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ABUNDANCE AND DISTRIBUTION OF THE GROUND BEETLES *Pterostichus melanarius* (Illiger, 1798) AND *Pseudoophonus rufipes* (De Geer, 1774) IN CORN FIELDS IN CROATIA

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Ground beetles (Coleoptera, Carabidae) have often been used to study the ecological effects of different agricultural measures. The present study was conducted in 2004 and 2005 on 22 corn fields located in the central and east parts of Croatia. The ground beetle fauna was studied during the whole growing season by placing 3 pitfall traps in each of the 9 corn fields in 2004 and the 13 corn fields in 2005. For each field agricultural practices were recorded. Traps were checked, every two weeks. All ground beetles were identified to species level. *Pterostichus melanarius* (IIIiger, 1798) and *Pseudoophonus rufipes* (De Geer, 1774), two common species in crop fields, were analysed to determine species distribution and abundance. In 2004, 3322 Carabidae belonging to 16 different ground beetle species were identified . In 2005, 1061 specimens belonging to 24 species were collected. *P. melanarius* was found in 7 out of 8 localities in 2004 and in all 13 localities in 2005. The dominance of this species varied from 7.69% to 36% in 2004 and from 5% to 95% in 2005. This species was designated as dominant at 2 localities in 2004 and 2 localities in 2005 while at all other localities it was designated as eudominant. *P. rufipes* has been found in 7 localities in 2004 and in 12 localities in 2005. The dominance of this species varied from 47% to 73% in 2004 and from 1.56% to 74.45% in 2005. This species was designated as eudominant at all localities in 2004 and in 11 localities in 2005 while at one locality in 2005 it was designated as subdominant. *P. melanarius* was a constant species in both years with a frequency index of 71.8% in 2004 and 66% in 2005, respectively. *P. rufipes* was a constant species in 2004 with a frequency index of 71.8% and an accessory species in 2005 with a frequency index of 44%. The impact of climatic conditions (temperatures and rainfall), agricultural practices (previous crop) and field maintenance (insecticide application and use of manure) on individual numbers of collected ground beetles is discussed.

Ground beetles, abundance, distribution, *Pterostichus melanarius*, *Pseudoophonus rufipes*, Croatia, corn fields, agricultural practice

R. BAŽOK, T. KOS, J. IGRC BARČIĆ, V. KOLAK, B. LAZAREVIĆ, A. ĆATIĆ, Gustoća populacije i rasprostranjenost trčaka *Pterostichus melanarius* (Illiger, 1798) i *Pseudoophonus rufipes* (De Geer, 1774) u kukuruzištima Hrvatske: Entomol. Croat. 2007, Vol. 11. Num. 1-2:39-51.

Istraživanja vezana na trčke (Coleoptera, Carabidae) često se provode radi utvrđivanja ekoloških učinaka različitih agrotehničkih mjera. Godine 2004. i 2005. na 22 lokaliteta smještena u središnjem i istočnom dijelu Hrvatske obavljena su istraživanja vezana na porodicu trčaka. U svako od 9 polja kukuruza u 2004. i 13 polja u 2005. postavljene su tri lovne posude. Posude su postavljene tijekom svibnja, pražnjene su svaka dva tjedna, a istraživanje je trajalo do kraja vegetacijske sezone. Svi uhvaćeni primjerci iz porodice Carabidae determinirani su do vrste. Ukupan broj determiniranih vrsta, broj svih jedinki te broj jedinki *Pterostichus melanarius* i *Pseudoophonus rufipes* bili su osnova za utvrđivanje dominantnosti i učestalosti tih dviju vrsta. Ukupno je u 2004. utvrđeno 3322 primjeraka, pripadnika 16 različitih vrsta trčaka. U 2005. utvrđen je 1061 primjerak iz 24 vrste. Vrsta *P. melanarius* nađena je na sedam lokaliteta u 2004. i na svih 13 lokaliteta u 2005. Dominantnost ove vrste kretala se od 7,69 % do 36 % u 2004., te od 5 % do 95 % u 2005. godini, te je označena kao dominantna na dva lokaliteta u 2004. i na dva lokaliteta u 2005., a na ostalim je lokalitetima eudominantna. *P. rufipes* nađen je na sedam lokaliteta u 2004. i na 12 lokaliteta u 2005. godini. Dominantnost se kretala od 47 % do 73 % u 2004., te od 1,53 % do 74,45 % u 2005. godini. Na svim lokalitetima u 2004. i na 11 lokaliteta u 2005. bila je eudominantna, a na jednom je lokalitetu u 2005. bila subdominantna. Vrsta *P. melanarius* konstantna je u obje godine s indeksom frekvencije od 71,8 % u 2004. i 66 % u 2005. godini. *P. rufipes* bio je konstantan u 2004. s indeksom frekvencije od 71,8 % i akcesoran u 2005. s indeksom frekvencije od 44 %. Zabilježen je utjecaj klimatskih uvjeta (temperatura i padalina) te agronomske prakse (predusjev, primjena insekticida i korištenje organskih gnojiva) na broj prikupljenih trčaka.

