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The significance of unmanaged "island" habitats for epigeic spiders in a uniform agricultural landscape

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Abstract
Epigeic spider assemblages of three areas in a uniform agrocoenosis were compared: 1) an unmanaged "island" covered with natural vegetation and with two little ponds, 2) a small winter wheat field adjoining the "island", 3) a large winter wheat field, which was located in different sites every year. Spiders have been collected by pitfall traps for three seasons (1998-2000). The largest number of species was recorded in the unmanaged patch. Some species uncommon in Poland were recorded there. The spider fauna of the small field was the most similar to the undisturbed "island" while the spider fauna of the large cereal field was the least diverse and it consisted mostly of agrobionts. The closer to the unmanaged patch the large cereal field was situated the more similar were their spider assemblages. As some spider species occurred in both the small field and the adjoining "island", it is supposed that the "island" can act as a refuge and a source of spiders to surrounding fields. It was concluded that: 1) the spider fauna of the unmanaged "island" enriched spider diversity in the simple agrocoenosis, because the "island" was much more diverse than the cultivated fields; 2) the distance from an unmanaged area is very important for spider diversity, so rather small fields and numerous patches of undisturbed vegetation should be maintained in farmlands.

Key words: agricultural landscape; biodiversity; cereal fields

INTRODUCTION

The fauna of farmlands is significantly poorer than that of natural habitats because of frequent human impact. This effect is intensified in agrocoenoses, which are composed of large crop fields without any refuge areas. In studies of biodiversity in agricultural landscapes great attention is paid to non-crop areas such as grasslands, field margins, hedgerows, fallows, forest islands, etc. It has been proved that they enrich spider diversity in agrocoenoses (Sunderland & Samu 2000). They are also the source of spider migration to crop fields and act as refuge areas for numerous species which could not survive farming practices in crop fields without possibilities of hiding (Łuczak 1979, 1993; Nyffeler 1982; Gravesen & Toft 1987; Kemp & Barret 1989; Klimeš & Sechterova 1989; Nazzi at al. 1989; Thomas at al. 1991; Lys & Nentwig 1994; Vangsgaard 1996). In the present study of the spider fauna in a uniform agrocoenosis particular attention was paid to an area covered with natural (undisturbed) vegetation. It was the only unmanaged area situated among cultivated fields. This habitat configuration seemed to be rare, as this kind of agrocoenosis usually contains no refuge areas. Fields adjoining this area were expected to be influenced by spiders from the unmanaged "island". This study examined how the spider fauna of the natural vegetation area exerted an influence on adjacent fields and enriched biodiversity in the whole agrocoenosis.

MATERIAL AND METHODS

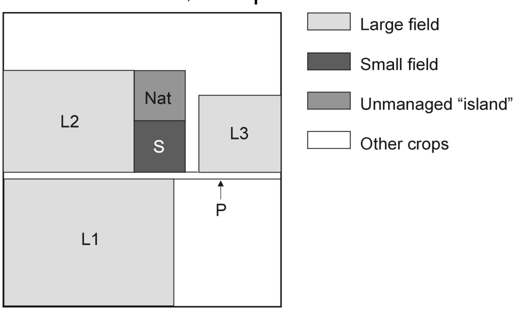
Study area

The studies were carried out near the village of Zawady, 25 km south-east of Siedlce, Eastern Poland (52°4' N, 22°34' E) in a uniform agrocoenosis of 224 ha. It was composed of large fields (usually more then 10 but less then 50 ha) adjoining each other. Not any meadows, balks or little woods were present there. The studied " island" was the only plot covered with natural vegetation, surrounded by crop fields. All cultivated fields were under intensive tillage: mechanical treatment with heavy machines and a lot of mineral fertilizers and pesticides were used.

Epigeic spider assemblages were studied in three sites: 1) an unmanaged „island" (*Nat*), with two little ponds, 2) a small winter wheat field (*S*) adjoining the unmanaged " island" and 3) a large winter wheat field (*L*), which was situated in different sites and had a different area every year (marked with symbols 1, 2, 3). Detailed characteristics of the studied areas are shown in Fig. 1.

There was a little slope of the terrain from L1 and L2 to L3 (values of the slope were not measured). Moreover, there were differences in the passing of water through the ground between sites. The large fields had sandy soil, whereas the unmanaged patch and the small field had loamy soil. Therefore in the latter the ground was wet in spring and autumn more than in other plots.

