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The carabid beetle fauna (Coleoptera, Carabidae) of a traditional garden in the Hrvatsko Zagorje region

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Abstract

Background and Purpose: *The carabid beetle fauna was studied in a traditional family garden in Konjščina (northwest Croatia). The garden was surrounded by different crop types, various habitat types, including a small marshland area, and a nearby railroad. The aim of our study was to determine the carabid beetle assemblage in a traditionally managed garden, to establish the seasonal dynamics of the dominant carabid species and to analyze carabid beetle fauna according to their ecological and habitat preferences, and geographical distribution.*

Material and Methods: *Carabid beetles were collected by pitfall traps. Zoogeographical distributions and species ecological characteristics were taken from the literature.*

Results: *A total of 547 specimens of carabid beetles belonging to 37 species were recorded. The dominant species were:* Pterostichus niger*,* Poecilus cupreus*,* Harpalus rufipes*,* Bembidion quadrimaculatum *and* B. properans*. Hygrophilous species prevailed over xerophilous and mesophilous. The majority of the species were spring breeders. Three rare carabid species were captured:* Clivina collaris*,* Drypta dentata *and* Oodes helopioides*. The majority of species had fully developed wings and are active fliers.*

Conclusions: *Carabid species diversity and abundance in the traditional garden were markedly determined by the diversity of habitats found on a relatively small surface area. The vicinity of a small marshland area had the main influence on the carabid beetle fauna, which mainly consisted of widely distributed hygrophilous species with good flight ability. The current study shows that traditional gardens may enhance biodiversity on a small scale level.*

INTRODUCTION

Carabid beetles (Coleoptera, Carabidae) are one of the most common beetle families with a large number of species and individuals (*1*). They are distributed over broad geographic ranges and in all major terrestrial habitats, such as: meadows, arable fields, steppes, savannahs and forests, except deserts (*1, 2*). Although carabids are a large group and some species are ubiquitous, many species are highly specialized to a particular habitat (*2*). Due to their abundance, taxonomical and ecological diversity, and sensitivity to human-caused disturbances, carabid beetles are good ecological indicators of environmental change (*2, 3*). Anthropogenic disturbance is one of the most important biotic factors confronting carabid beetles in their various native ecosystems (*2*).

A large number of studies have been directed at studying carabid beetles in arable fields (*4, 5, 6*), semi-natural and urban areas (*7, 8, 9, 10*). Relatively few data exist on the carabid beetle fauna of rural traditional areas, especially traditional gardens, which form an important part of the agricultural landscape. Due to high anthropogenic pressure, data on carabid beetles obtained from urban landscapes are not comparable to the carabid beetle fauna in rural areas. In arable fields, up to 25% of the species of the regional carabid fauna can be found (*11*). According to Trittelvitz & Topp (*12*) and Kegel (*13*), as many as 75 carabid species have been recorded in favourable, predominantly grain fields. If samples from different fields and years are combined, the number of species can reach 80–120 or more, especially where different crops and soil types are involved (*14, 15*). In North America, more than 400 carabid species have been recorded in arable fields (*16*). Gardens, especially in large urban and suburban areas, may serve to maintain biodiversity under appropriate management regimes (*17, 18*).

In Croatia, traditional family gardens have changed over the centuries, and form an integral part of the cultural heritage of the region and reflect upon the needs of the inhabitants (*19*). Such gardens serve to produce small quantities of various vegetables, fruit and ornamental plants. They usually represent extensive cultivation, and are typically managed without the use of pesticides and herbicides.

The carabid beetle fauna in the region of Hrvatsko Zagorje in northwest Croatia has been poorly investigated. There are few studies (*20, 21*), which arose more out of incidental collections than due to systematic research. Therefore, studies of carabid beetles in gardens (*22*) represent a contribution to learning about the fauna in a specific habitat that is slowly disappearing with the change in the life style of the local population. The objectives of our study were: (1) to determine the species of carabid beetle inhabiting a traditionally managed garden; (2) to establish the seasonal dynamics of the dominant carabid species; (3) to analyse carabid beetle fauna in relation to its ecological adaptation and the species biology, and geographical distribution.

