	*Uroleucon* sp.	–
Sorbus aucuparia	*Dysaphis sorbi*	*Ephedrus persicae*
Spirea vanhouttei	*Aphis spiraephaga*	*Binodoxys angelicae*
"	"	*Praon abjectum*
Tanacetum vulgare	*Macrosiphoniella tanacetaria*	*Praon absinthii*
"	*Metopeurum fuscoviride*	–
Taraxacum officinale	*Uroleucon* sp.	–
Thlaspi arvense	*Lipaphis erysimi*	*Ephedrus nacheri*
"	"	*Praon volucre*
Tilia sp.	*Eucallipterus tiliae*	*Trioxys tenuicaudus*
Trifolium pratense	*Acyrthosiphon pisum*	*Aphidius eadyi*
"	"	*Aphidius ervi*
"	"	*Aphidius picipes*
"	"	*Praon barbatum*
Triticum aestivum	*Rhopalosiphum padi*	*Trioxys auctus*
"	*Schizaphis graminum*	*Aphidius ervi*
"	"	*Aphidius rhopalosiphi*
"	"	*Diaeretiella rapae*
"	"	*Praon gallicum*
"	"	*Praon volucre*
"	*Sitobion avenae*	*Aphidius ervi*
"	"	*Aphidius picipes*
"	"	*Aphidius rhopalosiphi*
"	"	*Ephedrus plagiator*
"	"	*Praon gallicum*

(continued)

(Table 2 continued)

Plants	Aphids	Parasitoids
Triticum aestivum	*Sitobion avenae*	*Praon volucre*
Ulmus sp.	*Schizoneura* sp.	–
Umbelliferae sp.	*Cavariella* sp.	*Aphidius salicis*
"	"	*Ephedrus helleni*
Urtica dioica	*Microlophium carnosum*	*Aphidius microlophii*
"	"	*Aphidius picipes*
"	"	*Aphidius urticae*
"	"	*Praon longicorne*
"	"	*Praon volucre*
Viburnum opulus	*Aphis viburni*	*Aphidius colemani*
"	"	*Binodoxys angelicae*
Vicia cracca	*Aphis craccae*	*Binodoxys acalephae*
"	"	*Lysiphlebus fritzmuelleri*
Vicia faba	*Acyrthosiphon pisum*	*Aphidius eadyi*
"	"	*Aphidius ervi*
"	*Aphis fabae*	*Binodoxys acalephae*
Vicia sp.	*Aphis craccivora*	*Lysiphlebus fabarum*
"	*Aphis* sp.	*Binodoxys angelicae*
Zea mays	*Rhopalosiphum padi*	–

The presence of volunteer crop plants originating from neighbouring crop cultures means simultaneously some habitat diversification similar to intercropping. Such plants escape management including treatments and some cases can work as useful reservoirs of aphid and parasitoid associations (*Brassica napus* - *Diaeretiella rapae* in verges nearby cereals - *Diuraphis noxia*).

Newly introduced field bank system /biodiversification

The terracing system is targeted to prevent soil erosion and water loss. If related to insects, it may mean also the extension of field banks and shade trees in farmland. The species composition of the herbaceous plants seems not to have been controlled yet, thus consisting of volunteer weeds, wild plants and volunteer crops. The only determined components are the newly planted trees, such as *Sorbus aucuparia*, *Fraxinus excelsior*, and some other native species.

Changes in the composition of flora and fauna

Several cases reflecting the situation and response of the native and as-native communities on one hand, the extinction (or almost extinction-retreat) of some members, and on the other hand, the invasive exotic floral and faunal immigrants in many other parts of the country (Mlíkovský and Stýblo, 2006; Šefrová and Laštůvka, 2005) were also detected in the model area. However, only the relatively up-dated cases were selected.

Retreating or disappearing plant species

Apart from the targets, some critically endangered higher plant species (Křivka and Růžička, 1999) were observed to dissappear in the course of the over-all observation period. These were, for example, *Gentianella praecox bohemica*, *Orchis* spp. As no aphid-parasitoid associations were formerly determined, these cases were out of our scope and references.

Invasive plant species

Impatiens glandulifera (Balsaminaceae):

Originating as an escape from cultivation in Northern Bohemia at the end of 19th century, an all over expansion of this touch-me-not species since 1930 has covered the riparian habitats, prevailingly the banks of ponds, rivers, streams, wet meadows and forest undergrowth in most of the country (Mandák, 2006; Pyšek and Prach, 1995; Slavík, 1996).

In the model area, it was also initially determined as an ornamental plant in gardens, but it has manifested an extensive expansion (since at least 2000) along most of the rivers, streams and ponds. Moreover, the plants were capable of expanding even up the slopes, following roadsides and field banks far into the crop field margins.

Plant phenology (maturity and flowering) coincided with the decrease of *A. fabae* populations on secondary crop plants (*Chenopodium* spp., *Cirsium arvense*, etc.) and the aphid often reached high numbers until the late autumn, the same situation occurred in the associated parasitoids. Also, high population of the exotic *Impatientinum asiaticum* was observed. The plant was determined as rather useful for pollinators (Starý and Tkalců, 1998) and some aphid predators (Starý and Láska, 1999). It is commonly associated with *A. fabae* and *I. asiaticum*, less frequently with *Aphis nasturtii*; in a similar way as in *I. parviflora*, parasitoids were detected in other areas.

