Acta Zoologica Academiae Scientiarum Hungaricae 40 (1), pp. 1-14, 1994

COMPARATIVE ANALYSIS OF EDGE EFFECT ON BIRD AND BEETLE COMMUNITIES

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Effect of edge was studied at the same time and place on bird and beetle communities in a riparian forest in Hungary. The diversity of birds was similar in the edge and in the interior habitats, but density increased in the edge. There were no significant differences between the edge and the interior bird communities. The beetle communities sampled in the forest edge, interior-edge and interior habitats differed significantly from each other. There were differences in calculated species number, diversity and equitability. Flying ability was related to habitat, with the number of species with flying ability increasing towards the edge. Our study revealed that the effect of edge may have similar consequences on taxonomically distant groups, but the applied scale was appropriate to detect significant differences only for beetles, not for birds. With two original figures.

Key words: edge effect, bird communities, beetle communities, spatial scale

INTRODUCTION

An edge can be defined as the junction of two different habitats (FORMAN & GODRON, 1986, YAHNER, 1988). Animal communities associated with edges have been of considerable interest to conservation biologists and wildlife managers, because recent human induced changes in the landscape increase the amount of edge habitats.

Studies of edge effect and fragmentation usually have included only one taxonomic group, for example mammals (e.g. BENNETT, 1987), birds (e.g. HANSSON, 1983, HELLE & HELLE, 1982, KROODSMA, 1984, TEMPLE & CARY, 1988, MØLLER, 1989), amphibians (e.g. MANN *et al.*, 1991), or different invertebrates (e.g. DUELLI *et al.*, 1990, MAJER, 1987). There are also studies of a single species from several taxonomic groups (DE VRIES & DEN BOER, 1990, DODD, 1990, GJERDE & WEGGE, 1989, HANSKI, 1989, LANKESTER, *et al.*, 1991).

The number of complex or comprehensive studies are limited (HELLE & MUONA, 1985, NILSSON *et al.*, 1988, ROSENBERG & RAPHAEL, 1986) and generally include taxonomically, or from an anthropogenic point of view, closely related groups. Investigations on the relationship between distant groups, usually between vertebrates and invertebrates, are based on indirect data from the lit-

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erature. Such comparisons were made on data collected at different times and from different places, which may have affected the results (SCHOENER, 1986).

In the present paper we investigated the effect of edge on bird and beetle communities, with emphasis on comparing differences in community structure parameters for beetles and birds across the edge. The two studies were carried out concurrently in the same system, solving the problem of comparing indirect data.

STUDY AREA AND METHODS

The study was conducted in the Szigetköz region, Hungary, near the village Feketeerdő, in Felső Forest (47°53'N, 17°15'E). The original vegetation on the whole area of the Szigetköz were grove forests. Now the landscape is mainly farmland with remnants of seminatural vegetation.

The study site is situated along the River Mosoni Duna. The forest site is 220 ha bounded mainly by cultivated fields. The forest is managed (mainly selective cuts, but there are clear cuts and plantations as well), divided by paths into 200×200 m blocks. The paths are linear, and about 3-5 m wide, allowing cars to use them. The forest association of the area is a seminatural oak–elm–ash grove, *Querco-Ulmetum*. Trees are mixed in the canopy layer, largely consisting of *Quercus robur, Fraxinus angustifolia* and *Ulmus laevis*. The shrub layer is abundant, consisting of *Viburnum, Crataegus, Cornus, Acer* and *Frangula* species. In the grass layer, the abundant species are *Rumex saguineus, Rubus caesius, Festuca gigantea,* and *Carex* spp.

Bird census – Bird censuses were carried out in the edge and in the interior part of the forest, about 2-400 m from the edge, in 1990 and 1991. Two censuses were carried out, one in April, and one in May to record both early and late breeders. The transects in the two years were altogether 5.2 km long (13 ha) in the forest edge and 3.4 km long (16.9 ha) in the forest interior habitats. Average density values were used in the analysis so we could analyse the data in the similar way as the beetle data. We used the line transect method (JÄRVINEN & VÄISÄNEN, 1975), with only the forest side being counted at the edge. The other side was an intensively managed agricultural land, which was almost bare in spring. All birds detected were noted in the main belt (MB, <25 m) and supplementary belt (SB, >25 m). The quantitative indices and measures were based on the density estimations (MB, only) (Appendix A), whereas the qualitative measures were based on the whole data set (MB and SB). Description of the main types of bird communities in the Szigetköz region is reported by WALICZKY (1992).