Study area

Field studies of the entomofauna were carried out in a family garden situated in Konjščina in the Krapina River Valley, in the Hrvatsko Zagorje region (northwest Croatia) (Figure 1), at an altitude of 162 m. The garden covers an area of approximately 600 m^2 and lies at the edge of the settlement. It is surrounded by a low, sloping hill to the north, corn (*Zea mays*) and alfalfa (*Medicago sativa* L.) to the northwest, a ditch to the west, railway tracks to the south and the grounds of the family home to the east. The garden is divided into an area planted with various types of vegetables and ornamental plants, and an area covered by wild-growing vegetation. The following vegetable species were grown: *Allium cepa* L., *A. porrum* L., *A. sativum* L., *Anethum graveolens* L., *Apium graveolens* L., *Armoracia rusticana* P. Gaertn., B. Mey. et Scherb., *Artemisia absinthium* L., *Beta vulgaris* L. ssp. *vulgaris*, *Brassica cretica* Lam. ssp. *botrytis* (L.) O. Schwarz, *B. oleracea* L. ssp. *bullata* DC., *B. oleracea* L. ssp. *capitata* (L.) Duchesne, *B. rapa* L., *B. rupestris* Raf. ssp. *gongyloides* (L.) Janch., *Capsicum annuum* L., *Chamomilla recutita* (L.) Rauschert, *Cucumis sativus* L., *Cucurbita pepo* L., *Daucus carota* L., *Fragaria* x *ananassa* Duchesne, *Lactuca sativa* L., *Mentha piperita* L., *Petroselinum crispum* (Mill.) A. W. Hill, *Phaseolus vulgaris* L., *Pisum sativum* L., *Solanum lycopersicum* L., *S. tuberosum* L., *Valerianella locusta* (L.) Laterrade and *Zea mays* L. The following ornamental plants were grown: *Calendula officinalis* L., *Lilium candidum* L., *Narcissus* sp., *Paeonia* sp., *Rosa* sp., *Tagetes* sp., *Tulipa* sp. and *Zinnia elegans* Jacq. The uncultivated part of the garden, with the most humid soil, was covered by wetland vegetation (ass. *Phalaridetum arundinaceae* Libbert 1931). On the dryer parts, grassland vegetation was developed, though fragmented (class *Molinio-Arrhenatheretea* R. Tx. 1937 em. R. Tx. 1970). On areas under intensive anthropogenic influence, vegetation typical of trampled surfaces was developed (ass. *Lolietum perennis* Gams 1927). Ruderal vegetation was present between the cultivated plants (order *Chenopodietalia albi* R. Tx. (1937) 1950).

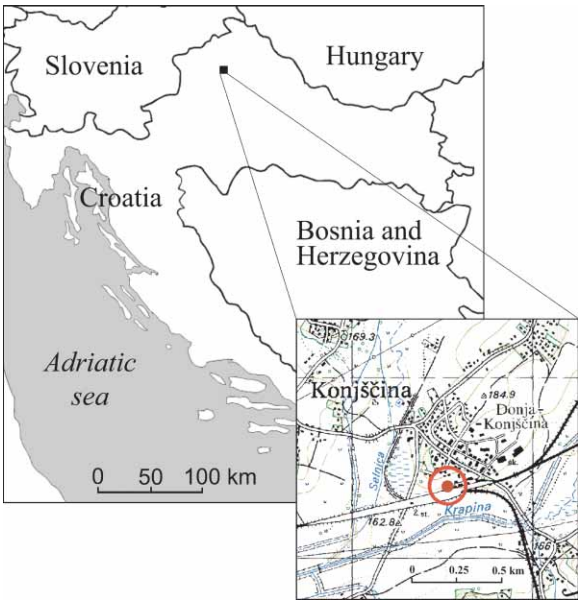

Figure 1. *Geographic position of the investigated garden in Konjščina (Hrvatsko Zagorje region).*

The entire area of the garden was subjected to greater or lesser anthropogenic influence. The most intensive impacts were in the areas with cultivated plants, which were subjected to mechanical soil processing, sowing, planting, weeding and fertilizing several times throughout the year. The remaining part of the garden, under the wild-growing vegetation, was subjected to mowing two or three times per year, and to trampling. With respect to humidity, the cultivated part of the garden was on slightly elevated terrain, in principle above the reach of the floodwaters. The lower part of the garden was subjected

to periodical flooding during periods of heavy precipitation during winter and early spring. The cultivated part was only partially covered by plants and had larger or smaller areas of bare soil, while the uncultivated part, and in particular the areas with wetland vegetation and fragmented grassland vegetation, had a very dense and lush plant cover.

MATERIALS AND METHODS

Pitfall sampling

Carabid beetles were collected by the widely used pitfall method which is the most significant method for qualitative and quantitative studies on ground fauna, and in particular of predatory species such as carabid beetles (*2*). Ten plastic traps were placed on the investigated site (polythene pots: 9 cm wide and 11 cm deep). More pitfall traps were distributed throughout the cultivated areas, than in areas with wild-growing vegetation. A dissolution of wine-vinegar, ethanol and water was used (1:1:1), which served as attractant and preservative. The traps were dug into the soil up to their rims and a styrofoam roof was placed above each trap to protect them from rainfall. Field investigations took place between May 1991 and October 1991. The samples were collected every two weeks. Determination of carabid beetles was carried out according to standard dichotomous keys (*23, 24*).

