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Authors: Cividanes, Francisco J., Araújo, Edileusa S., Ide, Sérgio, and Galli, Júlio C.

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DISTRIBUTION AND HABITAT PREFERENCE OF CARABIDAE AND STAPHYLINIDAE (COLEOPTERA) IN AN ORANGE ORCHARD AND A FOREST FRAGMENT

FRANCISCO J. CIVIDANES[1], EDILEUSA S. ARAÚJO[1], SÉRGIO IDE[2] AND JÚLIO C. GALLI[1]
[1]Universidade Estadual Paulista—FCAV, Via de Acesso Prof. Paulo Donato Castellane s/n, Jaboticabal, SP, 14884-900, Brazil

[2]Instituto Biológico, Av. Conselheiro Rodrigues Alves 1252, São Paulo, SP, 04014-900, Brazil

ABSTRACT

A survey of Carabidae and Staphylinidae (Coleoptera) was conducted in a forest fragment and an orange orchard located in the Gavião Peixoto municipality, São Paulo State, Brazil to identify dominant predator species that may be important in the biocontrol of orange pests. Beetles were captured by pitfall traps arranged along 2 parallel transects 200 m long, placed across the orchard/forest boundary, extending 100 m into each habitat. The Shannon-Wiener diversity and Bray-Curtis similarity indices were calculated for both habitats, and habitat preference of abundant species were investigated by analysis of variance. Carabids comprised 91% and 86% of the beetles observed in the fragment and orchard, respectively. *Abaris basistriata* Chaudoir, *Athrostictus* sp.1, *Tetracha brasiliensis* (Kirby), *Pseudabarys* sp.1, *Selenophorus seriatoporus* Putzeys, *Selenophorus* sp.4, and the staphylinid *Xenopygus* sp.2 were the dominant species. There was no significant increase or decrease in carabid and staphylinid species richness from the edge to the interior of the fragment and orchard. *Abaris basistriata* prefered the forest fragment and the orange orchard, while *Athrostictus* sp.1, *Pseudobarys* sp., *Selenophorus* sp.4, and *S. seriatoporus* were orchard associated. The presence of ground vegetation on the orchard soil can have favored the establishment of ground-dwelling beetles that may be acting to control important orange pests. Dominant species determined in this study should be considered in future researches aiming to enhance the biocontrol in orange orchards.

Key Words: biological control, *Citrus sinensis,* diversity, similarity indices

RESUMO

Neste estudo foi realizado um levantamento populacional de Carabidae e Staphylinidae (Coleoptera) em fragmento florestal e pomar de laranja localizados no município paulista de Gavião Peixoto, para identificar espécies dominantes de predadores que podem ser importantes no controle biológico de pragas da laranja. Os besouros foram amostrados com armadilhas de solo distribuídas em dois transectos paralelos de 200 m de comprimento instalados no fragmento e pomar, com 100 m em cada hábitat. A fauna foi caracterizada pelos índices de diversidade de Shannon-Wiener e de similaridade de Bray-Curtis e a preferência pelo hábitat foi avaliada por análise de variância. Os carabídeos representaram 91% e 86% dos besouros observados no fragmento e pomar, respectivamente. As espécies dos carabídeos *Abaris basistriata* Chaudoir, *Athrostictus* sp.1, *Tetracha brasiliensis* (Kirby), *Pseudabarys* sp.1, *Selenophorus seriatoporus* Putzeys, *Selenophorus* sp.4 e do estafilinídeo *Xenopygus* sp.2 distinguiram-se como dominantes. Não houve aumento ou declínio significativo da riqueza de espécies de carabídeos e estafilinídeos da interface para o interior do fragmento e pomar. *Abaris basistriata* teve preferência pelo pomar de laranja e fragmento florestal, enquanto *Athrostictus* sp.1, *Pseudobarys* sp., *Selenophorus* sp.4 and *S. seriatoporus* mostraram-se associados ao pomar. A presença de vegetação de cobertura no solo do pomar pode ter favorecido o estabelecimento de carabídeos e estafilinídeos que devem atuar no controle de importantes pragas de laranja. Espécies dominantes determinadas neste estudo devem ser consideradas em futuras pesquisas visando incrementar o controle biológico em pomares de laranja.