Impatiens parviflora (Balsaminaceae):

A species of west-Siberian origin, introduced and subsequently escaping outdoors, now distributed all over the country (Mandák, 2006; Slavík, 1996), including the model area. Its expansion in the course of the research

period in many places and sites, especially along many roadsides and in forest undergrowth, was observed. It was targeted because of the occurrence of *I. asiaticum* in the area.

The plant remained associated with the exotic (*I. asiaticum*) and native (*A. fabae*) aphids.

Lupinus polyphyllus (Fabaceae):

A species of North American origin. Its occurrence was patchy, at the edges of forests and clearings. Sometimes attacked by *Acyrthosiphon pisum* and *Macrosiphum albifrons*.

Quercus rubra (Fagaceae):

An exotic invasive species of North American origin. It occurs rarely, mostly in the parks in the original area. It was associated merely with *Myzocallis walshii*.

Invasive aphid species

Aphis spiraephaga Müller:

It is a recent immigrant of Central Asian origin that has become widely distributed in most of Europe and a part of Asia Minor. It is holocyclic dioecious, alternating between *Spirea* and *Bellis perennis*, *Carum carvi*, *Arabis hirsuta*, *Valeriana officinalis* (Holman, 1991; Starý, 1995). It was determined also in the model area on *Spirea* ornamentals. The local parasitoids were determined by Starý (1995).

Cinara curvipes (Patch):

This is a species originally distributed and associated with *Abies* and other conifers in North America (Canada, USA, Mexico). It was detected as an apparently accidental immigrant in Kew Gardens, London, in 2001, soon expanding to continental Europe (Germany, Serbia). Its invasion was soon followed by overpopulations in many parts of Germany (on *Abies concolor*), reaching a new pest status.

The first record from the Czech Republic comes from the autumn of 2006 (South Bohemia, *A. concolor*). In 2007, remarkably obvious overpopulations of the aphid were observed in many parts of the Czech Republic, and even pesticide treatments were used to supress the new pest on exotic ornamental trees in gardens and parks. The aphid was found attacking namely *A. concolor*, *A. grandis*, to a lesser degree *A. koreana*, *Pseudotsuga menziesii*. Infestation of *A. concolor* and *A. grandis* was detected in the target area in 2007 (Havelka *et al*., 2007a; 2007b; Mertelik *et al*., 2007; Šrůtka *et al*., 2007).

Diuraphis noxia (Kurdjumov):

The Russian wheat aphid (RWA) reached also the model area in about 1999 when extending its expansion from the Southeast to the Nortwest of Europe (Starý, 2000; Starý *et al*., 2003). *Aphidius ervi* and *Diaeretiella rapae* were detected as local parasitoids adapted to RWA in the model area (Starý, 2006). The aphid supplemented the pest aphid complex on cereals, its population increase started at the milky stage, namely on barley (Starý, 2000), high populations can occur in dry and host summer months (Starý and Lukášová, 2002). The aphid was determined yet at very high population levels on barley at 640 metres altitude a.s.l., which is the highest point in its distribution range in the country (2007, Františkov village, unpublished data).

Impatientinum asiaticum (Nevsky):

This invasive aphid of Siberian origin was detected in the Czech Republic in 1968 (Holman, 1971; 2006) and at least since 1991 it has been found in the model area as well; this concerns also the adapted local native parasitoids (Starý, 1970c; 2006).

The aphid remained associated solely with *I. parviflora* and *I. glandulifera*, contributing sometimes to weakening of plants resulting in the drop off of unripened drying seeds.

Macrosiphum albifrons (Essig):

This North American aphid associated with *Lupinus polyphyllus* was detected in the Czech Republic (including also the model area) for the first time in 1989; it represented a new host species for the local native *Aphidius ervi* (Starý, 2006; Starý and Havelka, 1991).

Myzocallis walshii (Monell):

This North American aphid associated with the North American *Quercus rubra* became distributed in many European countries, and it expanded also in the Czech Republic (including the model area - 2004). The local parasitoids *Trioxys pallidus* and *T. tenuicaudus* were detected (Havelka and Starý, 2007; Starý, 2006).

The aphid was observed to reach even rather high population levels on the red oak, but merely in the urban ecosystems, whereas its populations were generally low in the forests. Also, it contributed to the increase of the host list of some local parasitoids (Havelka and Starý, 2007; Starý, 2006).

Introduced aphid species

Schizaphis graminum (Rondani):

Laboratory-produced aphid colonies on small wheat plants were exposed regularly in a roadside site close to the wheat field aiming at the prediction of the adaptation of native antagonists to *Diuraphis noxia*, expanding from the Southeast inlands of the country (Starý, 2000; Starý *et al*., 2003). *S. graminum* is a native aphid species on cereals and namely maize in warmer areas of the country. But it was not, of course, possible to introduce *D. noxia* in a new (= model) area prior to its natural expansion, and *S. graminum* is a native host similar to *D. noxia*. Native parasitoids (*Aphidius ervi*, *Diaeretiella rapae* and *Praon gallicum*) attacked the exposed *S. graminum* colonies. This yielded important information on the predicted response of local native parasitoids to the expanding pest (Starý and González, 1992). The aphid is naturally distributed in warmer areas of the country so that it can be presumed to disappear again from the target area because of the adverse climatic conditions.

Introduced parasitoid species

Aphidius colemani Viereck:

It was released on *Aphis viburni* (in 2004) and *Diuraphis noxia* (in 2000) in the area, possibly established (Starý, 2006).