Data analyses

The dominance is presented in percentage shares of a particular species in community in accordance with (*25*) as follows: dominants (>5% of all species in community), subdominants (1–4.99%), recedents (0.5–0.99%) and subrecedents (0.01–0.49%).

Ecological characteristics of the species (Table 1) were taken from the literature (*2, 26, 27, 28, 29*). Classification was done with respect to: habitat preferences, associations with water bodies, reproduction period, wings development and flight ability. The threat status of Croatian carabid beetles was analyzed in accordance with the Red List (*30*). Zoogeographical distributions of species were classified according to the Biome Codes (*28*).

To calculate the diversity of the carabid assemblages, we used Simpson (1-λ') and Shannon-Wiener indices (H'). Evenness was estimated using Pielou's evenness. Analyses were carried out using the PRIMER program (*31, 32*).

Flora and vegetation

The nomenclature of plant species follows Flora Croatica Database [http://hirc.botanic.hr/fcd/]. The names of plant communities have been adjusted with Grabherr & Mucina (*33*) and Mucina *et al.* (*34*).

RESULTS

During the one year study, a total of 547 individuals belonging to 37 carabid species and 19 genera were caught (Table 1). The genera *Harpalus* Latreille, 1802 (6 species), *Bembidion* Latreille, 1802 (4 species), *Pterostichus* Bonelli, 1810 (4 species) and *Amara* Bonelli, 1810 (3 species) prevailed in terms of the number of species. The most abundant species was *Pterostichus niger* (21.2% of the total catch), followed by *Poecilus cupreus* (18.1%), *Harpalus rufipes* (7.1%), *Bembidion quadrimaculatum* (6.4%) and *B. properans* (5.5%). These five species comprised up to 58% of the total catch and belong to the group of dominant species. Subdominants were represented with 12 species, recedents with 7 species and subrecedents with 13 species. According to the Red List of Croatian carabid beetles (*30*), 3 species collected in the garden are classified as near threatened (NT) and 4 as least concern (LC). Three rare carabid species were captured: *Clivina collaris, Drypta dentata* and *Oodes helopioides*. The former two were recorded in low densities and belonged to the group of recedents species.

The diversity of fauna was relatively high: Simpson (1-λ') diversity index 0.9008, Shannon-Wiener index (H') 2.786 and Pielou's evenness 0.7715.

Analysis of habitat preferences (Table 1) showed the predominance of species inhabiting tall grasses or common reed (14 species) and open area species (13 species). Considering humidity requirements, hygrophilous species (17 species) prevailed over xerophilous (9 species) and mesophilous (7 species). Furthermore, 14 species found in the garden were species with a close affinity to bodies of stagnant water or slow streams, while a significant number of species area prefer open habitats that are associated with water bodies. The majority of species were spring breeders (28 species), whereas only 7 species were autumn breeders. With aspect to wing development and flight ability, most species (19 species) had fully developed wings and are active fliers. Also, 5 species (13.5%) had fully developed wings and could occasional fly. Some species such as *Carabus granulatus* and *C. violaceus* despite reduced or no wings still have good dispersal power.

According to the Biome Code (*28*), the majority of species are wide temperate species with a Eurasian distribution.

Annual cycles were only monitored for species belonging to the group of dominant species. Activity-density was expressed as the total number of beetles trapped on each sample day and plotted against time (Figure 2). The maximum seasonal activity for *P. cupreus* was observed at the end of June. During the summer, the number of individuals decreased, while there was a small increase in September. The maximum seasonal activity for *P. niger* and *H. rufipes* was observed at the end of August and in the beginning of September. *B. properans* showed a peak of activity in spring (April and June), with a sudden drop in abundance in May. Their abundance again declined after June. The maximum seasonal activity for *B. quadrimaculatum* was observed in July. *B. properans*