Trčci, gustoća populacije, distribucija, *Pterostichus melanarius*, *Pseudoophonus rufipes*, Hrvatska, kukuruz, agronomska praksa

Introduction

Ground beetles can be and are often used as indicator organisms for assessment of environmental pollution and habitat classification for nature protection. Most of the species which belong to this family are well known as natural enemi-

es of insect pests living in the soil (Lövei & Sunderland, 1996). Ground beetles are important both as natural enemies and as food items for animals feeding at a higher trophic level.

Ground beetles have been often used to study the ecological effects of different agricultural measures, because they are very abundant in arable crops and seem to be highly sensitive to habitat change, and because this species-rich family is taxonomically well known (Lovei & Sunderland, 1996; Rainio & Niemelä, 2003). Numerous papers have reported on the impact of different climatic and agronomic conditions on ground beetle communities.

Pterostichus melanarius (Illiger, 1798) and *Pseudoophonus rufipes* (DeGeer, 1774) are widespread in Europe and North America. They are specific to harvested areas in Europe and North America (De Boer, 1987 cit. Holland, 2002). According to Luff (2002), *P. melanarius* is one of the commonest agricultural carabids in both, Europe and North America, where it was introduced. In Europe, *P. melanarius* can dominate the carabid assemblage to excess. When it is very numerous, the diversity of other (smaller) species appears to decline, possibly because they are also preyed on by *P. melanarius,* or because they lose out in the competition for prey. *P. rufipes* (often treated as species *Harpalus rufipes* DeGeer 1812) is the predominant species among all the species of the genus *Harpalus* in the whole of Europe and North America (Luff, 2002).

P. melanarius is predatory in all stages. It is known as a species with an extreme dietary width. Polet & Desender (1985 and 1986 cit. Toft & Bilde, 2002) recorded 49 prey taxa at family level, including slugs, earthworms and a wide selection of insects. Species of the genus *Harpalus,* including *Pseudophonus,* are predominantly seed eaters (or granivores) (Toft & Bilde, 2002). *P. rufipes* larvae were able to complete the full development on seeds alone as well as on a pure insect diet (Luff, 1980 cit. Toft & Bilde, 2002). *P. rufipes* adults are granivores.

Both species over-winter as larvae. *P. melanarius* is a summer-autumn breeding species and partially biennial at the northern limits of its range (Luff, 2002). *P. rufipes* breeds primarily in the late summer and is flexible in its phenology; it may switch from annual life cycles in the south to being partially or wholly biennial in the north (Luff, 2002).

P. melanarius is a eurytopic organism. It prefers high humidity and dark (Holland, 2002). This species prefers agricultural areas (Desender & Alderweireldt, 1988 cit. Fournier & Loreau, 2002). It occurs in all types of soils, and in grasslan-

ds as well as arable habitats (Luff, 2002). *P. rufipes* prefers warm and dry habitats and high temperatures and avoids nocturnal activity (Kegel, 1990 cit. Holland, 2002). It is commonest on light soils with open, warm conditions.

