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THE EFFECT OF THE ORCHARD HABITAT STRUCTURE AND YEAR ON APPLE CLEARWING MOTH *S. MYOPAEFORMIS* ABUNDANCE

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Summary

In years 2008-2010 in orchard habitat near Czempiń in south Wielkopolska a mass appearance of apple clearwing moth *Synanthedon myopaeformis* and his larval ectoparasitoid *Liotryphon crassiseta* was stated. There were 7960 specimens of phytophage and 415 specimens of parasitoid caught using Moerick yellow traps. In order to evaluate the influence of orchard habitat structures and years on the number of both species statistical analysis such as ANOVA and Tukey test were conducted.

It was shown that biocenoses types, namely: apple orchards and orchard edges plants in form of field crops, shrubberies and road grown with trees and shrubs, effected essentially on the number of *S. myopaeformis* and *L. crassiseta.* Also years effected essentially on the number of both species, however effect of biocenoses type was independent of years.

It was stated that in case of *S. myopaeformis* the effect of orchard and orchard edges plants on the number of this species differed between each other. For *L. crassiseta* such difference was not observed.

It was determined that *S. myopaeformis* is a species closely connected with apple orchards and weakly moving towards adjacent biocenoses while *L. crassiseta* shifts between adjacent habitats. It was shown that this shifting occurs when the edges were a well-developed plant structures in the form of shrubberies and road grown with trees and shrubs.

Summarizing, well-developed plants of the orchard edges affected on the phytophage *S. myopaeformis* number in a lesser degree than on his larval ectoparasitoid *L. crassiseta* in apple orchard. Therefore orchard edges plants can determine the occurrence of entomophagy in fruit crops. These entomophagy can regulate the number of pests feeding in this habitat.

Keywords and phrases: *Synanthedon myopaeformis, Liotryphon crassiseta,* Sesiidae, Ichneumonidae, orchard, plants of orchard edge, ANOVA, three-way model, Tukey test.

Classification AMS 2010: 62-07, 62-09, 62H20

1. Introduction

The apple clearwing moth *Synanthedon myopaeformis* (Soentgen and Sengonca 1988). is a xylophagous species that occur in orchard and forest habitat. Host plants of this species are mainly apple tree, rarely pear tree, stone fruits species, hawthorn and rowan (Soentgen and Sengonca 1986, Bartsch 2004). The clearwing moth larvae feed under a bark, biting out corridors along trunks and large branches (Dickler 1976, Iren and Bulut 1981). The damages cause lowering of fruit trees health and in consequence lead to fruit reduction (Schnaider et al. 1961). In recent years the significance of this species as an apple orchards pest in Europe grows (Jenser et al. 1999, Kutinkova et al. 2006, Cossentine et al. 2010). Number of this phytophage can be regulated by biotic factors, that appear in the habitat or are puting in it. They include parasitoids (Soentgen and Sengonca 1988), nematodes (Kahounova and Mracek 1991), fungi (Cossentine et al. 2010) and bacteria (Shehata et al. 1999). One of the dominant parasitoids of apple clearwing moth larvae is ectoparasitoid *Liotryphon crassiseta* (Soentgen and Sengonca 1988). This parasitoid was firstly found from this host by Herting (1973), and next by Fitton et al. (1988).

The aim of this study was to evaluate the influence of orchard habitat structures and years on the number of apple clearwing moth *Synanthedon myopaeformis* and his larval ectoparasitoid *Liotryphon crassiseta.* The orchard habitat was composed of orchard biocenoses and biocenoses of plants in the nearest surroundings, namely: field crops, shrubberies and road.

2. Material and methods

The study was conducted in 2008-2010 and covered the orchards located near Czempiń, Wielkopolska (western Poland). The study sites included:

1. Apple orchard, Głuchowo (UTM, XT18; 52.17466°N, 16.71173°E) of 40 ha surface area (A1 = Głuchowo-orchard). The studies were conducted on 3-hectare plots with 15-year-old apple trees of the following cultivars: Gala, Ligol, Cortland, Paulared, Red Delicious and Golden Delicious. The apple tree plot was surrounded with cultivated fields (A2 = Głuchowo-field), where sweet corn was grown in 2008, oats in 2009, and triticale in 2010.