TABLE 1

Species captured between May and October 1991, in Konjščina (Hrvatsko Zagorje region, NW Croatia). Species ecological characteristics were taken according to (*2, 26, 27, 28, 29*). Explanation of special marks as follows. Habitat preferences: o-c – habitat shaded by grass or reeds, c-o – habitats shaded by some trees, o – open habitats, c – shaded habitats. Association with water bodies: • – associated, 0 – not associated, • – indifferent, – – no data. Ecological preferences: X–xerophilic species, M-mesophilic species, H-hygrophilic species, □ no data. Reproduction period: A – autumn breeder, Sp – spring breeder, – no data. Wing development /flight ability: + functional wings, +– reduced wings, – wingless, – does not fly, 0 – no data, + rarely flies, ++ flies. Biome Code – 1st number: 5-Boreo-temperate, 6-Wide temperate, 7-Temperate, 8-Southern temperate; 2nd number: 3-European, 4-Eurosiberian, 5-Eurasian, 6-Circumpolar (*28*). Croatian Red list status: NT – nearly threatened, LC – least concern (*30*). N – total number of species. % – percent share of total species.

Species name	Habitat prefrences	Assotiation with bodies of water	Ecological prefrences	Reproduc-tion period	Wing development/ flight abillity	Biome Code	IUCN threat category	N	%
Acupalpus meridianus Linné, 1761	o	o	M	Sp	+/++	66	LC	7	1,3%
Agonum duftschmidi J. Schmidt, 1994	o-c	•	H	Sp	–+/–	64		22	4,0%
Agonum viduum Panzer, 1796	o	•	H	Sp	+/+	75		2	0,4%
Amara aenea DeGeer, 1774	o-c	o	X	Sp	+/++	84		21	3,8%
Amara bifrons Gyllenhal, 1810	o	o	X	Sp	+/++	63		4	0,7%
Amara similata Gyllenhal, 1810	o-c	o	M	Sp	+/++	65		1	0,2%
Anchomenus dorsalis Pontoppidan, 1763	o	o	M	Sp	+/0	84		2	0,4%
Asaphidion flavipes Linné, 1758	o-c, c-o	•	H	Sp	+/++	63		12	2,2%
Bembidion inoptatum Schaum, 1857	o-c	–	H	Sp	0	83		4	0,7%
Bembidion lunulatum Geoffroy, 1785	o-c	•	H	A	+/++	54		2	0,4%
Bembidion properans Stephens, 1828	o	•	M	Sp	+–/+	65		30	5,5%
Bembidion quadrimaculatum Linné, 1761	o	□	M	Sp	+/++	65		35	6,4%
Carabus granulatus Linné, 1758	o-c,c-o,o,c	o	X	Sp	+–/–	65		11	2,0%
Carabus violaceus Sturm, 1815	c, c-o	o	M	A	–/–	65		1	0,2%
Chlaenius nigricornis Fabricius, 1787	o-c	•	H	Sp	+/++	64		2	0,4%
Chlaenius nitidulus Schrank, 1781	o	•	H	Sp	0	83		18	3,3%
Clivina collaris Herbst, 1784	o-c	•	H	Sp	+/++	56	LC	2	0,4%
Clivina fossor Linné, 1758	o-c	o	H	Sp	+/++	55		4	0,7%
Cylindera germanica Linné, 1758	o	o	X	A	+/+	65		2	0,4%
Drypta dentata P. Rossi, 1790	o	•	H	Sp	–+/0	64	NT	1	0,2%
Dyschirius aeneus Dejean, 1825	o-c	•	H	Sp	+/++	65		2	0,4%
Harpalus affinis Schrank, 1781	o	o	X	Sp	+/+	65		5	0,9%
Harpalus griseus Panzer, 1796	o	o	X	A	+/++	66		7	1,3%
Harpalus modestus Dejean, 1829	o-c	–	–	–	0	65	LC	4	0,7%
Harpalus rufipes DeGerr, 1774	o	o	X	A	+/++	65		39	7,1%
Harpalus sp.								3	0,6%
Harpalus tardus Panzer, 1796	o-c, c-o	o	X	Sp	+/++	65		2	0,4%
Loricera pilicornis Fabricius, 1775	c-o	•	H	Sp	+/++	56	LC	2	0,4%
Oodes helopioides Fabricius, 1792	o-c	•	H	Sp	+/+	66	NT	7	1,3%
Panagaeus cruxmajor Linné, 1758	o-c	•	H	Sp	+/++	66	NT	1	0,2%
Poecilus cupreus Linné, 1758	o-c	o	H	Sp	+/++	65		99	18,1%
Poecilus versicolor Sturm, 1824	o	o	–	Sp	0	75		20	3,7%
Pterostichus niger Schaller, 1783	c,o	o	M	A	+/+	65		116	21,2%
Pterostichus ovoideus Sturm, 1824	o-c	o	–	Sp	0	64		26	4,8%
Pterostichus quadrifoveolatus Letzner, 1852	c-o,o	o	X	A	+/++	65		15	2,7%
Pterostichus vernalis Sturm, 1824	o-c, c-o	•	H	Sp	+–/+	65		3	0,6%
Stenolophus teutonus Schrank, 1781	o-c, c-o	o	H	Sp	+/++	66		13	2,4%