Fig. 1. Scheme of the studied areas. Nat – unmanaged "island", 0.8 ha; L1 – large field in 1998, 32 ha of winter wheat; L2 - large field in 1999, 7 ha of winter wheat; L3 - large field in 2000, 12 ha of winter wheat; S – small field, 1.30 ha of winter wheat; P – a path.



Collecting methods

Spiders were collected by pitfall trapping in 1998-2000 once a month from March to October (in 2000 also in January). Ten plastic cups (7 cm diameter, 10 cm depth) were used. Traps contained a solution of propylene glycol as a preservative, with a few drops of detergent to prevent the spiders from escaping. The traps were placed in a straight line at least 40 m from the edge of the field. Spiders were identified to species level (juveniles only to genus or family) according to Heimer & Nentwig (1990), Locket & Millidge (1951) and Roberts (1995).

Data analysis

Two computer programs for data analysis were used (based on abundance of spiders): Multivariate Statistical Package (MVSP) (Kovach 1993) and Canoco for Windows (ter Braak & Šmilauer 1998). The following coefficients were calculated using MVSP.

1) Jaccard's coefficient of similarity, based on the presence or absence of a single variable,

2) Euclidean distance between samples, based on both presence or absence and abundance. The coefficient accentuates differences between samples,

3) Shannon-Wiener diversity index (H) and Evenness (E).

The second program was used for DCA (Detrended Correspondence Analysis) ordination, with Canodraw for visual illustration. The dominance structure was described using the system of Woźny (1992): eudominants - E (>10%), dominants - D (5.1 – 10%), influents - I (2.1 – 5%), recedents - R (1.1 – 2%), subrecedents - + (≤ 1%).

RESULTS

In total 10190 specimens representing 99 species were collected. Taking into consideration the abundance of spiders for all years (Fig. 2), the largest number of species with the least number of individuals was recorded in the unmanaged area. Many species were represented only by less then ten or single individuals (Appendix). Spider assemblages of cereal fields were composed of fewer species represented by a larger number of individuals - mainly agrobiont spiders. However, the small field had the spider fauna more diverse than the large one.

Unmanaged "island"

This had the most diverse spider fauna and it was different from both crop fields, as can be seen on Figures 2-5. The dominance structure, analysed only for adult spiders, was as follows: *Pardosa prativaga, Centromerus sylvaticus* and *Pardosa amentata* were eudominants (21.6%, 18.4% and 14.4% respectively) and *Alopecosa pulverulenta* was dominant (5.3%). Uncommon species in Poland were collected: *Allomengea vidua, Tapinocyba biscissa, Ero cambridgei, Silometopus reussi, Walckenaeria unicornis, Syedra garcilis,* as well as species often present in woods: *Walckenaeria nudipalpis, W. obtusa, W. melanocephala, Pardosa lugubris, Ero tuberculata, Micrargus herbigradus*.

Small field

Oedothorax apicatus (37.5%) and *P. amentata* (12.1%) were eudominants, while *Pachygnatha degeeri* (7.8%), *Pachygnatha clercki* (7.4%), *Erigone atra* (5.9%) and *P. prativaga* (6.5%) were dominants. Similarity of this field to the adjoining unmanaged " island" can be seen not only in dominance structure, but also in the values of the Shannon diversity index (Table 1). Characteristic species for wet habitats - *Pirata piraticus, Pirata latitans* and *Gnathonarium dentatum* - were also collected.

Large field

The least diverse spider composition and a skewed dominance structure was observed in this habitat. The most numerous spiders were common agrobiont species. Differences between the years related to the changing locality of this field can be seen. The most abundant species, *O. apicatus,* comprised 49.8% of total spiders in 2000, but 40.8% and 32.6% in 1998 and 1999 respectively. *Erigone atra* and *E. dentipalpis* comprised only 1.9% in 2000, while in previous seasons they were eudominants or dominants. *Pachygnatha degeeri* was eudominant in all years and *Pardosa palustris* was the most abundant in 2000 (15.7%).