Table 3. Aphid-parasitoid-plant associations in the model area.

Aphids	Parasitoids	Plants
ADELGIDAE		
Adelges laricis Vall	–	*Larix decidua*
"	–	*Picea abies*
Adelges viridis (Ratzeburg)	–	*Larix decidua*
"	–	*Picea abies*
Gilleteella cooleyi (Gillette)	–	*Pseudotsuga menziesii*
Pineus cembrae (Cholodkovsky)	–	*Pinus cembra*
APHIDIDAE		
Acyrthosiphon pisum (Harris)	*Aphidius eadyi*	*Medicago sativa*
"	"	*Pisum sativum*
"	"	*Trifolium pratense*
"	"	*Vicia faba*
"	*Aphidius ervi*	*Cytisus scoparius*
"	"	*Lathyrus* sp.
"	"	*Lupinus polyphyllus*
"	"	*Medicago sativa*
"	"	*Melilotus albus*
"	"	*Pisum sativum*
"	"	*Trifolium pratense*
"	"	*Vicia faba*
"	*Aphidius picipes*	*Medicago sativa*
"	"	*Trifolium pratense*
"	*Praon barbatum*	*Pisum sativum*
Aphis craccae L.	*Binodoxys acalephae*	*Vicia cracca*
"	"	*Vicia faba*
"	*Lysiphlebus fritzmuelleri*	*Vicia cracca*
Aphis craccivora Koch	*Lysiphlebus fabarum*	*Vicia* sp.
Aphis fabae Scopoli	*Binodoxys acalephae*	*Carduus* sp.
"	"	*Chenopodium* sp.
"	"	*Cirsium arvense*
"	"	*Daucus carota*
"	"	*Euonymus europaea*
"	"	*Galium* sp.
"	"	*Impatiens noli-tangere*
"	"	*Rumex* sp.
"	*Binodoxys angelicae*	*Cirsium arvense*
"	*Diaeretiella rapae*	*Chenopodium* sp.
"	*Ephedrus plagiator*	*Beta vulgaris*
"	"	*Cirsium arvense*
"	"	*Euonymus europaea*
"	"	*Impatiens noli-tangere*
"	"	*Rumex* sp.
"	*Lysiphlebus cardui*	*Chenopodium* sp.
"	"	*Cirsium arvense*
"	*Lysiphlebus fabarum*	*Carduus* sp.
"	"	*Chenopodium* sp.
"	"	*Cirsium arvense*
"	"	*Cirsium* sp.
"	"	*Matricaria perforata*
"	*Praon barbatum*	*Trifolium pratense*
"	*Praon volucre*	*Chenopodium* sp.
"	"	*Impatiens glandulifera*
"	"	*Papaver somniferum*
"	*Praon* sp.	*Impatiens noli-tangere*

(continued)

(Table 3 continued)

Aphids	Parasitoids	Plants
Aphis farinosa Gmelin	*Lysiphlebus confusus*	*Salix caprea*
"	"	*Salix* sp.
Aphis grossulariae Kaltenbach	*Lysiphlebus confusus-group*	*Ribes rubrum*
Aphis hederae Kaltenbach	*Binodoxys angelicae*	*Hedera helix*
"	*Ephedrus plagiator*	*Hedera helix*
"	*Lysiphlebus fabarum*	*Hedera helix*
Aphis idaei van der Goot	–	*Rubus idaeus*
Aphis jacobaeae (Schrank)	–	*Senecio nemorensis*
Aphid pomi deGeer	–	*Malus domestica*
Aphis sambuci L.	–	*Sambucus nigra*
Aphis spiraephaga F. P. Müller	*Binodoxys angelicae*	*Spirea vanhoutei*
"	*Praon abjectum*	*Spirea vanhoutei*
Aphis umbrella (Börner)	–	*Malva* sp.
Aphis viburni Scopoli	*Aphidius colemani*	*Viburnum opulus*
"	*Binodoxys angelicae*	*Viburnum opulus*
Aphis sp.	*Binodoxys angelicae*	*Vicia* sp.
"	"	*Daucus* sp.
Betulaphis brevipilosa Börner	*Aphidius aquilus*	*Betula* sp.
Brachycaudus lychnidis (L.)	*Lysiphlebus melandriicola*	*Silene alba*
"	*Praon volucre*	*Silene alba*
Brachycaudus sp.	*Aphidius matricariae*	*Matricaria perforata*
"	*Binodoxys angelicae*	*Carduus* sp.
Brachycorynella asparagi (Mordvilko)	*Aphidius colemani*	*Asparagus officinalis*
"	*Ephedrus plagiator*	*Asparagus officinalis*
Brevicoryne brassicae (L.)	*Diaeretiella rapae*	*Brassica napus*
"	"	*Sinapis arvensis*
Capitophorus sp.	*Aphidius matricariae*	*Cirsium arvense*
Cavariella pastinacae (L.)	–	*Heracleum sphondylium*
Cavariella sp.	*Aphidius colemani*	*Salix* sp.
"	*Aphidius salicis*	*Ulmus* sp.
"	*Ephedrus helleni*	*Umbelliferae* sp.
Chaitophorus sp.	*Adialytus salicaphis*	*Populus tremula*
Chromaphis juglandis (Kaltenbach)	–	*Juglans regia*
Cinara curvipes (Patch)	–	*Abies concolor*
"	–	*Abies grandis*
Cinara sp.	–	*Pinus sylvestris*
"	*Pauesia abietis*	*Larix decidua*
"	*Pauesia infulata*	*Picea abies*
"	*Pauesia laricis*	*Larix decidua*
"	"	*Pinus sylvestris*
"	*Pauesia piceaecollis*	*Picea abies*
"	"	*Pinus sylvestris*
"	*Pauesia pini*	*Larix decidua*
"	"	*Pinus sylvestris*
Corylobium avellanae (Schrank)	*Praon volucre*	*Corylus avellana*
Cryptomyzus galeopsidis (Kaltenbach)	*Aphidius ribis*	*Galeopsis* sp.
Diuraphis noxia (Kurdjumov)	*Aphidius colemani*	*Hordeum vulgare*
"	*Aphidius ervi*	*Hordeum vulgare*
"	*Diaeretiella rapae*	*Hordeum vulgare*
Drepanosiphum platanoidis (Schrank)	*Dyscritulus planiceps*	*Acer pseudoplatanus*
"	*Falciconus pseudoplatani*	*Acer pseudoplatanus*
"	*Trioxys cirsii*	*Acer pseudoplatanus*
Dysaphis sorbi (Kaltenbach)	*Ephedrus persicae*	*Sorbus aucuparia*
Eriosoma lanigerum (Hausmann)	–	*Malus domestica*
Eucallipterus tiliae (Kaltenbach)	*Trioxys tenuicaudus*	*Tilia* sp.