2. Apple orchard, Gorzyczki I (UTM, XT27; 52.10106°N, 16.81199°E) 20 ha in area (B1 = Gorzyczki I-orchard), where studies covered 5-hectare plots with 15–year-old apple trees of: Paulared, Red Delicious, Golden Delicious and Jonagold cultivars. The apple tree plot was surrounded by shrubberies (B2 = Gorzyczki I-shrubberies), namely thicket phytocenoses of *Euonymo-Prunetum spinosae* and *Querco-Ulmetum* forest, herbaceous communities and ruderal plant communities. Tree communities were formed mainly by: European elm (*Ulmus laevis* Pall.), sessile oak (*Quercus robur* L.), ash tree (*Fraxinus excelsior* L.), maple (*Acer platanoides* L.), boxelder maple (*Acer negundo* L.) and single apple trees (*Malus domestica* Borkh.) with hybrid black poplar (*Populus ×canadensis* Moench). Herbaceous plants were dominated by stinging nettle (*Urtica dioica* L.) and Canada thistle (*Cirsium arvense* (L.) Scop.). In the patches of ruderal shrubberies the following were recorded: elder (*Sambucus nigra* L.), common hawthorn (*Crataegus monogyna* Jacq.), matrimony vine (*Lycium barbarum* L.), dog rose (*Rosa canina* L.) and hazel (*Corylus avellana* L.).

3. Apple orchard, Gorzyczki II (UTM, XT27; 52.10208°N, 16.81451°E) 10 ha in area (C1 = Gorzyczki II-orchard). The studies were conducted on 2-hectar plots with 20-year-old Golden Delicious apple trees. The orchard borders on a road (C2 = Gorzyczki II-road) overgrown with plants typical of *Rhamno-Prunetea* class. The road was lined with walnut (*Juglans regia* L.), maples: box-elder (*Acer negundo* L.), common (*A. platanoides* L.), sycamore (*A. pseudoplatanus* L.) and sessile oak (*Quercus robur* L.), with some dog rose shrubs (*Rosa canina* L.), hawthorn (*Crataegus×media* Bechst.), hazel (*Corylus avellana* L.) and snowberry (*Symphoricarpos albus* Duhamel). Herbaceous plants were dominated by grass, stinging nettle (*Urtica dioica* L.), wormwood (*Artemisia absinthium* L.), yarrow (*Achillea millefolium* L.) and cleavers (*Galium aparine* L.).

In all the studied orchards apple trees grew 1.4 m from each other in rows set 3 m apart. Between the trees fallow land was maintained and the rows of trees were divided by sward. The orchards followed integrated fruit production policy.

During the study imagines of *Synanthedon myopaeformis* and *Liotryphon crassiseta* were caught into Moericke yellow traps (Moericke 1953). The trap was made from a yellow plastic pan filled with water and glycol (preservative) and liquid to reduce the surface pressure, with the diameter and the deep of the pan equal 18 cm and 11 cm, respectively. There were 20 pans put out on each site, from 1m to 1.5 m above the ground. The traps were situated in the following manner: 10 of them in the orchard and the other 10 further away, several meters from the orchard's edge. The traps were placed up to 10 m from each other. Specimens were collected in ten-day intervals. The one sample was defined as set of all the insects caught in the one pan during 10 days. The traps were placed in the orchard from April to October in each study year.

Statistical analysis were made with R software, version 3.2.1 (R Core Team 2015). In order to verify the hypothesis of the biocenoses and years effect on the *S. myopaeformis* and *L. crassiseta* number, analysis of variance ANOVA for three-way model with interaction was conducted. First, ANOVA assumptions have been tested and are satisfied. For more precise analysis Tukey's multiple comparison method was made.

In this study the effects of years are treated as fixed factor in the three-way analysis of variance. By this we mean, that the inference concerns the environmental conditions in the particular years which are considered. It is one of many approaches to the analysis of a series of experiments over the years (see also Smith et al. 2001). Sometimes the effects of years assumed to be random. This approach is often taken also into consideration. The weak point of such assumption is treating three successive years (as in the paper) as a random sample drawn from infinite population of years.

3. Results

In years 2008-2010 in orchard habitat near Czempiń in south Wielkopolska there were 3644 specimens collected, out of which 1818 in orchards and 1826 in orchard edges.