The similarity of spider assemblages can be seen in the cluster analysis diagrams (Figs. 3, 4), where two different groups of spiders

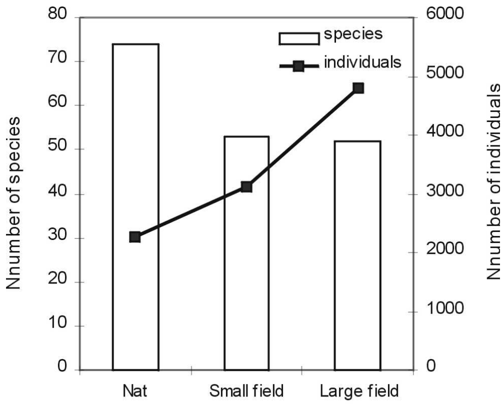


Fig. 2. Cumulative number of species and individuals in the studied areas for all years. Nat – unmanaged "island".

Table 1. Shannon index (H), evenness (E) and the number of species (N) for all studied areas. L1, L2, L3 – the large fields; S - the small field; Nat – the unmanaged "island"; the two - digit number denotes the year.

	L1 98	L2 99	L3 00	S 98	S 99	S 00	Nat 98	Nat 99	Nat 00
H	1.773	2.046	1.831	2.388	1.741	2.263	2.802	2.81	2.38
E	0.521	0.567	0.515	0.689	0.522	0.613	0.75	0.734	0.602
N	30	37	35	32	28	40	42	46	52

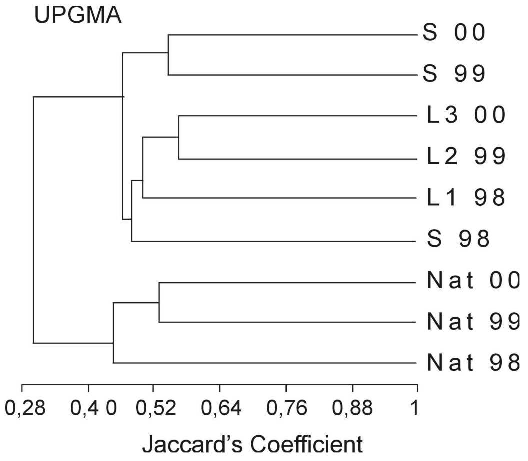


Fig. 3. Diagram of cluster analysis based on Jaccard's coefficient between sites. Nat – unmanaged "island", L1 – large field in 1998, L2 - large field in 1999, L3 - large field in 2000, S – small field.

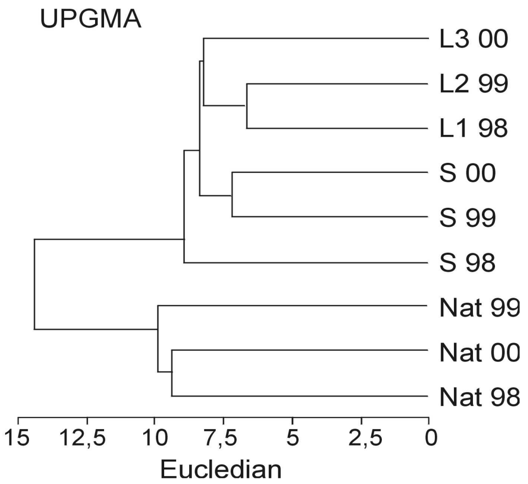


Fig. 4. Diagram of cluster analysis based on Euclidean distance between sites. Nat – unmanaged "island", L1 – large field in 1998, L2 - large field in 1999, L3 - large field in 2000, S – small field.

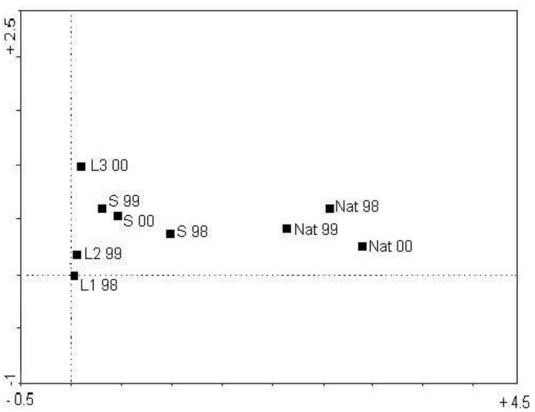


Fig. 5. DCA ordination of the studied sites based on their spider fauna. Nat – unmanaged "island", L1 – large field in 1998, L2 - large field in 1999, L3 - large field in 2000, S – small field.