(continued)

(Table 3 continued)

Aphids	Parasitoids	Plants
Euceraphis punctipennis (Zetterstedt)	*Praon flavinode*	*Betula* sp.
Eulachnus agilis (Kaltenbach)	*Diaeretus leucopterus*	*Pinus sylvestris*
"	*Praon bicolor*	*Pinus sylvestris*
Hayhurstia atriplicis (L.)	*Diaeretiella rapae*	*Chenopodium* sp.
"	*Ephedrus nacheri*	*Chenopodium* sp.
Hyalopteroides humilis (Walker)	–	*Phalaris arundinacea*
Hyalopterus pruni (Geoffroyi)	*Aphidius transcaspicus*	*Phragmites communis*
"	*Ephedrus plagiator*	*Phragmites communis*
"	*Praon volucre*	*Phragmites communis*
"	"	*Prunus domestica*
Hyperomyzus lactucae (L.)	–	*Sonchus oleraceus*
Impatientinum asiaticum Nevsky	–	*Impatiens glandulifera*
"	*Ephedrus plagiator*	*Impatiens parviflora*
"	*Praon longicorne*	*Impatiens parviflora*
"	*Praon volucre*	*Impatiens parviflora*
Impatientinum balsamines (Kaltenbach)	*Ephedrus lacertosus*	*Impatiens noli-tangere*
"	*Ephedrus plagiator*	*Impatiens noli-tangere*
"	*Monoctonus nervosus*	*Impatiens noli-tangere*
"	*Praon longicorne*	*Impatiens noli-tangere*
Kallistaphis sp.	*Aphidius aquilus*	*Betula* sp.
Lipaphis erysimi (Kaltenbach)	*Ephedrus nacheri*	*Thlaspi arvense*
"	*Praon volucre*	*Thlaspi arvense*
Macrosiphoniella millefolii (de Geer)	*Aphidius absinthii*	*Achillea millefolium*
"	*Ephedrus niger*	*Achillea millefolium*
Macrosiphoniella oblonga Mordvilko	*Aphidius phalangomyzi*	*Artemisia vulgaris*
Macrosiphoniella tanacetaria (Kaltenbach)	*Praon absinthii*	*Tanacetum vulgare*
Macrosiphum albifrons Essig	*Aphidius ervi*	*Lupinus polyphyllus*
Macrosiphum cholodkowskyi Mordvilko	–	*Filipendula ulmaria*
Macrosiphum funestum (Macchiati)	–	*Rubus caesius*
Macrosiphum rosae (L.)	*Aphidius rosae*	*Rosa* sp.
"	*Praon volucre*	*Rosa* sp.
Macrosiphum sp.	*Praon volucre*	*Euphorbia* sp.
Megoura viciae Buckton	–	*Lathyrus* sp.
Metopeurum fuscoviride Stroyan	–	*Tanacetum vulgare*
Metopolophium dirhodum (Walker)	–	*Avena sativa*
Microlophium carnosum (Buckton)	*Aphidius microlophii*	*Urtica dioica*
"	*Aphidius picipes*	*Urtica dioica*
"	*Aphidius urticae*	*Urtica dioica*
"	*Praon longicorne*	*Urtica dioica*
"	*Praon volucre*	*Urtica dioica*
Mindarus abietinus Koch	*Pseudopraon mindariphagum*	*Abies alba*
Myzocallis carpini (Koch)	*Trioxys betulae*	*Carpinus betulus*
Myzocallis coryli (Goetze)	*Praon flavinode*	*Corylus avellana*
"	*Trioxys tenuicaudus*	*Corylus avellana*
Myzocallis walshii (Monell)	*Trioxys curvicaudus*	*Quercus rubra*
"	*Trioxys pallidus*	*Quercus rubra*
Myzus cerasi (F.)	–	*Prunus avium*
Myzus persicae (Sulzer)	*Aphidius ervi*	*Solanum tuberosum*
Nasonovia nigra Hille Ris Lambers	*Aphidius hieraciorum*	*Hieracium murorum*
"	*Monoctonus crepidis*	*Hieracium murorum*
"	*Praon pubescens*	*Hieracium murorum*
"	*Paramonoctonus angustivalvus*	*Hieracium murorum*
Nasonovia sp.	*Aphidius hieraciorum*	*Hieracium murorum*
Ovatus crataegarius (Walker)	–	*Crataegus oxyacantha*
Periphyllus testudinaceus (Fernie)	*Areopraon silvestre*	*Acer pseudoplatanus*

