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

Abstract

Background and Purpose: The carabid beetle fauna was studied in a traditional family garden in Konjičina (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, Drypetta dentata and Oodes helenoides. 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 Konjičina 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 m² 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., Anthemis graveolens L., Apium graveolens L., Armoracia rusticana P. Gaertn., B. Mey. et Scherb., Arte-
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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, Dryptera dentata and Oodes helioptoides. 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


<table>
<thead>
<tr>
<th>Species name</th>
<th>Habitat preferences</th>
<th>Association with bodies of water</th>
<th>Ecological preferences</th>
<th>Reproduction period</th>
<th>Wing development / flight ability</th>
<th>Biome Code</th>
<th>IUCN threat</th>
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<td>M</td>
<td>Sp</td>
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<td>LC</td>
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<td>•</td>
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<td>18</td>
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<td>o</td>
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<td>Sp</td>
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<td>4</td>
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<tr>
<td>Cylindera germanica Linné, 1758</td>
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<td>X</td>
<td>A</td>
<td>+/-</td>
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<td>•</td>
<td>H</td>
<td>Sp</td>
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<td>A</td>
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<td>–</td>
<td>0 / 65</td>
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<td>X</td>
<td>A</td>
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<td>Sp</td>
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<td>H</td>
<td>Sp</td>
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<td>A</td>
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<td>116</td>
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<td>H</td>
<td>Sp</td>
<td>+/- /65</td>
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<td>Sp</td>
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<td>13</td>
<td>2,4%</td>
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Carabid beetles in a traditional garden

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 Konjišćina, 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 Konjišćina 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 recendent and subrecent 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 (42), 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 these 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. quadrimaculatum 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 majorit 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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