appeared. The unmanaged area formed one group. The distinct character of this group is strongly marked. Spiders of cereal fields formed the second group. The greatest value of the Jaccard coefficient (Fig. 3) was between spider assemblages of the large field in 1999 and 2000. These two fields had similar area. Differences between the faunas of the studied habitats are revealed in the diagram of Euclidean distance. This coefficient, which includes not only the presence but also abundance in the samples, attained the highest values between the unmanaged area and the crop fields. The above arrangement of spider assemblages was confirmed by DCA ordination (Fig. 5). The assemblages were distributed along the axis according to a specific gradient. Axis 1 is interpreted to represent the gradient of spider assemblages from the unmanaged area covered with dense and diverse vegetation, via the small cereal field adjoining it, to the large cereal field with typical agrobiont species dominating. Axis 1 (has a gradient length of 2.936 SD, an eigenvalue of 0.611) explains 46% of the variation in the spider assemblage data. The eigenvalue of Axis 2 is 0.076 and explains 51.7 % of the variation.

DISCUSSION

The studies show that the unmanaged "island" is a habitat of great importance in the simple agrocoenosis. It has a distinct spider fauna, much richer in species than the surrounding crop fields. In the crop fields epigeic spider assemblages seemed to be impoverished by human practices, in comparison to the unmanaged patch, and consisted mainly of agrobiont species. The super-abundant species were *Oedothorax apicatus, Erigone atra, E. dentipalpis* and *Pachygnatha degeeri*. One characteristic of agrobiont spiders is the synchronisation of their life cycle with the arable crop-growing season. They reach adulthood and reproduce during the main vegetation period (Samu & Szinetár 2002).

Unlike in the fields, agrobiont spiders were represented by only few tens of individuals in the unmanaged patch. Many species, that typically occur in set-aside areas were present in this plot: e.g. *Troxochrus scabriculus, Bathyphantes gracilis, Micaria pulicaria, Dicymbium brevisetosum, Drassyllus pusillus, Robertus lividus*. *Centromerus sylvaticus*, which was one of the eudominant species there, was collected in the hundreds in January 2000. It is a stenochronous spider, which reproduces in the winter and stays active during that season (Schaefer 1977).

The closeness of ponds created specific microclimatic conditions, optimal for several spider species like *Larinioides cornutus, Allomengea vidua, Bathyphantes nigrinus, Helophora insignis* and *Pirata piraticus.* A relationship between diverse and undisturbed vegetation and high spider diversity is quite clear, as noted in other studies (Lagerlöf & Wallin 1993; Barthel & Platcher 1995, 1996; Bergthaler 1996; Riecken 1997; Wolak 2000, 2001). These authors have pointed out that every kind of unmanaged (or only partially managed) area in the agrarian landscape, like hedgerows, field margins, fallows, balks or artificially sawn weed strips, enriches spider diversity and makes an exchange of arthropods between them and the adjoining fields possible. Apart from being a refuge, the "island" had another significance in the uniform agrocoenosis: it acted as a source of spider migration into adjacent fields. Some species were found both there and in the small field. These species, which occurred in similar abundances in these plots, belonged mainly to the families Lycosidae (*Trochosa ruricola, T. spinipalpis, P. prativaga, P. piraticus*) and Linyphiidae (*Bathyphantes gracilis, B. parvulus, Centromerita bicolor, Lepthyphantes nebulosus*). An exchange of arthropods between crop fields and natural or semi-natural habitats has been found in numerous studies (Łuczak 1979; Gravesen & Toft 1987; Thomas at al. 1991; Kajak 1990; Kajak & Łukasiewicz 1994; Frank & Nentwig 1995). It seems that in the studied agrocoenoses spider migration probably took place from the unmanaged area to the small field, mainly by wandering on the ground surface (Lycosidae) and by " ballooning" (Linyphiidae) (Marc et al. 1999). Some authors have pointed out that intensity of immigration to the crop field from neighbouring habitats depends on physical similarity between the adjacent habitats. Sometimes, when similarity is low, immigrants do not reach further than a few metres (Downie at al. 1996; Sunderland & Samu 2000) or a few tens of metres (Bedford & Usher 1994). Similarity of species composition in the small field and the adjoining " island" might be a result of similar wetness. *P. piraticus* and *P. clercki* are considered by Vangsgaard et al. (1990) to be species characteristic of swampy areas. The other species, such as *G. dentatum, Marpissa radiata, Ozyptila trux, P. latitans* and *Pocadicnemis pumila*, are not typical crop field inhabitants (Hänggi et al. 1995; Żabka 1997), so they could have immigrated to the small field from the "island".