P. melanarius is seldom capable of flight; most individuals are brachypterous (Luff, 2002). Both species are classified after Den Boer (1977 cit. Holland 2002) as T-species, species with a greater dispersal ability and better adapted to living in unstable or temporary habitats. Both species may escape the impacts of autumn farming practices by burying themselves deeply when hibernating. They have been found at 45 cm or more below the soil surface (Briggs, 1965 cit. Holland 2002).

Tréfás and van Lentern (2004) reported a higher number of eggs laid by *P. melanarius* in barley than in Brussels sprouts. These results were supported by a significant preference for moist, shady, structurally complex environments as egg laying sites. The same authors indicate that vegetation characteristics in themselves may influence egg laying site preferences, apart from the availability of prey for the adults and larvae in the different plant systems.

According to the research conducted by Lövei (1984) corn monoculture is more favorable to beetle communities than a crop rotation system. The use of insecticides reduces the population of ground beetles (Hence, 2002). According to Hence (2002) the content of organic matter in soil has no effect on ground beetle populations.

Durbešić et al. (2006) conducted an investigation in order to establish which species dominate meadows as refuge areas located between agrarian surfaces. The individual number of *P. rufipes* was almost fifty times higher than the number of *P. melanarius*.

The fauna of ground beetles in Croatia was surveyed in leguminous fields (Kovačević & Balarin, 1960), in wheat fields (Sekulić et al., 1973), meadows (Durbešić, 1987; Durbešić et al., 2006) and in forest ecosystems (Durbešić, 1982; Vujčić-Karlo, 1999). There is a lack of investigations into ground beetles in agricultural land in Croatia. The first investigation of ground beetle fauna in corn fields started in 2003 (Kos et al., 2006). The results indicated that the most common species in corn fields in Croatia are *P. melanarius* and *P. rufipes* .

Because *P. melanarius* and *P. rufipes* were established as the most common species, this research was conducted in order to establish the abundance and frequency of *P. melanarius* and *H. rufipes* in the total fauna of ground beetles in

corn fields in Croatia, and the possible impact of the agricultural practices used on the distribution and abundance of these two species.

Material and methods

During two years (2004-2005), the fauna of ground beetle species was investigated in 22 corn fields. Nine corn fields in 2004 and 13 corn fields in 2005 were observed (Figure 1).

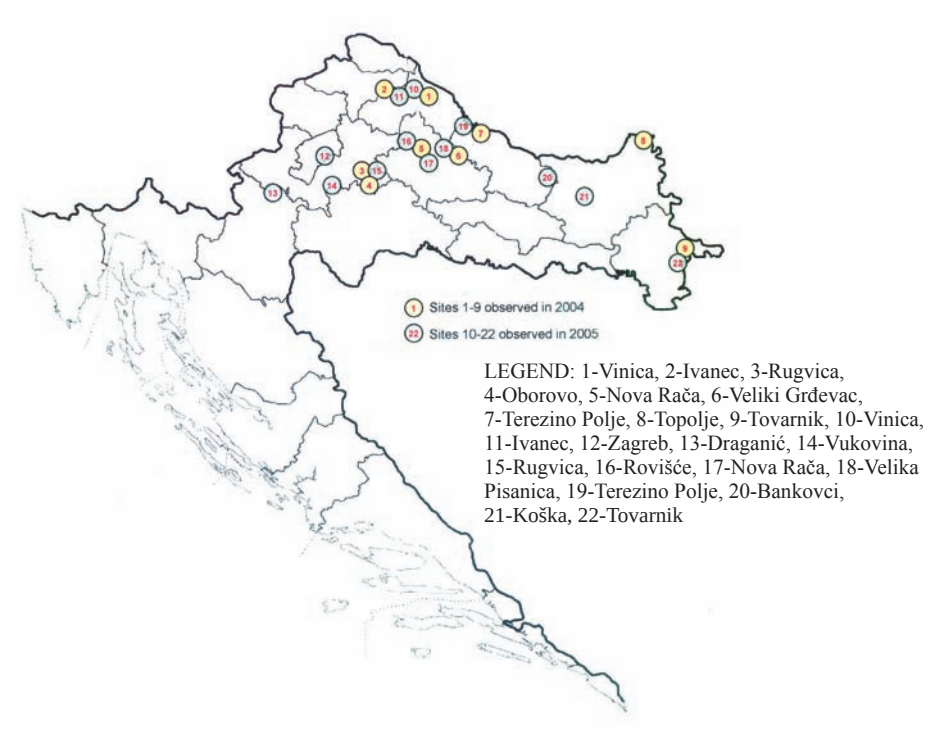

Figure 1. Distribution of the observed corn fields.