Synanthedon myopaeformis analysis

Overall there were 7960 specimens of S. myopaeformis caught. In particular biocenoses: Głuchowo 2355 specimens [orchard (A1) – 1955, field (A2) – 360]; Gorzyczki I 2970 specimens [orchard (B1) – 2337, shrubberies (B2) – 633]; Gorzyczki II 2635 specimens [orchard (C1) – 2092, road (C2) – 543] (Fig. 1.).

In order to verify the hypothesis of the biocenoses type and years effect on the *S. myopaeformis* number analysis of variance ANOVA for three-way model with interaction was conducted (Table 1).

Type of biocenoses as well as years impacted essentially on the *S. myopaeformis* number. Values of probability reached Pr(>F)= 0.0006 for orchards and

Pr(>F)= 0.0237 for years. It was also concluded that the biocenoses effect on the *S. myopaeformis* number was independent of years (Pr(>F)= 0.9451).

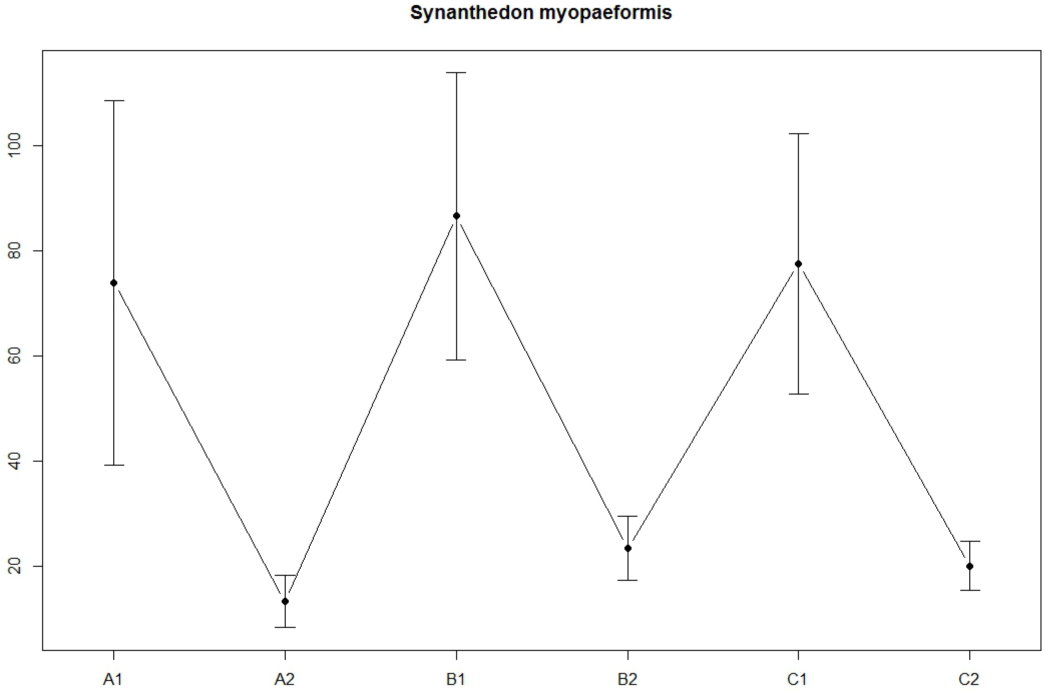

Fig. 1. Line plot of the mean and standard error for *Synanthedon myopaeformis.*

Table 1. ANOVA for *S. myopaeformis*

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Orchard	1	147485	147485	12.4798	0.0006***
Habitat	2	3511	1756	0.1486	0.8621
Year	2	90826	45413	3.8427	0.0237*
Orchard:Habitat	2	223	112	0.0094	0.9906
Orchard:Year	2	44690	22345	1.8908	0.1547
Habitat:Year	4	7145	1786	0.1512	0.9622
Ochard:Habitat:Year	4	8821	2205	0.1866	0.9451
Residuals	144	1701778	11818		

'*': Pr(>F) < 0.05, '**': Pr(>F) < 0.01, '***': Pr(>F) < 0.001

For more precise comparison of biocenoses type effect on the *S. myopaeformis* number Tukey's multiple comparison method was conducted. The obtained results were presented in Table 2.