Collection of beetle data – The data were collected from April to September, 1991, using pitfall trapping. Sixty plastic 300 cm^3 jars were set out into the study area. Three groups were formed, each contained twenty jars. The jars were placed along a line, with about 1m between each trap. The first group of the traps was placed within the forest-agricultural land boundary, along a line parallel with the edge of the forest. The second group was inside the forest (200 m apart from the edge) but was placed along a line beside a path, 2.5 m from it. The third group was inside the forest (300 m apart from the edge) in the center of a 200×200 m block.

All jars were filled with 1 dl ethylene-glycol to preserve the caught animals. Traps were emptied three-weekly. We did not include the rarely caught species in the analysis.

To determine the community structure parameters we applied some simple biomathematical methods (see e.g. SOUTHWOOD, 1978, KREBS, 1989). The Shannon-Wiener diversity index (H') was used to calculate the diversity of the communities:

$$H' = -\sum p_i \ln p_i$$

where

H'= Shannon-Wiener diversity index and p_i= relative frequency of the species i

The most commonly used index of evenness (equitability) in the literature is based on the Shannon-Wiener function:

$$J' = H'/\ln(S)$$

where

J' = evenness measure (range 0-1) and S = total number of species.

To examine the similarity of the edge and inside communities in the same taxon we used the Sørensen index:

$$C_s = 2j/(a+b)$$

where

C_s=Sørensen coefficients, *j*=number of common species (in both communities), *a*=number of species in community *a*, *b*=number of species in community *b*

The Bray-Curtis index, a modified version of the Sørensen index, was also applied:

$$C_{BC} = 2jN/(aN+bN)$$

where

C_{BC}= Bray-Curtis index, jN = the sum of the lesser values for the species common to both habitats, aN = total individuals sampled in habitat a, bN= total individuals sampled in habitat b.

As the sample sizes differed, we applied the rarefaction method (see KREBS, 1989) to estimate the expected species number on a unit area using the program RAREFRAC.BAS (LUDWIG & REYNOLDS, 1988).

Chi-square tests were applied to test differences between the distribution of individuals per species, species area and dominance curves.

RESULTS

There were 38 bird species observed in the study period, 34 in the forest edge and 28 in the forest interior part. The total density of birds preferring edge was three times higher than that of the birds preferring forest.

Edge preference or avoidance was determined for 15 species from the total 38 based on density estimations. Two species were excluded from these 15 species, *Garrulus glandarius* and *Turdus iliacus* because only one flock was observed for each species. The remaining 13 species can be clustered into different groups based on their preference for edge (Appendix A). Most of the species show edge preference, some did not show any preference, and only *Parus major* exhibited a weak avoidance of edge.

During the study period we emptied the pitfall traps six times. We caught 822 individual beetles of 65 species (Appendix B). Six species were abundant in the edge, seven species in the interior-edge, and three species in the forest interior habitats. One species was equally distributed in inside-edge and edge habitats.

Rarefaction is an appropriate method to calculate the expected species number for species richness. The distribution of number of individuals per species did not differ significantly between the inside and edge communities of birds, but for

Table 1. Values of chi-square tests between edge and interior communities of birds and beetles, based on number of individuals per species.

		χ^2	D.f.	Significance
Birds	edge-interior	38.241	32	NS
Beetles	edge - interior edge	138.702	64	$p<0.001$
	interior edge-interior	203.056	64	$p<0.001$
	edge - interior	195.355	64	$p<0.001$