Spider migration from the undisturbed "island" could have taken place not only to the small field but in all directions, as non-agrobiont spiders could also be found in the large field. It must be stressed that their abundances depended on the location and area of this field in different years. In 1998, when the large field had much bigger area and was situated the farthest from the " island", the least was its diversity (spiders from only 5 families: Theridiidae, Linyphiidae, Lycosidae, Tetragnathidae and Thomisidae were recorded). Differences between the spider assemblages of the large field in 1998 and in other years can be seen in Figs. 2-5.

There was an ecotone at the border between the " island" and the cereal field. Although spiders of this biotope type were not studied in the present paper, it is well known that the fauna of such places is more diverse than those in the adjacent habitats (Łuczak 1993, 1995; Dąbrowska-Prot 1995). This is another reason why natural vegetation areas are important in the agrarian landscape. It is worth mentioning that richness and taxonomic diversification of the spider fauna can promote natural pest control, which, in turn, enables the reduction (or elimination) of pesticide usage during farming (Marc et al. 1999). This emphasizes the important role of habitat islands for maintaining biological stability in the whole agrocoenosis.

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Appendix. List of spider species collected in the study areas. Nat - unmanaged "island"; S - small cereal field; L1-98, L2-99, L3-00- large cereal fields in the years 1998-2000. E: eudominants (> 10%), D: dominants (5.1-10%), I: influents (2.1-5%), R: recedents (1.1-2%), +: subrecedents (< = 1%).

Species	Nat	S	L1 98	L2 99	L3 00
Dysderidae					
Harpactea rubicunda (C.L .Koch, 1839)				+	
Mimetidae					
Ero cambridgei (Kulczyński, 1911)	+				
Ero tuberculata (De Geer, 1778)	+				
Theridiidae					
Neottiura bimaculata (Linnaeus, 1767)		+			+
Robertus arundineti (O. P.- Cambridge, 1871)		+	+	+	+
Robertus lividus (Blackwall, 1836)	+		+		
Linyphiidae					
Allomengea vidua (L. Koch, 1879)	+				
Araeoncus humilis (Blackwall, 1841)	+	+	+	R	
Bathyphantes approximatus (O. P.- Cambridge, 1871)			+		
Bathyphantes gracilis (Blackwall, 1841)	+	+		+	+
Bathyphantes nigrinus (Westring, 1851)	+				
Bathyphantes parvulus (Westring, 1851)	+	+			
Bolyphantes alticeps (Sundevall, 1833)	+				
Centromerita bicolor (Blackwall,1833)	+	+	+		+
Centromerus sylvaticus (Blackwall, 1841)	E	+	+	+	+
Ceratinella brevis (Wider, 1834)	+				
Dicymbium brevisetosum (Locket 1962)	+	+	+	+	
Diplostyla concolor (Wider, 1834)	I	+			