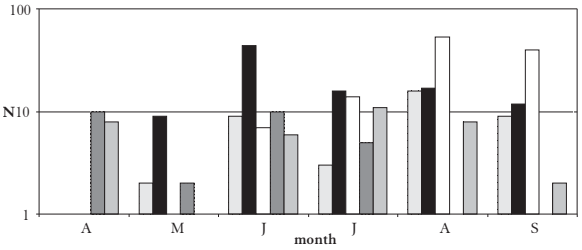

Figure 2. *Seasonal activity of* Poecilus cupreus *Linné, 1758 (■),* Pterostichus niger *Schaller, 1783 (□),* Harpalus rufipes *DeGeer, 1774 (▫),* Bembidion properans *Stephens, 1828 (▪) and* B. quadrimaculatum *Linné, 1761 (▫) in a traditional garden in Konjščina, Hrvatsko Zagorje region from total pitfall captures from May to October 1991. Values are shown according to logarithmic scale.*

and *B. quadrimaculatum* were abundant in April, absent in May and again appear in June, July and August.

DISCUSSION

Carabid species diversity and abundance in a traditional family garden in Konjščina were strongly determined by the diversity of habitats found in a relatively small surface area, and especially by the proximity to a small marshland. Many factors, such as abiotic factors (e.g. temperature, soil moisture, vegetation cover, pH and soil characteristics) (*35*), crop type (*11*), pesticide application (*36*), type of management (*37*) and adjacent habitats (*11*) will determine and influence the carabid beetle diversity and abundance in a different agricultural areas. Therefore, a mosaic of habitats, differences in shade, differences in soil moisture levels and levels of human disturbance have allowed for various carabid species with different ecological preferences to inhabit the area.

The carabid species richness is comparable to those found in south Bohemian villages (38 species) (*38*); to unmulched potato plots in a home garden in the USA (31 species) (*39*), and to single fields investigated during the growing season (around 20 to 40 species) (*11*). According to Duelli (*40*) a small scaled mosaic of different crops is likely to be optimal for carabid diversity at the agricultural landscape level. The close proximity to a small marshland had a considerable influence on the carabid beetle assemblage in the garden. The carabid beetle fauna mainly consisted of widely distributed hygrophilous species associated with water bodies. Furthermore, the majority of species had well developed wings and flight ability. This allows them to escape to safer regions during periods of land cultivation, and to return to these habitats once work on the land is complete. Moreover, species of the genus *Carabus* are highly mobile with a large radius of movement. We can see how the carabid beetle fauna in the garden is comprised of species that can quickly react to environmental changes. Diverse habitats, especially grassland and wetland vegetation, may act as field margins and provided the specific microhabitat requirements for certain species. Field margins are not only crucial as over-wintering sites and as a breeding ground, but also harbour quite a number of additional species (*41*).

It is known that any soil disturbance affect species assemblage, their phenology and behaviour (*41*). Considering that the soil in the cultivated part of the garden was subjected to human-caused disturbance on multiple occasions, and therefore we consider that most species found here are in transit. The conditions for reproduction are likely not sufficiently suitable in the cultivated part of the garden for their survival, as seen by the large number of recedent and subrecedent species. In the adult phase, these species can easily find food and shelter, though in the larval phase, they are highly sensitive to being buried, and avoid such habitats. They often use marginal habitats from where they can repopulate the surrounding areas (*42*). The presence of mainly spring breeders in the garden may be a consequence of the cultivation methods. In fields with root crops, the soil structure is radically disrupted by hoeing in spring, when the spring breeders are present as adults, whereas the autumn breeders are represented by growing larvae and pupae. According to Heydeman (*43*), the larvae are less affected by soil tillage than adults. In contrast, Tischler (*44*) stated that adults were more vulnerable to ploughing, and recent studies published by Holland & Luff (*41*) supported both theories.

Carabid body size is an indicator of habitat disturbance (*45, 46*) and, accordingly, more disturbed habitats have a carabid fauna with a smaller average body size. Furthermore, small carabid beetles were found to be dominant in the village of southern Czech Republic (*38*). In contrast, three medium-sized and two small carabid beetle species were dominant in the family garden. Therefore, it can be concluded that the human impacts in the studied family garden are substantially less than in large agricultural areas. The medium-sized beetles, particularly *H. rufipes* which prefers open warm conditions (*47*), are commonly found in gardens, parks, arable fields, urban areas and in landfills, and are not sensitive to human caused disturbance (*2, 26*).