(continued)

(Table 3 continued)

Aphids	Parasitoids	Plants
Periphyllus testudinaceus (Fernie)	*Trioxys falcatus*	*Acer pseudoplatanus*
Periphyllus sp.		*Acer platanoides*
"	*Areopraon silvestre*	*Acer pseudoplatanus*
Phyllaphis fagi (L.)	–	*Fagus sylvatica*
Prociphilus fraxini (F.)	–	*Abies alba*
"	–	*Abies grandis*
"	–	*Abies koreana*
"	*Ephedrus prociphili*	*Fraxinus excelsior*
Pterocomma sp.	*Euaphidius cingulatus*	*Salix caprea*
"	"	*Salix* sp.
Rhopalosiphoninus lonicerae (Siebold)	*Aphidius urticae*	*Phalaris arundinacea*
Rhopalosiphum insertum (Walker)	–	*Malus domestica*
Rhopalosiphum padi (L.)	*Ephedrus plagiator*	*Avena sativa*
"	"	*Holcus lanatus*
"	"	*Prunus padus*
"	*Praon volucre*	*Prunus padus*
"	*Trioxys auctus*	*Triticum aestivum*
"	"	*Zea mays*
Schizaphis graminum (Rondani)	*Aphidius ervi*	*Triticum aestivum*
"	*Aphidius rhopalosiphi*	*Triticum aestivum*
"	*Praon gallicum*	*Triticum aestivum*
"	*Praon volucre*	*Triticum aestivum*
Schizolachnus pineti (F.)	*Pauesia unilachni*	*Pinus sylvestris*
Schizoneura sp.	–	*Ulmus* sp.
Sitobion avenae (F.)	*Aphidius ervi*	*Avena sativa*
"	"	*Hordeum vulgare*
"	"	*Secale cereale*
"	"	*Triticum aestivum*
"	*Aphidius picipes*	*Avena sativa*
"	"	*Secale cereale*
"	"	*Triticum aestivum*
"	*Aphidius rhopalosiphi*	*Secale cereale*
"	"	*Triticum aestivum*
"	*Aphidius uzbekistanicus*	*Avena sativa*
"	"	*Gramineae* sp.
"	"	*Hordeum vulgare*
"	*Ephedrus plagiator*	*Gramineae* sp.
"	"	*Hordeum vulgare*
"	"	*Secale cereale*
"	"	*Triticum aestivum*
"	*Praon gallicum*	*Hordeum vulgare*
"	"	*Triticum aestivum*
"	*Praon volucre*	*Avena sativa*
"	"	*Hordeum vulgare*
"	"	*Secale cereale*
"	"	*Triticum aestivum*
"	"	*Dactylis glomerata*
"	"	*Lolium* sp.
Stomaphis quercus (L.)	–	*Quercus rubra*
Symydobius oblongus (von Heyden)	*Trioxys betulae*	*Betula* sp.
Thelaxes dryophila (Schrank)	–	*Quercus rubra*
"	–	*Ranunculus* sp.
Tuberculatus annulatus (Hartig)	*Praon flavinode*	*Quercus* sp.
"	*Trioxys pallidus*	*Quercus* sp.
Tuberculatus sp.	*Trioxys curvicaudus*	*Quercus* sp.

(continued)

(Table 3 continued)

Aphids	Parasitoids	Plants
Uroleucon murale (Buckton)	*Binodoxys centaureae*	*Mycelis muralis*
Uroleucon obscurum (Koch)	*Aphidius funebris*	*Mycelis muralis*
Uroleucon sp.	*Aphidius funebris*	*Carduus* sp.
"	"	*Centaurea* sp.
"	"	*Cirsium palustre*
"	"	*Crepis* sp.
"	*Binodoxys centaureae*	*Carduus* sp.
"	"	*Centaurea* sp.
"	"	*Crepis* sp.
"	*Praon yomenae*	*Centaurea* sp.
"	"	*Crepis biennis*
"	"	*Hieracium murorum*
"	"	*Sonchus oleraceus*
"	"	*Taraxacum officinale*

Aphidius transcaspicus Telenga:

Release trials of this parasitoid on *Hyalopterus pruni* /*Phragmites communis* were carried out in 1964, but the parasitoid apparently failed to establish permanently in the area (Starý, 2006).

Interactions in a model site

The interactions within and between the members of the individual tritrophic associations which are also related to habitat and seasonal period can be derived from the data presented in the tables 1, 2 and 3.

Discussion

The presented database of structural associations is centered to the identification of parasitoid-aphid-plant food webs and their possible (presumed) interactions in the model farmland area. However, some ecological phenomena of the parasitoids to be considered are briefly reviewed below.