Translation Provided by the authors.

Studies dealing with the occurrence of arthropod predators in citrus orchards are rare in Brazil. The information available is related to coccinellids, lacewings, and syrphids (Rodrigues et al. 2004), ants (Carvalho et al. 2000), wasps (Galvan et al. 2002), and mites (Silva & Oliveira 2006). Some studies have reported on the occurrence of parasitoids in orchards (Garcia et al. 2001; Jahnke et al. 2005).

Ground beetles (Carabidae) and rove beetles (Staphylinidae) include important ground dwelling predator species that can contribute to the natural

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control of pests, and are strongly influenced by environmental conditions (Pfiffner & Luka 2000; Holland 2002). Factors known to influence their abundance and distribution include vegetation type, temperature, humidity, food availability, and the species' life cycles (Lovei & Sunderland 1996; Kromp 1999).

In Brazilian citrus orchards occur several insect pests whose larval and/or pupae stage develop in the soil and, therefore, can be encountered and consumed by ground-dwelling beetles. Among these pests are the Mediterranean fruit fly *Ceratitis capitata* (Wied.) and several species of *Anastrepha* (Diptera: Tephritidae), the citrus borer, *Ecdytolopha aurantiana* (Lima) (Lepidoptera: Tortricidae) and the beetles *Macrodactylus pumilio* Burm. (Coleoptera: Scarabaeidae), *Naupactus cervinus* (Boheman) and *Naupactus rivulosus* (Oliv.) (Coleoptera: Curculionidae). It is noteworthy that already carabid species have been observed and considered voracious consumers of *C. capitata* pupae (Urbaneja et al. 2006). On the other hand, currently most of Brazilian orange orchards have been conducted without cultivation for weed suppression. As a consequence, the soils of these orchards are covered with spontaneous vegetation composed mainly of grasses. This agricultural practice can contribute to the natural control of pests by providing refuge to natural enemies of pests including ground-dwelling beetles (Miñarro & Dapena 2003; Bone et al. 2009).

The diversity and abundance of predatory insects in crops are related to the vegetation in the vicinity, which may favor the occurrence of these insects in agroecosystems (Thomas et al. 2002). The presence of natural habitats may increase the occurrence of carabids and staphylinids in crops (Dyer & Landis 1997). As these predators are potencially important natural pest-control agents, they can be crucial for sustainable agricultural systems by preventing insect pest outbreaks (Kromp 1999).

Farming practices such as cultivation of different plant species and changes in habitat structure due to cultivation methods can alter the species composition, distribution, and abundance of insects (Lovei & Sunderland 1996). To increase the effectiveness of carabids and staphylinids as biological control agents, it is necessary to evaluate the influence of habitat type on their assemblage composition (Holland & Luff 2000).

The objectives of this study were to determine the habitat preferences of abundant species, the species diversity, and the distribution of individual species of Carabidae and Staphylinidae across a forest fragment, an orange orchard and the edge between these habitats.

Materials and Methods

The study was carried out in an area located in Gavião Peixoto municipality, São Paulo State, Brazil (21°49'19"S, 48°24'46"W). The soil is classified as an Ultisol. The site comprised 10 ha of an orange *Citrus sinensis* (L.) Osbeck orchard adjacent to 19 ha of a semi-deciduous broadleaf tropical forest fragment.

Beetles were sampled by pitfall traps, arranged on 2 parallel 200-m transects, 10 m apart, from Nov 2004 to Oct 2006, totaling 36 sampling dates. A total of 48 traps were installed (20 traps in the fragment, 20 in the orchard and 8 in the edge). Each transect spanned the habitat boundary, with 100 m in the crop field and 100 m in the forest fragment. Four traps were set close to each other (1 m) at the edge between the forest fragment and the crop, and from this point additional traps were installed at 10-m intervals. Sampling was biweekly during the growing season and monthly otherwise. On each sampling date, the traps were set and remained in the field for 1 week. Beetles were preserved for identification at the Insect Ecology Laboratory at Unesp, Jaboticabal Campus. Identifications were made by 1 of the authors (SI). The specimens were identified to generic level with help of keys by Navarrete-Heredia et al. (2002) and Reichardt (1977). Specific identifications were done by comparison with specimens deposited in the Coleção Entomológica Adolph Hempel, Instituto Biológico, São Paulo (IBSP-IB) and Museu de Zoologia, Universidade de São Paulo, São Paulo. The exemplars are deposited in IBSP-IB.