According to Thiele (*2*) and Luff (*47*), the basic dominant agricultural carabid fauna is rather uniform across Europe. It is comprised of widely distributed, eurytopic carabid species, many of which have high tolerance to disturbances and chemical pollution. The dominant species in a garden are commonly found in northwest and central east European agricultural fields (*2, 47*). *P. niger* is typical for damp, often shaded habitats and for deciduous forest in central Europe (*26*). Holopainen *et al.* (*48*) found this species among the three most common species in spring cereal fields in Finland. *P. niger* in northern Europe, has its activity peak in June or July (*26, 27, 49, 50*), though in our garden, peak activity was recorded in August or early September. *P. cupreus* and *H. rufipes* are among the most abundant species in central and Eastern Europe agricultural fields (*47*). The seasonal dynamics of these two species is comparable to seasonal dynamics in northern Europe (*26, 49*). However, the activity peaks in our investigation were about one month later, likely

due to the processing method. The seasonal dynamics of *B. properans* and *B. qudrimaculatum* is similar to that in northern Europe, though the activity peak was recorded one month later (*50*). In this study, a sudden decline in the abundance of both species was recorded in May, likely due to soil cultivation at that time. *Bembidion* species tend to be most active in crops with little shade and some bare ground, and the conditions in the garden were therefore suitable.

Carabid beetles and their larvae are mostly carnivorous, and some genera feed on plants (e.g. *Harpalus, Zabrus, Amara*). Although some carabids, such as *H. rufipes,* may destroy some culture like strawberries, the majority of carabid beetles are extremely beneficial and important predators which help in the natural control of many garden and crop pests (*2*).

The current study showed that both species with a wide ecological niche and those that are highly specialized and rare (such as *O. helopiodes* or *D. dentata*) live in villages, which are endangered by the nearby agricultural landscape. This is confirmed by the results of Boháč & Fuchs (*38*). Furthermore, seven threatened species included on the Croatian Red List of carabid beetles (*30*) were recorded in a relatively small area in the garden. The traditionally managed family gardens are disappearing in Croatia due to changes in the lifestyle of the population. Therefore, the preservation of traditional family gardens will play an important role in preserving biodiversity on a small local scale.