Table 2. Tukey multiple comparisons of means of habitats for *S. myopaeformis* (A1 = Głuchowo-orchard, A2 = Głuchowo-field, B1 = Gorzyczki I-orchard, B2 = Gorzyczki I-shrubberies, C1 = Gorzyczki II-orchard, C2 = Gorzyczki II-road; diff – the difference in the observed means; p-adj - the p-value after adjustment for the multiple comparisons)

Compared biocenoses	diff	p-adj	Compared biocenoses	diff	p-adj
A1-A2	60.56	0.3215	A2-C2	-6.78	0.9999
A1-B1	-12.67	0.9981	B1-B2	63.11	0.2764
A1-B2	50.44	0.5308	B1-C1	9.07	0.9996
A1-C1	-3.59	0.9999	B1-C2	66.44	0.2237
A1-C2	53.78	0.4578	B2-C1	-54.04	0.4522
A2-B1	-73.22	0.1386	B2-C2	3.33	0.9999
A2-B2	-10.11	0.9994	C1-C2	57.37	0.3829
A2-C1	-64.15	0.2592			

It was indicated that:

- the influence of orchards all biocenoses on the *S. myopaeformis* number was similar (A1-B1, A1-C1, B1-C1),
- the influence of all biocenoses adjacent to orchards, that are fields, shrubberies and roads, on the number of this species was similar (A2-B2, A2-C2, B2-C2),
- the influence of orchards biocenoses and the biocenoses adjacent to orchards on the number of apple clearwing moth differed essentially between each other (A1-A2, A1-B2, A1-C2, A2-B1, A2-C1, B1-B2, B1-C2, B2-C1). The differences were intensively noticeable between the orchard in Gorzyczki I (B1) and the plants adjacent to all orchards (A2-B1, B1-B2, B1-C2), with most evident when on the edge of the orchard was a field under cultivation (A2).

For more precise comparison of years effect on the *S. myopaeformis* number Tukey's multiple comparison method was conducted also. The obtained results were presented in Table 3.

Years effected essentially on S. *myopaeformis* number. Especially the difference between years 2008 and 2009 was clearly seen, because the absolute value of the diff coefficient reached for them the highest value. One should also see that for all compared years the absolute value of the diff coefficient reached high values.

Table 3. Tukey multiple comparisons of means of years for *S. myopaeformis*

Compared years	diff	p-adj
2008-2009	**-57.29**	**0.0189****
2008-2010	-20.85	0.5802
2009-2010	36.44	0.1933

'*': p-adj < 0.05

Liotryphon crassiseta analysis

In the three years of research there were 415 specimens of L. *crassiseta* caught. In particular biocenoses: Głuchowo 74 specimens [orchard (A1) – 71, field (A2) – 3]; Gorzyczki I 88 specimens [orchard (B1) – 55, shrubberies (B2) – 33]; Gorzyczki II 253 specimens [orchard (C1) – 159, road (C2) – 94] (Fig. 2.).