Beetle communities were assessed by the Shannon-Wiener (H) and Bray-Curtis (I_{BC}) indices (Brower et al. 1998). Species with the highest abundance, dominance, frequency, and constancy faunistic coefficients (Silveira Neto et al. 1995) were designated as dominant. Regression analysis was used to determine the effect of distance from the edge on species richness, for orchard and forest habitats. To establish the distribution frequency of species that had at least 20 individuals captured during the study, the total number of individuals caught in a trap was plotted against their position on the transect. The habitat preference of these species were determined by analysis of variance (ANOVA) and Tukey test, considering the total number of individuals captured in the fragment, orchard and edge, at each sampling date.

Results and Discussion

Among the beetles captured, 71% of individuals occurred in the orange orchard and 21% in the forest fragment. The carabids comprised 91% and 86% of the individuals observed in the fragment and orchard, respectively (Table 1), and were therefore more abundant in the forest fragment and orange orchard than the staphylinids. Magagula (2006) observed that carabids were at least 26 times more numerous than staphylinids

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TABLE 1. TOTAL NUMBER OF CAPTURED INDIVIDUALS OF CARABIDAE AND STAPHYLINIDAE IN ORANGE ORCHARD, FOREST FRAGMENT AND EDGE. DOMINANT SPECIES IN BOLD TYPE.

Family/species	Orchard	Forest	Edge	Total
Carabidae				
***Selenophorus* sp.4**	137	5	6	148
***Abaris basistriata* Chaudoir**	64	59	4	127
***Athrostictus* sp.1**	74	2	9	85
***Tetracha brasiliensis* (Kirby)**	27	2	9	38
***Selenophorus seriatoporus* Putzeys**	35	0	0	35
***Pseudabarys* sp.1**	19	7	4	30
Scarites sp.2	7	11	6	24
Sphalera plaumanni Liebke	3	9	1	13
Scarites sulcipes Chaudoir	3	8	1	12
Odontochila nodicornis (Dejean)	0	9	0	9
Loxandrus aff. *subvittatus* Straneo	5	3	0	8
Scarites sp.3	0	5	2	7
Notiobia sp.1	6	0	0	6
Barysomus punctatostriatus van Emden	4	1	1	6
Notiobia amethystinus Dejean	1	4	0	5
Helluomorphoides squiresi (Chaudoir)	4	0	1	5
Cymindis sp.1	3	1	0	4
Selenophorus alternans Dejean	4	0	0	4
Selenophorus discopunctatus Dejean	4	0	0	4
Arthrostictus speciosus (Dejean)	0	1	0	1
Eucheila strandi (Liebke)	1	0	0	1
Loxandrus catharinae Tschitschérine	0	1	0	1
Notiobia chalcites (Germar)	1	0	0	1
Odontochila cupricollis Kollar	1	0	0	1
Selenophorus sp.2	1	0	0	1
Trichonilla festiva Tschitschérine	1	0	0	1
Total no. individuals	405	128	44	577
Total no. species	22	16	11	26
Staphylinidae				
***Xenopygus* sp.2**	43	5	1	49
Atheta sp.6	16	0	0	16
Atheta sp.3	0	4	0	4
Eulissus chalybaeus Mannerheim	4	0	1	5
Glenus biplagiatus Perty	1	1	0	2
Lathropinus torosus (Erichson)	1	1	0	2
Renda sp.1	0	2	0	2
Lathrobium sp.1	1	0	0	1
Smilax pilosa (Fabricius)	1	0	0	1
Xenopygus sp.1	1	0	0	1
Total no. individuals	68	13	2	83
Total no. species	8	5	2	10

in a citrus orchard and a windbreak. The low occurrence of carabids and staphylinids in the fragment (141 individuals) compared to 473 individuals in the orchard may result from a smaller number of prey, and/or unfavorable habitat characteristics. Lovei & Sunderland (1996) reported similar results where the density of adult carabids in annual crops was 32/m^2, but was extremely low in forests (2/m^2).