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REFERENCES

1. LÖVEI G L, SUNDERLAND K D 1996 Ecology and behavior of ground beetles (Coleoptera: Carabidae). *Annu Rev Entomol 41:* 231–256
2. THIELE H U 1977 Carabid Beetles in their Environments. A Study on Habitat Selection by Adaptation in Physiology and Behavior. Zoophysiology and Ecology 10. Springer Verlag, Berlin, p 369
3. MAELFAIT J P, DESENDER K 1990 Possibilities of Short-term Carabid Sampling for Site Assessment Studies. *In*: Stork N E (*ed*) The role of Ground Beetles in Ecological and Environmental Studies. Intercept, Andower, p 217–225
4. EVERSHAM B C, ROY D B, TELFER M G 1996 Urban, industrial and other manmade sites as analogues of natural habitats for Carabidae. *Ann Zool Fenn 33:* 149–156
5. SANDERSON R A 1994 Carabidae and cereals: a multivariate approach. *In:* Desender K, Dufrêne M, Loreau M, Luff M L, Maelfait J-P (*eds*) Carabid Beetles Ecology and Evolution. Kluwer Academic Publishers, Dordrecht, p 457–465
6. CARMONA D M, LANDIS D A 1999 Influence of refuge habitats and cover crops on seasonal activity-density of ground beetles (Coleoptera: Carabidae) in field crops. *Environ Entomol 28(6):* 1145–1153
7. COLE L J, MCCRACKEN D I, DOWNIE I S, DENNIS P, FOSTER G N, WATERHOUSE T, MURPHY K J, GRIFFIN A L, KENNED M P 2005 Comparing the effects of farming practices on ground beetle (Coleoptera: Carabidae) and spider (Araneae) assemblages of Scottish farmland. *Biodiversity Conserv 14:* 441–460
8. NIEMELÄ J K, KOTZE D J 2000 GLOBENET: the search for common arthropogenic impacts on biodiversity using carabids. *In*: Brandmayr P, Lövei G L, Zetto Brandmayr T, Casale A, Vigna Taglianti A (*eds*) Natural history and applied ecology of carabid beetles. Pensoft, Sofia-Moscow, p 241–247
9. SCWERK A 2000 Ecological aspects of carabid beetle coenoses (Coleoptera: Carabidae) on industrial fallow grounds in the Ruhr Valley Area. *In*: Brandmayr P, Lövei G L, Zetto Brandmayr T, Casale A, Vigna Taglianti A (*eds*) Natural history and applied ecology of carabid beetles. Pensoft, Sofia-Moscow, p 277–289
10. KOIVULA M J, KOTZE D J 2003 Carabid beetles in median strips of three highways around the city of Helsinki, Finland. *In*: Lövei G L, Toff S (*eds*) DIAS report-Proceedings of the 11th Europaean Carabidologists Meeting, Århus, p 151–163
11. BOOIJ K 1994 Diversity in carabid assemblages in relation to crops and farming systems. *In*: Desender K, Dufrêne M, Loreau M, Luff M L, Maelfait J-P (*eds*) Carabid Beetles Ecology and Evolution. Kluwer Academic Publishers, Dordrecht, p 425–431
12. TRITTELVITZ W, TOPP W 1980 Verteilung und Ausbreitung der epigaeischen Arthropoden in der Agrarlandschaft, I Carabidae. *Anz Schädlingskd Pfl Umwelt 53:* 17–20
13. KEGEL B 1991 Frieland und Laboruntersuchungen zur Wirkung von Herbiziden auf Epigäischen Arthropoden, insbesondere der Laufkäfer (Col: Carabidae). PhD thesis. University of Berlin.
14. RIVARD I 1966 Ground beetles (Coleoptera: Carabidae) in relation to agricultural crops. *Can Entomol 98:* 189–195
15. DUELLI P, STUDER M, MARCHAND I 1989 The influence of the surroundings on arthropod diversity in maize fields. *Acta Phytopathol et Entomol Hung 24:* 73–76
16. ALLEN R T 1979 The occurence and importance of ground beetles in agriculture and surrounding habitats. *In*: Erwin T L, Ball G E, Whitehead D R (*eds*) Carabid beetles, their evolution, natural history and classification. Junk Publishers, The Hague, p 485–505
17. GASTON K J, SMITH R M, THOMPSON K, WARREN P H 2005 Urban domestic gardens (II): experimental tests of methods for increasing biodiversity. *Biodiversity Conserv 14:* 395–413
18. SMITH R M, GASTON K J, WARREN P H, THOMPSON K 2006 Urban domestic gardens (VIII): environmental correlates of invertebrate abundance. *Biodiversity Conserv 15:* 2515–2545
19. ŽIDOVEC V, VRŠEK I, ANIČIĆ B, GRZUNOV S 2006 Tradicijski seoski vrtovi sjeverozapadne Hrvatske/ Traditional rural gardens in north-west part of Croatia. *Sjemenarstvo 23 (3):* 273–283
20. BREGOVIĆ A 1985 Zbirka karabida Entomološkg odjela Gradskog muzeja Varaždin. *GGMV (Varaždin) 7:* 221–248
21. RUCNER Z 1994 Beittrag zur Entomofauna einiger Waldassoziationen Kroatiens. *Natura Croatica 3:* 1–22
22. STANČIĆ Z 1992 The insects fauna of a traditional garden in the Hrvatsko Zagorje region. Degree thesis. Faculty of Science, University of Zagreb, Zagreb, p 99
23. TRAUTNER J, GEIGENMÜLLER K 1987 Tiger Beetles and Ground Beetles, Illustrated Key to the Cicindelidae and Carabidae of Europe. Margraf Publishers, Aichtal, p 487
24. FREUDE H, HARDE K-W, LOHSE G A, KLAUSNITZER B 2006 Die Käfer Mitteleuropas. II Band. Adephaga 1. Elsevier GmbH, München, p 521
25. TIETZE F 1973 Zur Oekologie, Sociologie und Phänologie der Laufkäfer (Coleoptera, Carabidae) des Grünlandes im Süden der DDR II, Hercynia N F 10, p 111–126
26. LINDROTH C H 1992 Ground beetles (Carabidae) of Fennoscandia, a zoogeographic study, Part I. Intercept, Andover, UK, p 630
27. WACHMANN E, PLATEN R, BRANDT D 1995 Laufkäfer – Beobachtung, Lebenweise, Naturbuch Verlag, Augsburg, p 295
28. ANDERSON R, McFERRAN D, CAMERON A 2000 The Ground Beetles of Northern Ireland. Ulster Museum, Dublin, p 256
29. LUFF M L 2007 The Carabidae (ground beetles) of Britain and Ireland. Handbooks for the Identification of British Insects. Royal Entomological Society, St. Albans p 247
30. VUJČIĆ-KARLO S, BRIGIĆ A, ŠERIĆ-JELASKA L, KOKAN B, HRAŠOVEC B 2007 Crveni popis trčaka (Coleoptera: Carabidae) Hrvatske. On line.
31. CLARKE K R, WARWICK R M 2001 Change in marine communities: an approach to statistical analysis and interpretation, ed. 2. PRIMER-E, Plymouth.
32. CLARKE K R, GORLEY R N 2001 PRIMER v5: User Manual/Tutorial. PRIMER-E, Plymouth, p 91
33. GRABHERR G, MUCINA L (*eds*) 1993 Die Pflanzengesellschaften Österreichs. Teil II. Natürliche Waldfreie Vegetation. Gustav Fischer Verlag, Jena-Stuttgart-New York, p 523