The fauna was investigated with the use of pitfall traps. These pitfall traps were modified Barber traps, Barber (1931) cit. Durbešić (1982). Traps were buried in the soil to the top edge (the diameter of the trap was 70 mm, and it was 150 mm deep). Traps were 500 cm^3 filled with water. A few drops of detergent

were put in the traps to reduce surface tension. Apart from detergent the traps contained no chemicals. Over each trap a 100 mm-high plastic roof was placed. In each field 3 pitfall traps were set up 25 m from the edge of the field. The distance between the pitfall traps was 10 m. Pitfall traps were set up at the beginning of the corn season (which, depending on the field, was between May 10 and May 31 in 2004 and between May 4 and May 27 in 2005). Traps were checked every two weeks until the end of August. All ground beetles were identified to species level. For identifying ground beetle species the following keys were used: Auber, 1965; Bechyne, 1974; Harde & Severa, 1984;

Based on the total individual number of all species of the Carabidae family and the individual number of *P. melanarius* and *P. rufipes,* the dominance and frequency of the two species were calculated for each field.

The dominance was calculated with Balogh's formula (cit. Balarin, 1974)

$$D_l = \frac{a_l}{\Sigma a_i} \text{ x } 100 \qquad (1)$$

where:

a_l = number of identified specimens of one species;

Σa_i = total number of all ground beetle specimens;

The results (eudominant, dominant, subdominant, recent, subrecent) were classified according to Tischler and Heydeman (cit. Balarin, 1974)

The frequency was calculated with Balogh's formula: (cit. Balarin, 1974)

$$C_{a_l} = \frac{U_{a_l}}{\Sigma U_i} \text{ x } 100 \qquad (2)$$

where:

U_{a_l} = number of samples with identified species

ΣU_i = total number of samples

The results (euconstant, constant, accessory, accidental) were classified according to Tischler. (cit. Balarin, 1974).

Climatic conditions about soil temperature, air temperature, and rainfall were taken from official data of the Meteorological and Hydrological Service in Zagreb. The data for each field were taken from the nearest meteorological station. These were the stations Zagreb, Virovitica (Bikana), Osijek, Našice and Gradište.

For each field soil humidity, previous crop, tillage type, manure and insecticide use were recorded.

Results

The climatic conditions in two years were characterized with higher humidity and lower temperatures respectively to the average data of the same time period. The humidity was much higher in 2005. Two fields (N° 10 and 15) were partially flooded for a short period by rain. The previous crop, at 20 out of 22 localities, was corn while at 2 localities (N° 2 and 5) clover and grass mixtures had been sown. At all localities deep autumn plowing was done. At 20 localities only chemical fertilizers were used and at 2 localities (N° 17 and 20) manure was used too. At 2 localities (N° 7 and 11) there were broad applications of soil insecticides, and at 1 locality (N° 19) soil insecticide was applied as seed dressing.

In 2004, a total of 3322 specimens belonging to 16 different ground beetle species were identified. In 2005, the total number of collected beetles was 1061, belonging to 24 ground beetle species. The total number of individuals in the surveyed localities is shown in Figure 2.