Species	Nat	S	L1 98	L2 99	L3 00
Dismodicus bifrons (Blackwall, 1841)	+	+			
Erigone atra (Blackwall, 1833)	+	D	E	E	R
Erigone dentipalpis (Wider, 1834)	+	I	E	D	R
Erigone longipalpis (Sundevall, 1829)		+			
Gnathonarium dentatum (Wider, 1834)		+			
Helophora insignis (Blackwall, 1841)	+				
Leptyphantes angulipalpis (Westring, 1851)	+				
Lepthyphantes insignis (O. P.- Cambridge, 1913)	+				
Lepthyphantes mengei (Kulczyński, 1887)	+				
Lepthyphantes nebulosus (Sundevall, 1829)	+	+			
Lepthyphantes tenebricola (Wider, 1834)	+				
Lophomma punctatum (Blackwall, 1841)		+			
Meioneta rurestris (C.L .Koch, 1836)	+	+	+	+	+
Micrargus herbigradus (Blackwall, 1854)	+				
Micrargus subaequalis (Westring, 1851)				+	
Microlinyphia pusilla (Sundevall, 1829)			+		
*Neriene clathrata (*Sundevall, 1829)	+				
Oedothorax agrestis (Blackwall, 1853)			+		
Oedothorax apicatus (Blackwall, 1850)	R	E	E	E	E
Oedothorax fuscus (Blackwall, 1841)		I	+	+	+
Oedothorax retusus (Westring, 1851)		R	+	+	+
Oedothorax gibbosus (Blackwall, 1841)		+			
Pelecopsis radicicola (L. Koch, 1872)	+				
Pocadicnemis pumila (Blackwall, 1841)	R	+		+	
Porrhomma pygmaeum (Blackwall, 1834)					+
Silometopus reussi (Thorell, 1871)	+		+	+	
Stemonyphantes lineatus (Linnaeus, 1758)	I				
Syedra gracilis (Menge, 1869)	+				
Tallusia experta (O. P.- Cambridge, 1871)	R	+		+	+
Tapinocyba biscissa (O. P.- Cambridge, 1872)	+	+			
Tapinocyba insecta (L. Koch, 1869)		+			
Tiso vagans (Blackwall, 1834)		+	+	+	+
Troxochrus scabriculus (Westring, 1851)	+	+			
Walckenaeria atrotibialis (O. P.- Cambridge, 1878)	+				
Walckenaeria nudipalpis (Westring, 1851)	+				+
Walckenaeria obtusa (Blackwall, 1836)	+				+
Walckenaeria unicornis (O. P.- Cambridge, 1861)	+				
Tetragnathidae					
Pachygnatha clercki (Sundevall, 1823)	R	D	R	+	+
Pachygnatha degeeri (Sundevall, 1830)	R	D	E	E	E
Pachygnatha listeri (Sundevall, 1830)		+	+		
Araneidae					
Araneus diadematus (Clerck, 1758)	+				
Araniella cucurbitina (Clerck, 1758)	+				
Mangora acalypha (Walckenaer, 1802)	+				
Lycosidae					
Alopecosa aculeata (Clerck, 1758)	+				
Alopecosa cuneata (Clerck, 1758)	+				

Species	Nat	S	L1 98	L2 99	L3 00
Alopecosa pulverulenta (Clerck, 1758)	D	+	+	+	+
Arctosa leopardus (Sundevall, 1833)	+	+			
Pardosa agrestis (Westring, 1861)	+	+	+	+	+
Pardosa agricola (Thorell, 1856)	+	+		+	R
Pardosa amentata (Clerck, 1758)	E	E	+	+	I
Pardosa lugubris (Walckenaer, 1802)	+				
Pardosa monticola (Clerck, 1758)				+	+
Pardosa paludicola (Clerck, 1758)		+			
Pardosa palustris (Linnaeus, 1758)	R	I	+	D	E
Pardosa prativaga (L. Koch, 1870)	E	D	R	I	R
Pardosa pullata (Clerck, 1758)	+	R	+	+	R
Pirata latitans (Blackwall, 1841)	+	+			
Pirata piraticus (Clerck, 1758)	+	+	+		
Trochosa ruricola (De Geer, 1778)	I	R	+	R	+
Trochosa spinipalpis (F. P.- Cambridge, 1895)	+	+		+	+
Xerolycosa miniata (C.L. Koch, 1834)	R				
Pisauridae					
Pisaura mirabilis (Clerck, 1758)	+	+		+	
Agelenidae					
Agelena gracilens (C.L. Koch, 1841)				+	
Tegenaria agrestis (Walckenaer, 1802)				+	
Dictynidae					
Argenna subnigra (O. P.- Cambridge, 1861)	+				
Liocraniade					
Agroeca proxima (O. P.- Cambridge, 1871)	+				
Phrurolitus festivus (C.L. Koch, 1835)	+				
Clubionidae					
Clubiona lutescens (Westring, 1851)	+				
Gnaphosidae					
Drassyllus lutetianus (L. Koch, 1866)		+			
Drassyllus pusillus (C.L. Koch, 1833)	+				
Haplodrassus signifer (C.L. Koch, 1839)				+	
Micaria pulicaria (Sundevall, 1832)	+				
Zoridae					
Zora spinimana (Sundevall, 1833)	+				+
Philodromidae					
Thanatus striatus (C.L. Koch, 1845)					+
Tibellus oblongus (Walckenaer, 1802)	+	+			+
Thomisidae					
Ozyptila trux (Blackwall, 1846)	+	+	+	+	+
Xysticus cristatus (Clerck, 1758)	R	+		+	R
Xysticus kochi (Thorell, 1872)	+	+	+	+	R
Xysticus ulmi (Hahn, 1831)	R	+			+
Salticidae					
Euophrys frontalis (Walckenaer, 1802)	+			+	
Marpissa radiata (Grube & Ohlert, 1859)		+			