Ecology and selection of the model group

A clearly prevailing part of parasitoids are definably oligophagous species. Strictly species-specific species are rare. Their oligophagy manifests different, prevailingly taxonomically definable host levels. The latter reflects the congeneric aphid species, or species of different genera, and groups. Aphid ecology (niche) may have a contributing significance (Starý, 1970b; 1981; 2006).

Parasitoids can be rather opportunistic within the framework of their host list. They can occur on a more or less complete host listed species but, on the other hand, the complete list may not commonly be present in full in samples and, also, in a part of the geographic distribution area. They are capable to accept hosts which are included in their host list in another area, or even exotic hosts which are new for the target species. This opportunistic phenomenon can be broadly determined in the agroecosystems, but even illustrated by changes in various ecosystems (Starý, 1970a; 1993; Starý *et al*., 1988; 2004).

Host species alternation and site-dependence in parasitoids

Parasitoids can also alternate between different host aphid species on the same plant or different plants in the course of the season. However, compared with the aphids, they manifest biological/ecological phenomena which may affect their occurrence in different ecosystems accordingly (Starý, 1972; 1978a, 1978b) and the ecosystem relationships classified through the biology/ecology of the aphids and their parasitoids may be identical to rather different in the course of the season (Starý, 1972).

Field interaction of con-specific parasitoid populations sourcing from different hosts is primarily derived from the field-collected/laboratory-reared material. On such a background, a set of laboratory transfer trials from one to another host species (Starý, 1986c; 2006) resulted in that the field evidence corresponds prevailingly to the laboratory tests. The latter, too, can indicate some taxonomic problems resulting from or contributing to the description of new species (for example: *Aphidius ervi* populations from *Acyrthosiphon pisum* and *Sitobion avenae* vs. *Microlophium carnosum* (Müller *et al*., 1999; Němec and Starý, 1983a; 1983b; 1985a; Pennacchio *et al*., 1994; Pennacchio and Tremblay, 1986; Pungerl, 1984; Starý, 2006). Bribosia *et al*. (1998) also compared the field evidence with the lab tests on *Binodoxys angelicae* within an IPM framework.

The interaction of parasitoid population originating from different hosts is of key significance in classifying and deriving the ecosystem relationships of this group fundamentally. Extensive information on the parasitization of different aphid species by the same parasitoid can be also found (Rodriguez *et al*., 2002).

Host species alternation (i.e. switching from one to another host species) apparently may affect the gene flow. Hence the background evidence derived from the integration of the field evidence (reared material) and laboratory proofs (transfer trials) needs respective population analysis as a supporting step. Němec and Starý (1985b) hypothetized on grounds of some screening tests that host alternation works as a more selective net

which affects the composition and frequency of different lineages in the parental (host species A) and filial (host species B) generations. As well, they hypothesized and discussed the role of the main host species (= highest population diversity) of a parasitoid species in agroecosystems (Němec and Starý, 1986; Powell, 1994).

Fundamental population genetic studies on some parasitoid species parasitizing two different hosts did not determine significant changes in the respective populations (Antolin *et al*., 2006), and the ongoing gene flow appears to prevent the formation of host races (Baer *et al*., 2004). (Note: a part of the target material of *Diaeretiella rapae* originated in the studied area). These results might support the above hypothesis by Němec and Starý (1985b). These genetic considerations are of key importance for classifying the relationships of parasitoids originating from different aphid species and crops in the course of season.

Host alternation of parasitoids is also nicely documented by the development of the host list in the newly introduced exotic parasitoids (Starý *et al*., 1988; 2004).

Seasonal interactions

Yet, there may still be a difference between the individual species of a parasitoid complex (guild) on a target aphid species co-existing in a community. The differences can be derived from table 1 if the combinations of parasitoid-aphid associations reflecting also the habitats and months of occurrence are compared. In the model area, the community composition and interactions between the key crops (red clover and fodder mixtures, spring-sown and winter-sown cereals, rape and potatoes) are apparently of key position in the updated situation.

Crop rotation and ploughing, together with their seasonal history may affect the parasitoids fundamentally. Hibernation possibilities and sites are of importance, including herbal field banks, roadsides and winter-sown and volunteer crops (rape, cereals).

Semiperennial crops: both seasonal history of the aphids (*Acyrthosiphon pisum*) and associated parasitoids yield also hibernation sites for aphids and parasitoids, and close coincidence can be also observed since the early spring (Starý, 1974a; 1978a; 1978b). A similar situation occurs in the rape fields (*Brevicoryne brassicae* - *Diaeretiella rapae*).

The annual crops manifest a different situation. For example, in the cereals, aphids overwinter in the crops (winter-sown cultures) or they immigrate from main host plants (*Rosa* sp., *Prunus padus*) in the early season. Migration again occurs when cereals are ripening, to annual grasses, volunteer cereals, and to winter-sown cereals (Lukasova and Starý, 2000; Starý, 1996). For potatoes, beans, peas, and others (table 2). For examples of seasonal interactions and differences in other areas of the country (Starý, 1972; 1974a; 1976; 1978a, 1978b).

Some approaches of the farmers have been followed in the model area in spite of that their eventual role for insect population management was not considered at all. Strip-cutting of fodder crops (red-clover) is commonly utilised to get daily green fodder for cattle. As experimentally proved in other countries, strip-cutting contributes to preservation of insect population and does not have such a disruptive effect as clean-cutting system (Starý, 1978c). Also, potato field headlands are commonly left uncropped, but they are also frequently sown with spring barley, faunal interrelationship not considered. Our preliminary investigation indicated that such crop-sown headlands manifest features of spring sown barley fields; aphid and parasitoid fauna of barley and potatoes is but rather different and significant interactions were not determined.