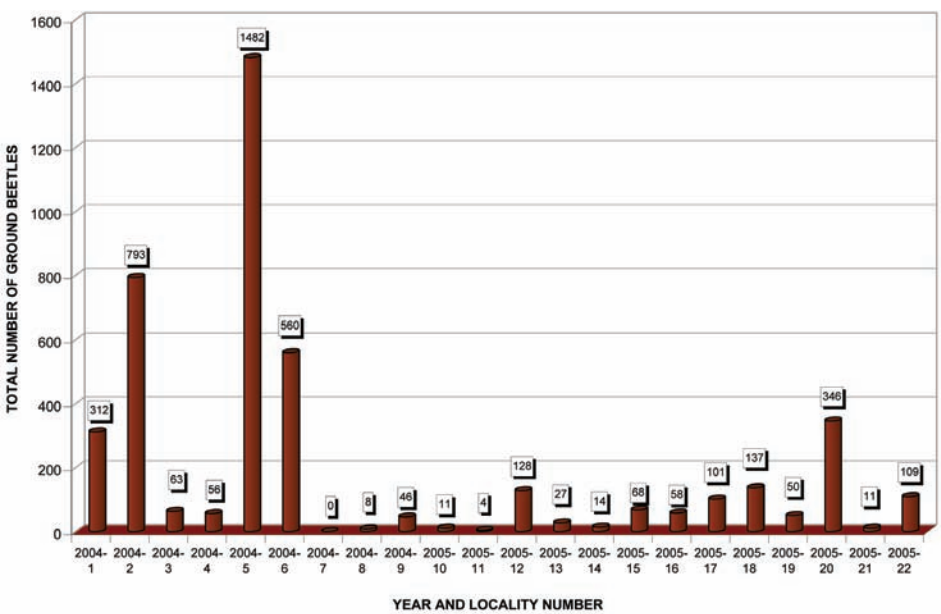

Figure 2. Total number of ground beetles caught in 2004 and 2005.

The number of ground beetle specimens collected for each locality ranged between 0 and 1482 in 2004 and between 4 and 346 in 2005 (Figure 1). On the fields on localities 2 and 5 (previous crop: clover and grass mixture), 793 and 1482 ground beetle specimens were found, respectively. Insecticides, especially broad applications of soil insecticides, strongly reduced the number of ground beetles in corn fields at localities 7 and 11, where 0 and 4 beetles were found, respectively. Seed dressing with insecticides slightly reduced the number of ground beetles (locality 19).

Figures 3 and 4 show the dominance of *P. melanarius* and *P. rufipes* in each of the observed fields.

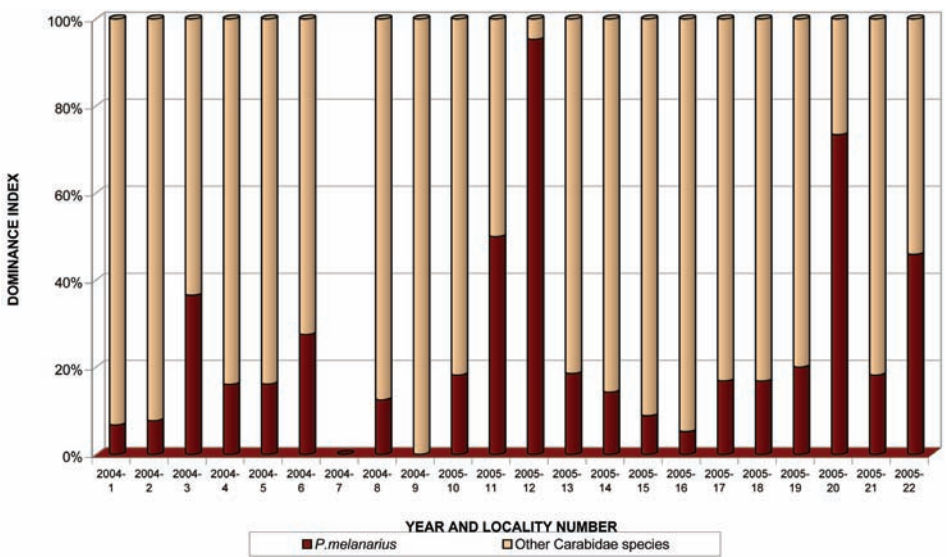

Figure 3. Dominance of *P. melanarius* in corn fields in Croatia, 2004 and 2005.

The majority of ground beetles belonged to two main species, *P. melanarius* and *P. rufipes*.