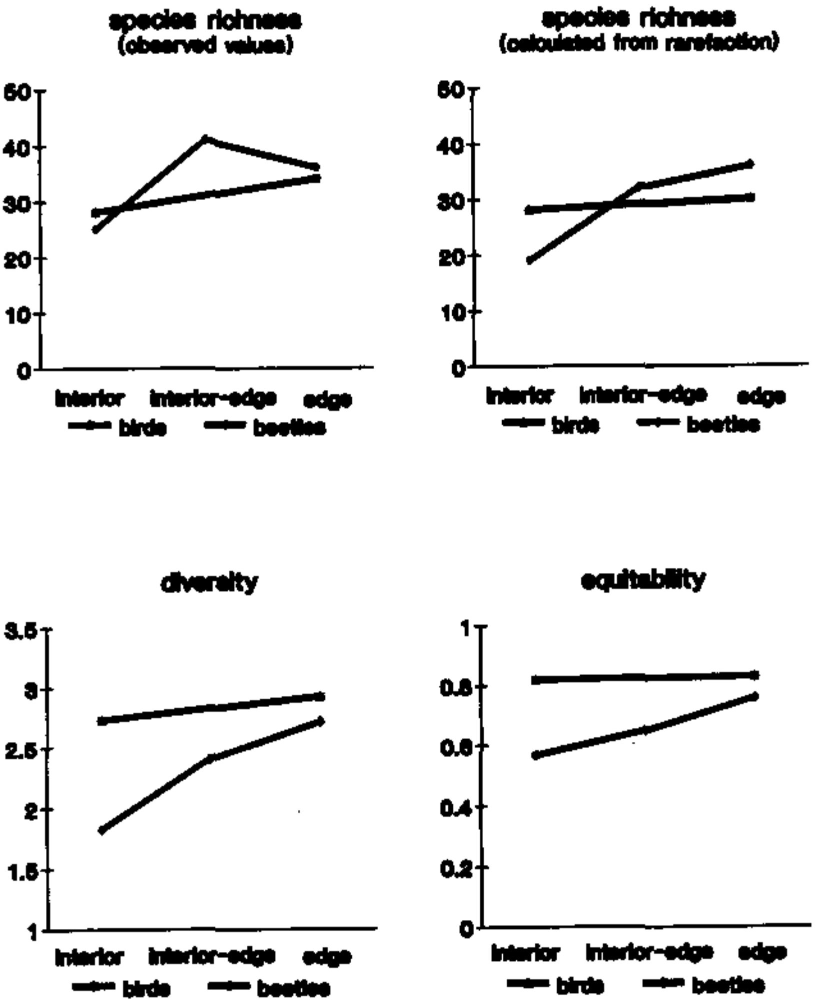

Fig. 1. Changes in community structure parameters for birds and beetles from the forest interior to the edge habitats.

beetles there were significant differences in each case (Table 1). The changes of community structure parameters (species richness, rarefied species richness, diversity and equitability) were compared within and between taxa (Fig. 1). In birds there was a slight increase in species richness from inside toward the edge in both observed values and calculated values by the rarefaction method and almost no change in diversity and equitability. In beetles the observed values of species richness showed an increasing tendency toward the edge, but the inside-edge community had higher species richness than that of the edge community. However, after rarefying there was a continuous increase in the expected species number $E(S_n)$ from inside to the edge (Fig. 1). The diversity and equitability values of beetles also increased gradually from the inside community to the edge community.

The slopes of rarefaction curves of birds were similar, and the distances between them were small (Fig. 2). In beetles the curve for the forest interior community separated from the other two curves. The increase in species number of these two latter communities was higher (Fig. 2).

The similarity indices showed high similarity between the edge and interior bird communities (Table 2). Comparisons among beetle communities by the indices showed that the difference was highest between the inside and edge communities. The indices showed that the difference between edge and interior communities was much smaller for birds than for beetles.

DISCUSSION

In this study we use the term community to refer to only birds or only beetles, not as the entire animal community.

Birds and the edge effect

Data from the literature show great variety on the edge preference or avoidance of bird species (see e.g. FROCHOT, 1981, 1987, FULLER & WHITTINGTON, 1987, FULLER & WARREN, 1991, MOSKÁT & FUISZ, 1992 for data from deciduous forests). This diversity suggests that great differences exist in the behaviour of species and communities in relation to the type and/or pattern of landscape and habitat. Naturally many other factors may affect the distribution of birds, for example HAILA *et al.* (1987) argued that the habitat selection of hole-nesting passerines related to the number of available snags rather than to the area of fragments. However, there are some species which may be considered edge-species, because they were found to show the same preference in most of the studies, e.g.,

Table 2. Values of Sørensen and Bray-Curtis similarity indices between edge and interior communities of birds and beetles.