34. MUCINA L, GRABHERR G, ELLMAUER T (*eds*) 1993 Die Pflanzengesellschaften Österreichs Teil l. Anthropogene Vegetation. Gustav Fischer Verlag, Jena-Stuttgart-New York, p 578

35. HOLLAND J M 2002 Carabid Beetles: Their Ecology, Survival and Use in Agroecosystems. *In*: Holland J M (*ed*) The Agroecology of Carabid Beetles. Intercept, Andover, p 1–40

36. HANCE T 2002 Impact of cultivation and crop husbandry practices. *In:* Holland J M (*ed*) The Agroecology of Carabid Beetles. Intercept, Andover, p 231–250

37. CÁRCAMO H A, NIEMELÄ J K, SPENCE J R 1995 Farming and ground beetles: Effects of agronomic practice on populations and community structure. *Can Entomol 127*: 123–140

38. BOHÁČ J, FUCHS R 1994 Carabidae and Staphylinidae of Bohemian villages. *In*: Desender K, Dufrêne M, Loreau M, Luff M L, Maelfait J-P (*eds*) Carabid Beetles Ecology and Evolution. Kluwer Academic Publishers, Dordrecht, p 235–240

39. WIEDENMANN R N, DIAZ R R, SADOF C S, O'NEIL R J 2004 Ground beetle (Coleoptera: Carabidae) assemblages in mulched and non-mulched garden plots. *Jour Kans Entomol Soc 77(2):* 99–109

40. DUELLI P 1990 Population movements of arthropods between natural areas. *Biol Conserv 54:* 193–207

41. HOLLAND J M, LUFF M L 2000 The effects of agricultural practices on Carabidae in temperate agroecosystems. *IPM 5:* 109–129

42. BOIVIN G, HANCE TH 1994 Phenology and distribution of carabid beetles (Coleoptera: Carabidae) in muck-grown carrots in southwestern Québeck. *In:* Desender K, Dufrêne M, Loreau M, Luff ML, Maelfait J-P *(eds*) Carabid Beetles Ecology and Evolution. Kluwer Academic Publishers, Dordrecht, p 417–422

43. HEYDEMAN B 1955 Carabiden der Kulturfelder als ökologische Indikatoren. Ber. 7. Wanderversamm. *Deut Entomol* 7: 172–185

44. TISCHLER W 1955 Effects of agricultural practice on the soil fauna. *In:* Kevan D K M (*ed*) Soil Zoology. London, Butterworth, p 215–230

45. SUSTEK Z 1987 Changes in body size structure of carabid communities (Coleoptera: Carabidae) along an urbanisation gradient. *Biologia 42:* 145–56

46. BLAKE S, FOSTER G N, EYRE M D, LUFF M L 1994 Effects of habitat type and grassland management practices on the body size distribution of carabid beetles. *Pedobiologia 38:* 502–12

47. LUFF M L 2002 Carabid assemblage organization and species composition. *In:* Holland J M (*ed*) The Agroecology of Carabid Beetles. Intercept, Andover, p 41–80

48. HOLOPAINEN J K, BERGMAN T, HAUTALA E-L, OKSANEN J 1995 The ground beetle fauna (Coleoptera: Carabidae) in relation to soil properties and foliar fluoride content in spring cereals. *Pedobiologia 39:* 193–206

49. TURIN H, HAECK J, HENGEVELD R 1977 Atlas of the carabid beetles of the Netherlands. North-Holland Publishing Company, Amsterdam, p 228

50. TUOVINEN T, KIKAS A, TOLONEN T, KIVIJÄRVI P 2006 Organic mulches vs. black plastic in organic strawberry: does it make a difference for ground beetles (Col., Carabidae)? *J Appl Entomol 130 (9–10):* 495–503