Both species could be described as constant or accessory at all the investigated localities. *P. melanarius* was found in 7 out of 8 localities in 2004 (in one locality no ground beetles were found) and in all 13 localities in 2005. The dominance of this species (Figure 3) varied from 7.69% to 36% in 2004 and from 5%

to 95% in 2005. At 2 localities in 2004 and at 2 localities in 2005 this species was classified as dominant while at all other localities it was eudominant.

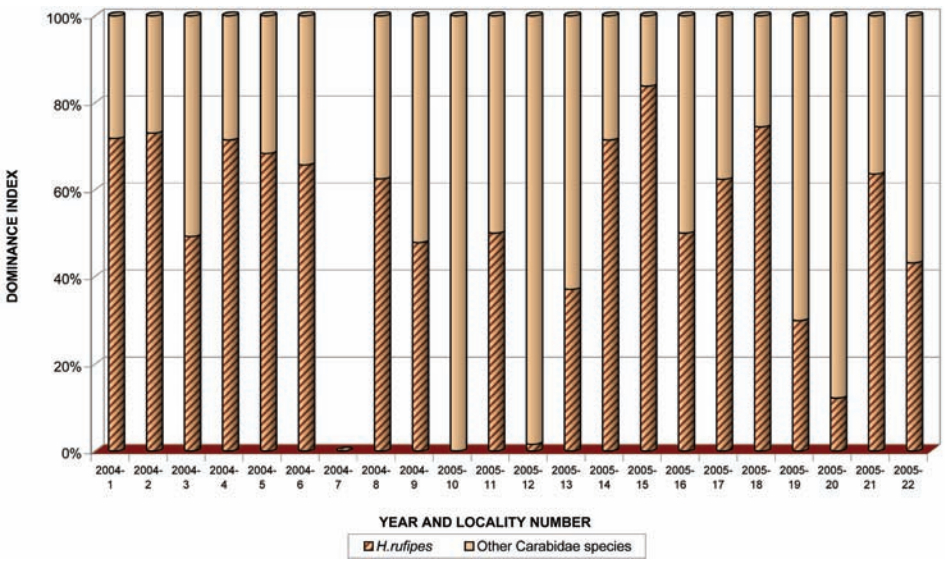

Figure 4. Dominance of *H. rufipes* in corn fields in Croatia, 2004 and 2005.

P. rufipes was found in all 8 localities in 2004 (in one locality no beetles were found) and in 12 localities in 2005. The dominance of this species (Figure 3) varied from 47% to 73% in 2004 and from 1.56% to 74.45% in 2005. At all localities in 2004 and at 11 localities in 2005 this species was classified as eudominant while at one locality in 2005 it was subdominant.

The frequencies of both species in both years are shown in Figure 4.

P. melanarius was a constant species in both years, with a frequency index of 71.8% in 2004 and 66% in 2005 (Figure 4). *P. rufipes* was a constant species in 2004 with a frequency index of 71.8% and an accessory species in 2005 with a frequency index of 44% (Figure 5).