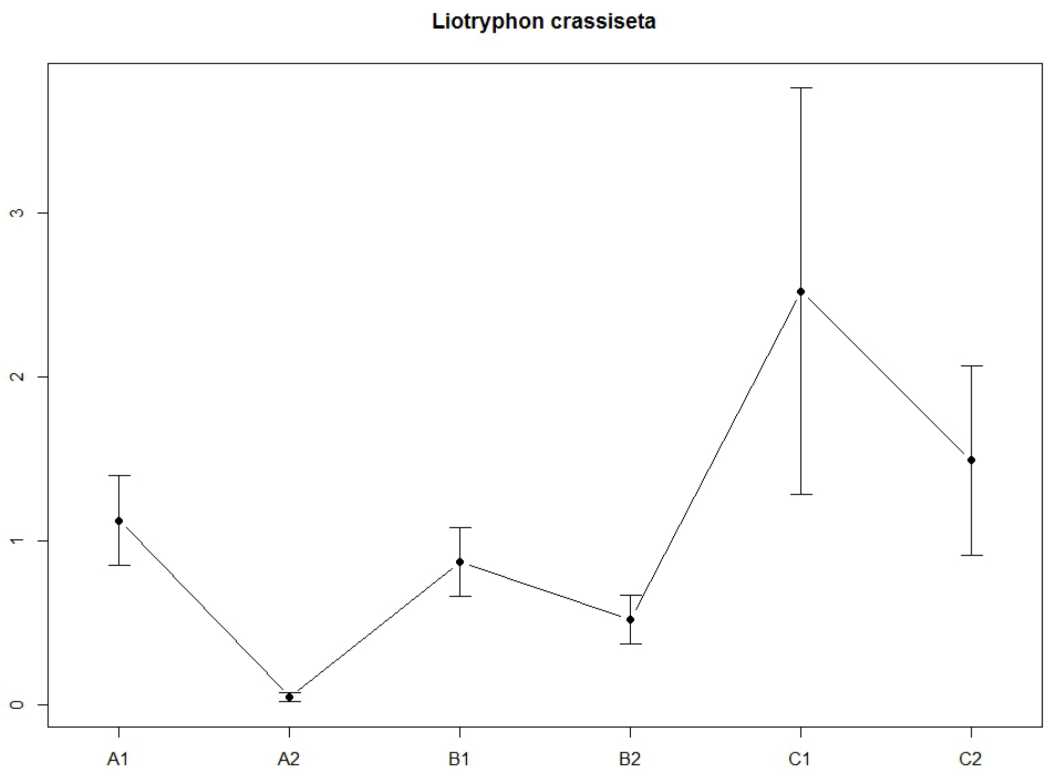

Fig. 2. Line plot of the mean and standard error for *Liotryphon crassiseta*.

In order to verify the hypothesis of the biocenoses type and years effect on the *L. crassiseta* number analysis of variance ANOVA for three-way model with interaction was conducted (Table 4).

Type of biocenoses as well as years impacted essentially on the *L. crassiseta* number. Values of probability reached Pr(>F)= 0.0114 for habitats and Pr(>F)= 0.0002 for years. It was also concluded that the biocenoses effect on the *L. crassiseta* number was independent of years (Pr(>F)= 0.9794).

For more precise comparison of biocenoses type effect on the *L. crassiseta* number Tukey's multiple comparison method was conducted. The obtained results were presented in Table 5.

The effect of all orchard habitat biocenoses, that are orchards and plants adjacent to orchards, on the *L. crassiseta* number differed between each other. It was also shown that this effect was most evidently seen in Gorzyczki's II orchard (C1). It was also confirmed by statistically relevant difference between the numbers of the *L. crassiseta* in the orchard in Gorzyczki II (C1) and the cultivated field in Głuchowo (A2).

For more precise comparison of years effect on the *L. crassiseta* number Tukey's multiple comparison method was conducted. The obtained results were presented in Table 6.

The obtained results indicate that years 2009 and 2010 impacted similarly on the *L. crassiseta* number, however in 2008 this impact differed essentially from other years.

Table 4. ANOVA for *L. crassiseta*

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Orchard	1	72.0	72.0	1.7982	0.1820
Habitat	2	369.7	184.86	4.6168	0.0114*
Year	2	714.9	357.45	8.9273	0.0002***
Orchard:Habitat	2	26.0	13.02	0.3251	0.7230
Orchard:Year	2	39.1	19.57	0.4889	0.6143
Habitat:Year	4	543.0	135.76	3.3905	0.0110*
Orchard:Habitat:Year	4	17.4	4.34	0.1085	0.9794
Residuals	144	5765.8	40.04		

'*': Pr(>F) < 0.05, '**': Pr(>F) < 0.01, '***': Pr(>F) < 0.001

Table 5. Tukey multiple comparisons of means of habitats for *L. crassiseta* (A1 = Głuchowo-orchard, A2 = Głuchowo-field, B1 = Gorzyczki I-orchard, B2 = Gorzyczki I-shrubberies, C1 = Gorzyczki II-orchard, C2 = Gorzyczki II-road)

Compared biocenoses	diff	p-adj	Compared biocenoses	diff	p-adj
A1-A2	1.08	0.7555	A2-C2	-1.44	0.4610
A1-B1	0.25	0.9996	B1-B2	0.35	0.9979
A1-B2	0.60	0.9746	B1-C1	-1.65	0.3066
A1-C1	-1.39	0.4999	B1-C2	-0.62	0.9715
A1-C2	-0.37	0.9975	B2-C1	-2.00	0.1253
A2-B1	-0.83	0.9063	B2-C2	-0.97	0.8305
A2-B2	-0.48	0.9912	C1-C2	1.03	0.7892
A2-C1	-2.48	0.0252*			