	Birds	Beetles		
	edge and interior	edge and interior edge	interior edge and interior	edge and interior
Sørensen	0.7741	0.5741	0.4545	0.3606
Bray-Curtis	0.4623	0.4061	0.5205	0.3697

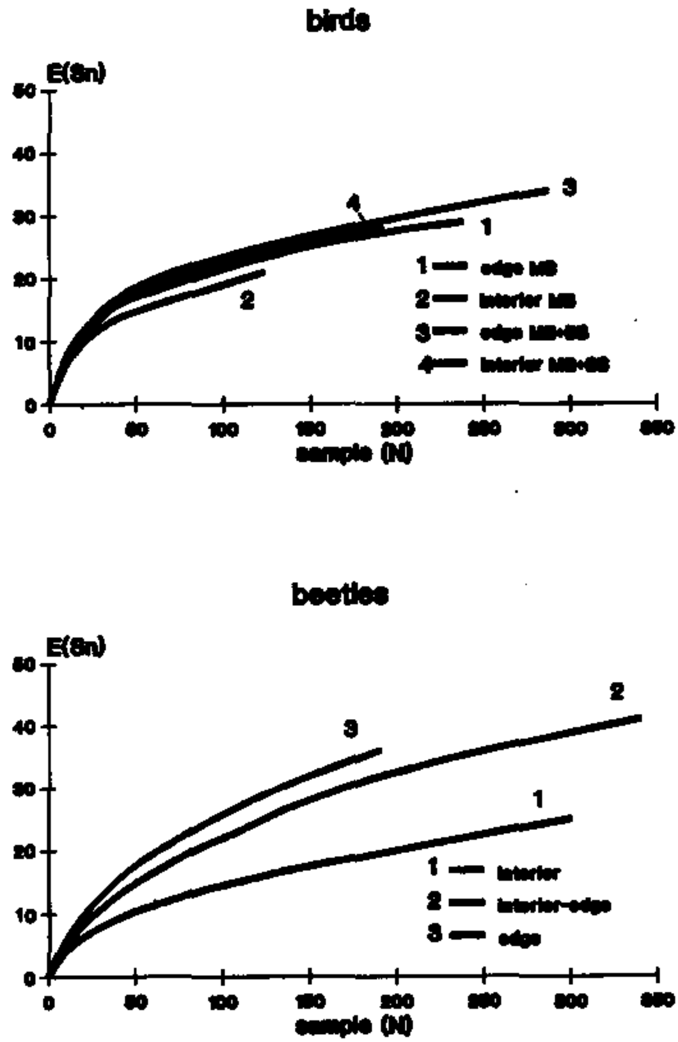

Fig. 2. Rarefaction curves for birds and beetles in the forest edge and forest interior habitats.

Sylvia atricapilla, Emberiza citrinella. The variability of results within taxon also strengthens the argument to conducting comparative studies at the same time and place.

Recently MOSKÁT & FUISZ (1992) reflected on the importance of vegetation structure. They counted birds in three habitats, edge, interior without shrubs and interior with shrubs. They found that the distribution of some species were not related to the edge, but to the presence of the shrub-layer (e.g. *Sylvia atricapilla*). Other species preferred shrubs, but avoid edge (e.g. *Erithacus rubecula*), or avoid interior habitats at all (e.g. *Carduelis chloris*).

Ecotones often harbour more diverse and dense communities than either of the two joining habitats (first reported by LEOPOLD (1933), cited in YAHNER (1988)). In our study the density of breeding birds was three times higher in the edge (within 0-25 m) than in the interior forest. However, the diversity values were almost the same. We suggest that the increased density in the edge was mainly a consequence of the nesting possibilities in tree holes (e.g. for *Sturnus vulgaris* and *Passer montanus*). The high density of these two species may be due to the proximity of the village. Indeed, the great majority of them were observed in that edge section which was nearest the village. The agricultural fields which bounded the other sites harboured only a few species, therefore open fields did not contribute much to the observed number of species.

Carduelis carduelis, C. chloris, Emberiza citrinella and *Serinus serinus* preferred edge trees for singing or resting, otherwise they are field species. On the other hand, a group of forest species also showed edge preference (*Parus caeruleus, Sitta europaea, Sylvia atricapilla, Phylloscopus collybita, Erithacus rubecula*).

Beetles and the edge effect

Studies of edge effect and fragmentation on invertebrates have showed that abundance and species diversity usually increase toward the edge of habitats (DENNIS & FRY, 1992, DUELLI *et al.*, 1990, HELLE & MUONA, 1985, KROMP & STEINBERGER, 1992, LAGERLÖF *et al.*, 1992). Our results on species richness are in accordance with this after rarefying the observed data.