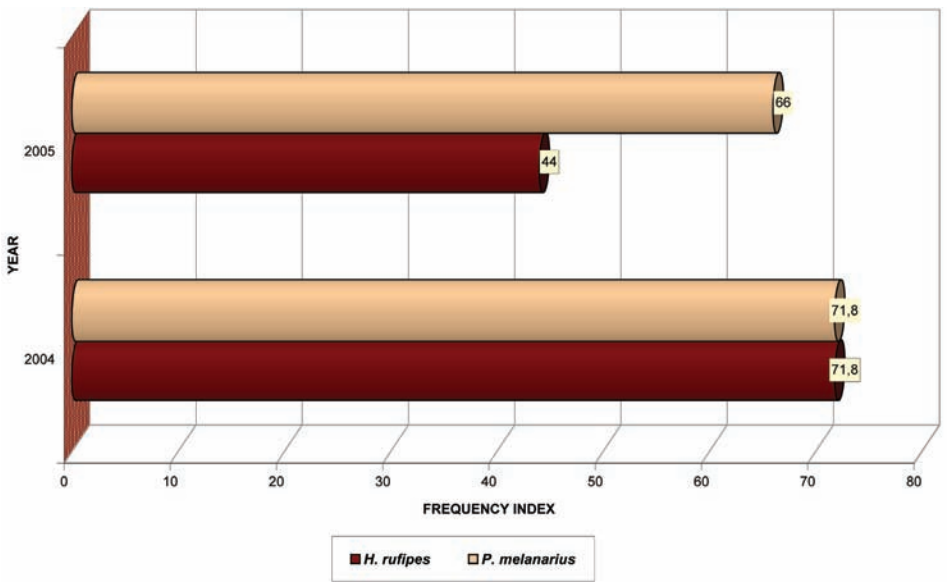

Figure 5. Frequency index of *P. melanarius* and *H. rufipes,* Croatia, 2004 and 2005.

Discussion

The total individual number of ground beetles in 2005 was lower than in 2004. This could be explained by the impact of climatic conditions (lower temperatures and higher amount of rainfall in 2005 than in 2004) on the number of beetles. Other authors reported the same findings. Sekulić (1977) for example stated that strong rains, especially at the end of spring beginning of summer, could reduce the abundance and frequency of ground beetles. The portions of the fields at the localities N^{o} 10 and 15 which were flooded for a short period resulted in a lower number of total ground beetles.

In continuous corn fields a lower number of ground beetles was found than in fields with clover and grass mixtures (localities 2 and 5) as previous crop. These findings do not correspond with the statement of Lövei (1984) who reported that corn in monoculture for nearly 20 years has a higher number of autumn breeder ground beetles because reproduction is not disturbed by harvest and subsequent soil cultivation. Lövei and Sunderland (1996) report that several factors can influ-

ence habitat and microhabitat distribution such as: temperature, food conditions, presence and distribution of competitors, life history and season. Habitat choice is very specific for ground beetles, because larvae usually cannot migrate long distances, and ovipositing females have to deliver eggs to microhabitats where their survival can be maximized. According to Tréfás and van Lenteren (2004) *P. melanarius* prefers shaded and more humid microhabitats for their egg laying sites. The year 2003 was extremely dry and hot. In such conditions *P.melanarius* females probably moved to clover and grass mixture fields to lay eggs. But only two cases in one year are not enough for a proper conclusion.

A high individual number of ground beetles was recorded in corn fields after the use of manure (localities 17 and 20). According to Grégoir Vibo (1980, 1983) cit. Hence (2002) the population of autumn breeders does not respond to a higher level of organic matter in soil. Based on only two fields in Croatia it cannot be concluded that organic matter influenced the individual number or abundance of ground beetles.

Chombon (1982) cit. Hence (2002) wrote that daily capture in pitfall traps can be reduced by 80% after the use of insecticides. A population of ground beetles needs two months to recover after the use of soil insecticides (Sekulić 1987, cit. Hence 2002). In investigated fields treated with insecticides (localities 7 and 11) a reduction of the number of ground beetles was recorded.

Thomas et al. (1997) cit. Durbešić et al. (2006) explain the low agility of *P. rufipes* by its herbivorous diet, whicht is more available in meadows, as compared to the widely available diet of the hunting *P. melanarius.* Our investigations of the abundance of *P. rufipes* and *P. melanarius* show that in corn fields the number of these two species did not differ very much. This could be due to the presence of weeds suitable for the diet of *P. rufipes*, and also the range of the fields, which were rather smaller than one hectare, surrounded by refuge areas.

Conclusions

During the investigation (2004-2005) the total inumber of 4383 ground beetles was captured. Captured specimens belonged to 24 species. Croatia has a species-rich ground beetle fauna in the majority of investigated corn fields.

The negative impact of low temperatures and high rainfall on the abundance of ground beetles was recorded. The impact of agronomic conditions (previous crop) and field maintenance (use of manure and insecticide application) on the

number of collected ground beetles was recorded. Since not enough pairs of data have been collected no direct correlation between cultivation practice and ground beetle communities could be assessed.

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