Field exposure trials

Field exposure trials (*Schizaphis graminum* - *Diuraphis noxia*) were found to be useful in predicting of the response of local native parasitoids to a new immigrant aphid (pest) (Starý and Gonzalez, 1992). Also, they were found valuable for detection of parasitization (Milne, 1995) and establishment of introduced parasitoids (Starý, 1968). At last, parasitoid-alternate host combination can be used to establish a target parasitoid prior to target pest occurrence in the environment (Starý, 1993).

Key-stone parasitoid species

Information on the seasonal occurrence of parasitoid-aphid-plant associations (table 1) also indicates to some extent the phenology and a possibility of parasitoid populations to alternate between the individual host species (and ecosystems) in the course of the season. This includes both the crop - crop and crop - non-crop (wild plants, weeds) relationships (table 2).

An analysis of the associations (table 1) indicated several parasitoid species as the key-stone species which should be considered in the ecologically-friendly management and approaches. The key-criterion applicable in the farmland should be the relationships to the grown crops. The species are at least as follows: *Aphidius ervi* (legumes, cereals, potatoes), *A. picipes* (legumes, cereals, potatoes), *A. uzbekistanicus* (cereals), *Binodoxys angelicae* (beans), *Diaeretiella rapae* (rape, cereals, potatoes), *Ephedrus plagiator* (cereals), *Lysiphlebus cardui* (beans), *L. fabarum* (beans), *Praon volucre* (cereals, rape).

It should be notified that the aphidiines are associated with aphids in certain complexes (= guilds) of species, which consist prevailingly of two to several oligophagous species, species-specific parasitoids being rare. Also, the individual species-members manifest often different host range patterns which are prevailingly affected by the taxonomical characteristics of the host aphid in combination with the respective geographic area patterns and local aphid and parasitoid fauna (Porter and Hawkins, 1998; Starý, 1981; Starý and Rejmánek, 1981). These phenomena also affect their interactions inside and between the (agro) ecosystems and thus a guild on a target aphid species can be even rather heterogeneous as far as the interrelations through its individual species members are concerned. This naturally also pertains to the key-stone parasitoid species included in a respective parasitoid complex. For example: *Acyrthosiphon pisum* - *Aphidius eadyi*, *A. ervi*, *A. pici-*

pes, *Praon barbatum*, *P. volucre*. *Sitobion avenae* - *Aphidius ervi*, *A. picipes*, *A. rhopalosiphi*, *A. uzbekistanicus*, *Ephedrus plagiator*, *Praon gallicum*, *P. volucre* (table 1).

The results from an agroecosystem area in Serbia (Tomanović and Brajković, 2001) can be used also for a comparison in a different area.

Also, although an over-all list of parasitoids species can be determined for a target aphid species in an area, this listed parasitoid complex is often not present in full and it may vary broadly depending especially on the sample size and other factors such as a nearby community, and others. Also, the abundance of the individual species members may vary in a similar way although a broader set of samples may result in detection of overall dominant, less frequent and occasional species members (Pankanin-Franczyk, 1987; Starý, 1974a; 1976; 1986b).

As well, it should be emphasized that many, even often numerous aphid - parasitoid associations are aphid group specific and do not manifest any relations to the neighbouring crops. For example: *Achillea*, *Artemisia*, *Hieracium*, *Tanacetum* and others; (Barczak, 1993a; Starý, 2006; Tomanović *et al*., 2008a; Völkl and Starý, 1998). Some others can have mixed relationships, for *Uroleucon* and *Aphis* - *Cichorium intybus*, *Centaurea cyanus*) (Starý, 2006; table 1).

Aphid predators

The more or less significant differences between the predators and parasitoids of aphids should be emphasized reflecting the generalised management recommendations. Of the numerous cases, the nettle (*Urtica dioica*) and its associated aphidophagous guild may be presented. Apart from the taxonomical problems in the parasitoids there is a key difference between the predators (coccinellids) and parasitoids; field trials on "aphidophagous guild" in Belgium comparing nettle strips and field crops were generalised on grounds of coccinellids (Alhmedi *et al*., 2007). Similarly, cereal aphid parasitoids do not have any relations to the *Cirsium arvense* - *A. fabae* associations, whereas *Coccinella septempunctata* migrates in masses from ripening cereals to *Cirsium* - associated aphid prey (Starý, 1986b). In our opinion, however, the host specificity features of parasitoids would lead to rather different conclusions manifesting much closer specificity of parasitoids affecting basically also their host and habitat alternation. In this respect, comparative studies on integrating conservation of generalist predators and specialist parasitoids in the Pacific Northwest (USA) organic vegetables were made by Snyder (2003).

Aphid-attending ants

Soil variables, tillage practice and insecticide use manifest a negative impact on the abundance of ants in the agricultural landscape (Peck *et al*., 1998). Many ant species attend the aphid colonies and protect them from predators, but some parasitoid species (*Lysiphlebus cardui*, *L. fabarum*) possess chemical and behavioural adaptations so that they are protected by the ants against predators (coccinellids, syrphid flies, chrysopids, etc.). Absence of the ants in the crop fields thus reduces effectiveness of the parasitoids (Starý, 1986b; 1987b; Völkl, 1992; 1994; Völkl and Mackauer, 1993; Völkl and Stechmann, 1988; Weisser and Völkl, 1997). However, field banks and roadsides tend also to be reservoirs of at least some ant species. For example: *A. fabae* on *C. arvense* can commonly be observed to be ant-attended (Starý, 1970b; 1986b; 1986c; 1987b; Völkl and Mackauer, 1993).