The Coleoptera species fulfil an important role in terrestrial ecosystems (THIELE, 1977, WEIDEMANN, 1971, 1972). They are good indicators for the condition of habitats (THIELE, 1977), and management (KROMP, 1990, RUSHTON *et al.*, 1989), and have been shown to be useful indicators of conservation value (EYRE & RUSHTON, 1989). For this reason the examination of their distribution in different habitats and the effects of different factors and processes on them and their habitat characteristics are important for their preservation and management.

The microclimates of the edge and interior areas are markedly different (HANSSON, 1992, LOVEJOY *et al.*, 1986). Microclimate has a significant effect on the distribution of Coleoptera species, mainly on ground-dwelling beetles (THIELE , 1977).

In our study community distribution seems to change gradually from the interior toward the edge of the forest. Six species were found to prefer edge (Appendix B). *Harpalus rubripes* prefer bushy ravines and *H. rufipes* is found widespread on cultivated land (THIELE, 1977), therefore their edge preference reflected their normal habitat selection. Half of these species are perdators and half are herbivores. All of them can fly. Three species preferred the interior site; *Barypeithes* species, which is herbivorous; *Abax carinatus*, which is a predator; and *Platarea dubiosa* also a predator. Only one of them can fly. We found that eight species preferred the interior-edge habitat (Appendix B). There were pherbivors, predators and dung-eaters among them. There was an equal proportion of flying and non flying species, which reflects a gradual change in this characteristic from edge to interior habitats.

Comparison of the effect of edge on birds and beetles

The comparison of different ecological communities has a long history, dating from the CLEMENTS-GLEASON debate (SCHOENER, 1986). However, comparable studies of vertebrates and arthropods are lacking (SCHOENER, 1986, but see NILSSON *et al.*, 1988). Comparison of communities between distant taxa causes difficulties. Many measures of community cannot be applied because of the lack of common species. Therefore only indirect measures can be used, such as distributional characteristics and community structure parameters. However, the differences between vertebrates and invertebrates, namely between birds and beetles, are so large that even comparisons of community indices may not be valid. Therefore we restricted our analysis to a comparison of the changes in bird and beetle communities between the edge and interior habitats.

WIENS (1989) pointed out that ecologists must study nature on the appropriate scale. FUISZ & MOSKÁT (1992) showed that beetle community parameters vary at different hierarchical levels of the local spatial scale. The imposition of a single scale on all of the species in a community causes difficulties in interpreting the results.

Spatial scaling has an important role on conservation biology as well. WIENS (1989) pointed out that the disagreements over the design of nature reserves are at least partly due to a failure to appreciate scaling differences among organisms.

The samples of birds and beetles in the present study were collected at the same spatial scale, therefore differences in the significance of edge effect were expected. However, two points need further discussion. First, the strong similarity between edge and interior bird community parameters and distributions showed that for birds there was not as pronounced edge effects at the studied scale as for beetles. The small distance between edge and interior transects and the small area of the forest plot may have caused the lack of differences.

Second, for beetles the applied spatial scale was much more appropriate. Significant differences between beetle communities of edge and interior-edge, and between interior and interior-edge showed that the beetles were sensitive to even a 4 m wide path in the forest.

The present study shows that a conservation biological survey of an area requires multiple studies on different scales to determine the needs of a wide range of taxa. Conservation biologists frequently apply the keystone or umbrella species hypothesis (e.g. SOULÉ & SIMBERLOFF, 1986). This hypothesis states that if a large-bodied or specialised animal is able to survive in a site, because of the large area, heterogeneity or conservation management of the site, a lot of smaller or more generalized species can survive there as well. Nevertheless, there are controversies over this hypothesis at the species level, because the "valuable" species have usually different ecological requirements. However, our study seems to strengthens this hypothesis, at least at the community level, since the beetle communities showed high variability, whereas the bird communities did not. That is, if we provide an appropriate area for birds, the beetle communities will show much greater diversity.

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Acknowledgements – We are indebted to L. HANSSON, C. MOSKÁT, J. SWENSON and two anonymous reviewers for valuable and constructive comments. L. ÁDÁM and G. SZÉL collected and identified the beetles. The field work was financed by a grant of the Hungarian Academy of Sciences to F. MÉSZÁROS (AKA fund, No. 1-300-2-91-0-759). Preparation of the paper was supported by a grant of the National Scientific Research Fund to C. MOSKÁT (OTKA, No. I/3 3188).

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Received February 1, 1993; accepted December 1, 1993

Appendix A. Population densities (pair/10ha) of birds in forest edge and interior habitats. (E: edge preference; I: inside preference; r: rare species, not considered in the analysis at the population level; *: one flock was seen.)