Table 6. Tukey multiple comparisons of means of years for *L. crassiseta*

Compared years	diff	p-adj
2008-2009	-1.84	0.0035**
2008-2010	-2.22	0.0003***
2009-2010	-0.38	0.7783

'*': p-adj < 0.05, '**': p-adj < 0.01, '***': p-adj < 0.001

4. Discussion and conclusions

In years 2008-2010 a mass appearance of apple clearwing moth *Synanthedon myopaeformis* and his larval ectoparasitoid *Liotryphon crassiseta* was stated in the orchard habitat of southern Wielkopolska. The apple clearwing moth is a species commonly occurring in Poland (Bogdanowicz et al. 2004). In Wielkopolska it was found by Bąkowski (1992, 2011) in vicinity of Poznań. He classified this specimen as an orchard pest (Schnaider et al. 1961), but usually occurring in Wielkopolska in a small number and was not included as an economically relevant apple orchards pest. However in recent years his number is increasing and his mass appearance in 2008-2010 years in Wielkopolska indicates that he is a threat to apple orchards in this region (Dolańska-Niedbała et al. 2010, Dolańska-Niedbała et al. 2011).

The studies shown that types of biocenoses, like: apple orchards and edges plants in the form of field crops, shrubberies and road grown with trees and shrubs, effected essentially on the *S. myopaeformis* number. This effect was independent of years. As it has been shown the effect of orchards and edges differe between each other. From the analysis of biocenoses type effect on the apple clearwing moth number and on the basis of his number in particular biocenoses one could indicate that apple clearwing moth is a species closely connected with apple orchards and weakly moving towards adjacent biocenoses. Therefore he constitutes a harmful element of apple orchards entomofauna, however in a lesser degree of adjacent habitats. Thus it could be concluded that orchard edges plants are not a dispersal habitat of apple clearwing moth into fruit crops.

The studies show that years also effected essentially on the phytophage number.

An interesting point of view of plant protection seems to be also the fact of a mass appearance of *Liotryphon crassiseta* parasitoid. It is a species which occur in Europe (Herting 1973, Fitton et al. 1988) in particular, in Poland. In the orchards of Wielkopolska it was found by Piekarska-Boniecka and Wilkaniec (1996), also Piekarska-Boniecka and Suder-Byttner (2002), but its occurrence was not so numerous as in years 2008-2010. This numerous appearance of *L. crassiseta* indicates that this parasitoid could limit the number of apple clearwing moth. This parasitoid was earlier denoted as one of two dominant species of parasitoids that reduce the number of apple clearwing moth even up to 14.0% in apple orchards of Germany (Soentgen and Sengonca 1988).

The studies indicated also that, similarly as in the case of *S. myopaeformis*, orchard habitat structure as well as years effected essentially on *L. crassiseta* number. The biocenoses type effect was also independent of years. Nevertheless separateness of orchards and edges effect on the number of this parasitoid was not observed. From the analysis of biocenoses type effect on the parasitoid number and on the basis of his number in particular biocenoses one could indicate that parasitoid is moving between adjacent habitats, which are orchards and plants. The studies shown that this moving occurs when the edges are a well-developed plant structures in the form of shrubberies and road grown with trees and shrubs. Therefore it was concluded that well-developed plants of orchard edges constitutes a living habitat for *L. crassiseta*, from which it could move into apple orchards and reduce the number of apple clearwing moth. The research indicated a positive influence of edges plants on parasitoid occurrence in apple orchard. At the same time the studies confirmed a positive influence of orchard edges wild plants on orchard parasite entomofauna which was earlier shown by Olszak (1992), Jenser et al. (1999), Miliczky and Horton (2005) and Sarvary et al. (2007).

Summarizing, well-developed plants of the orchard edges affected on the phytophage *S. myopaeformis* number in a lesser degree than on his larval ectoparasitoid *L. crassiseta* in apple orchard. Therefore orchard edges plants can decide upon the occurrence of entomophagy in fruit crops. These entomophagy can regulate the number of pests feeding in this habitat.

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