Conclusions

It is concluded that aphid parasitoids manifest several phenomena which can be considered in the biodiversification of landscape and ecologically friendly approaches in plant protection (DAPHNE, 2007). Derived from the updated state, following recommendations are presented:

1. It is emphasized that all the approaches presented target the aphid parasitoids as a part of the aphid antagonists, whereas the situation may be significantly different even in other groups of antagonists, the predators such as coccinellids, hoverflies, and others.
2. Host range of parasitoids is definable, derived from the field samples and rearing of defined aphid-plant associations in the area (or references for the state). On this ground, the interactions of parasitoid populations originating from different host plant combinations can be derived and/or predicted.
3. Forest type habitats and plants manifest specific associations, and there are only some cases of interactions with the field type habitats through the life cycle of some aphids (*Euonymus europaea*, *Fraxinus excelsior*, *Prunus padus*, *P. avium*, *P. domestica*, *P. spinosa*, *Rosa* spp.). In general, trees and shrubs in hedges are associated mainly with the forest type fauna of the targets. Adelgid aphid group does not have any parasitoids at all.
4. Key-stone parasitoid species in the farmland have the main available host species in the agroecosystems, whereas the list of overall host aphid plant associations is significantly restricted in the updated farmland situation in the area.
5. Semi-perennial legume crops (red clover, alfalfa) seem to have the key position as reservoirs (also hibernation sites) of key-stone parasitoids in the area. Thus, belts of legumes as well as the gradual strip-cutting (green fodders) are classified as useful together with the intercropping in extensive cereal crop field areas, contributing to the biodiversification and stability. The presented relationships are derived from the parasitoids, but they can be similar to rather different in the aphids.
6. There are important seasonal interactions between aphid parasitoid complexes on the semi-perennial (alfalfa, red clover) and annual (peas) legumes, cereals and potatoes, whereas the respective aphid species do not prevailingly manifest such relations (except a single aphid case: semi-perennial legumes vs. peas and partially even beans).

7. There are important interactions between rape (*Brevicoryne brassicae*), *Chenopodium* (*Hayhurstia atriplicis*) and potatoes (*Myzus persicae*) and cereals (*Diuraphis noxia*), through *Diaeretiella rapae* parasitoid. Aphid species do not largely manifest such relations.
8. Winter-sown and volunteer cereals and rape are important as reservoirs (and hibernation sites) for spring populations of parasitoids (cereals, rape) but even for their aphid hosts.
9. *Cirsium arvense* is a useful reservoir plant (*A. fabae*, non pest biotype) of parasitoids of aphids on beans (*A. fabae*, pest biotype).
10. The role of a number of "weed" species in the field ecotones, field banks and roadsides needs to be reclassified because of their role as reservoirs of prey for the beneficial fauna.
11. Several common plants commonly occurring on roadsides and field banks (*Achillea*, *Artemisia*, *Crepis*, *Hieracium*, *Tanacetum*, *Urtica*) are associated with respectively specific aphid-parasitoid associations which do not have any relations to the crops.
12. The invasive *Impatiens glandulifera* has been determined as an important and seasonally powerful reservoir for aphid parasitoids (on *A. fabae*) in wetlands (apart from its positive role for pollinators and aphid predators). Its key importance is derived from its phenology, namely from the mid-summer to the late autumn, when many local wild species (*Cirsium*) become senescent and the respective period becomes thus critical both for many aphids and parasitoids (*A. fabae* association).
13. The invasive *Diuraphis noxia* manifests usually moderate populations which, however, can reach even high levels formerly corresponding to the warmer barley growing areas (southeastern Moravia).
14. The species structure of key tritrophic associations did not fundamentally change on ground of comparisons between 1958-2007. However, respective changes followed due to alien invasive plant species (*I. parviflora*, *I. glandulifera*), aphid species (*Diuraphis noxia*, *Impatientinum asiaticum*, *Macrosiphum albifrons*, *Myzocallis walshii*) and, to a smaller degree, introduced aphid parasitoids (if established). The changes pertained both to the adaptation of native aphids to invasive plants, of invasive aphids to native and as-native plants, of native parasitoids to invasive aphid species and, at last, of introduced parasitoids to native and/or invasive aphids.
15. Species composition of the plant species, associated aphids and parasitoids in field banks and roadsides is rather low today. The species richness has to be generally improved favouring the overall host range of antagonists and favourable interactions between these habitats and the nearby crops.
16. In general terms, the selected model area manifests landscape and agriculture phenomena or a background useful for application of ecologically compatible or friendly agriculture as proposed/accepted for some other areas in the Czech Republic (DAPHNE, 2007).

Acknowledgements

The research was partially supported by the Grant IA-A600960705 (Grant Agency of the Academy of Sciences of the Czech Republic) and from the Entomology Institute project Z50070508 (Academy of Sciences of the Czech Republic). Technical assistance was provided by J. Stará (Inst. of Entomology), and language was kindly edited by V. Regulová (C. Budejovice).

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Received January 9, 2008. Accepted June 18, 2008.