	Inside	Edge	Status
Aegithalos caudatus		0.39	r
Anthus trivialis	0.59	0.77	r
Carduelis carduelis		1.89	E
Carduelis chloris	0.30	1.93	E
Coccothraustes coccothraustes	0.30	0.39	r
Corvus corone cornix		0.39	r
Dendrocopos major	2.07	2.31	?
Emberiza citrinella	1.19	4.62	E
Erithacus rubecula	4.14	6.54	E
Ficedula albicollis		0.39	r
Fringilla coelebs	6.81	8.85	?
Garrulus glandarius	1.19		*
Hippolais icterina		0.77	r
Muscicapa striata		1.93	E
Oriolus oriolus	0.30		r
Parus caeruleus	2.37	5.77	E
Parus major	7.40	5.20	?
Passer montanus	0.89	7.31	E
Phylloscopus collybita	2.07	3.08	E
Phylloscopus sibilatrix	0.59	0.77	r
Phylloscopus trochilus	0.30		r
Picus viridis		0.39	r
Serinus serinus	0.59	2.31	E
Sitta europaea	0.59	4.23	E
Streptopelia turtur	0.30	0.77	r
Sturnus vulgaris	0.30	15.0	E
Sylvia atricapilla	3.85	10.0	E
Sylvia borin		0.39	r
Sylvia nisoria		0.39	r
Turdus iliacus		4.23	*
Turdus merula	0.30		r
Turdus philomelos		0.39	r

Appendix B. Abundance of beetle species in the inside, inside-edge and inside habitats. (E: edge preference; IE: inside-edge preference; I: inside preference; r: rare, not considered in the analysis at the population level).

	Inside	Inside-edge	Edge	Status
Abax carinatus	124	14	2	I
Abax paralellepipedus	60	93	42	IE
Alapsodus compressus			1	r
Allocypus melandris		1	1	r
Amara anthobia			1	r
Amara saphyrea		1	2	r
Anobiidae			1	r
Anoplotrupes stercorosus	1			r
Anthobium atrocephalum	1	1		r
Aphthona euphorbiae		1		r
Athous haemorrhoidalis	1	1	2	r
Atomaria analis		1		r
Barypeithes sp.	5	2	1	I
Bothynoderes punctiventris		2		r
Carabus coriaceus		4	1	r
Carabus ulrichii	28	50	22	IE
Coccinella septempunctata			1	r
Dienerella separanda	1			r
Dorcus paralellepipedus		2		r
Harpalus atratus		4	11	E
Harpalus rubripes		1	6	E
Harpalus rufipes			24	E
Kolon sp.	1			r
Lamprohiza splendidula		1		r
Loricera pilicornis		1		r
Margarinotus carbonarius	2			r
Melandryidae	1			r
Meligethes aeneus			1	r
Meloe proscarabeus	1			r
Meloe violaceus	3	2		r
Mesosa curculionoides			1	r
Mocyta fungi			1	r
Nicrophorus vespillo	1	2		r

Appendix B continued

	Inside	Inside-edge	Edge	Status
Nothiophylus rufipes		2	5	E
Omalium rivulare	1	1	4	E
Onthophagus coenobita	1	9		IE
Onthophagus nutans		5	1	IE
Ontholestes haroldi		1	19	E
Otiorhynchus ligustici	1	3	1	r
Otiorhynchus raucus	1	20	2	IE
Ouchaemus caesareus		3	3	IE-E
Philonthus laminatus		1		r
Philontus proximus			1	r
Phosphuga atrata	1	2	1	r
Platarea dubiosa	11	4	1	I
Platydracus chalcocephalus	48	79	14	IE
Podoxya vicina	2			r
Polydrusus pterygomalis			1	r
Pseudocypus mus		3		r
Pterostichus anthracinus			1	r
Pterostichus oblongopunctatus	1			r
Ptomaphagus sericatus			1	r
Rhagonycha sp.	2			r
Rugilus rufipes		1	1	r
Salpingus ruficollis		1		r
Scaphidema metallicum		1	1	r
Sepedophilus marshami			2	r
Sitona hispidulus	1			r
Sitona sp.		3		r
Stenomax aeneus		1		r
Tachyporus sp.		1		r
Tasgius pedator			1	r
Trox sabulosus		2		r
Trypocopris vernalis		6		IE
Valgus haemipterus		1		r