The carabids classified as dominant species were: *Abaris basistriata* Chaudoir, *Athrostictus* sp.1, *Tetracha brasiliensis* (Kirby), *Pseudabarys* sp.1, *Selenophorus seriatoporus* Putzeys, and *Selenophorus* sp.4; only *Xenopygus* sp.2 was dominant among the staphylinids (Table 1).

The species richness of carabids and staphylinids was higher in the orchard than in the fragment (Fig. 1). A relatively high number of beetle species was observed at the edge, often exceeding the number of species in the fragment. The species richness of carabids at the edge was lower than in the orchard, whereas for staphylinids it

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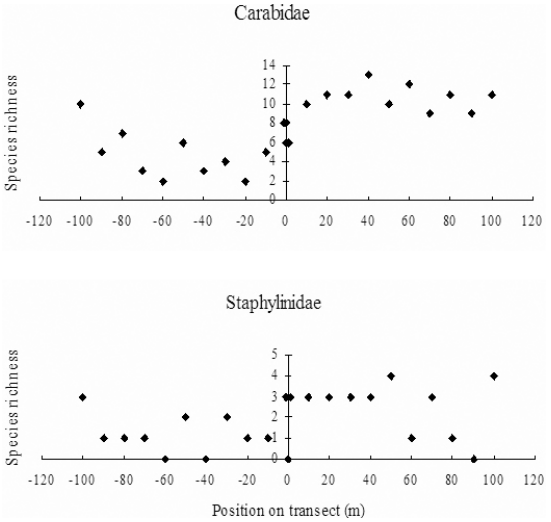


Fig. 1. Carabidae and Staphylinidae species richness plotted against position on the transect. The zero indicates the edge between the orange orchard (positive numbers) and the forest fragment (negative numbers).

was similar from the edge to 40 m within the orchard. Regression analyses did not indicate a significant relationship between species-richness distribution of carabids and staphylinids, and the distance from the edge for both the fragment ($y_{Carabidae} = 4.9535 + 0.0065x$, $r = 0.0860$, $P > 0.05$; $y_{Staphylinidae} = 1.8252 - 0.0071x$, $r = 0.2256$, $P > 0.05$) and orchard ($y_{Carabidae} = 8.6926 + 0.0267x$, $r = 0.4293$, $P > 0.05$; $y_{Staphylinidae} = 2.447 - 0.0025x$, $r = 0.0600$, $P > 0.05$). Therefore the variation in number of species did not depend on the position on the transect.

The carabid species diversity coefficients for the fragment ($H = 0.871$) and orchard ($H = 0.900$) were close to each other, indicating that they are similar in richness and dominance structure. Because the occurrence of carabids depends on environmental conditions such as temperature, moisture, and vegetation type (Kromp 1999; Holland 2002), the present results indicate that the forest fragment and the orange orchard with ground vegetation support carabid assemblages of similar diversity. A greater diversity of staphylinids was found in the fragment ($H = 0.614$) than in the orchard ($H = 0.483$), which may indicate that the fragment was more favorable for the occurrence of species of these beetles. However, there are limitations to the interpretation of results on staphylinids, because of the lack of information on the ecology and adult behavior of these beetles (Frank & Thomas 2008).

A low species similarity was observed between the carabid and staphylinid communities present in the orchard and the fragment (I_{BC} Carabidae = 0.353; I_{BC} Staphylinidae = 0.173). In agricultural areas, soil arthropods have been observed to move between crops and forest fragments (French et al. 2001; Thomas et al. 2002). The apparent low rate of movement of carabids and staphylinids between the fragment and the orchard may be related to the presence of ground vegetation on the orchard soil providing favorable conditions that kept the beetles in the orchard.

Table 2 shows the average number of carabids and staphylinids captured in 36 sampling dates. *Abaris basistriata* appears to prefer the fragment and orchard, while *Athrostictus* sp.1, *Pseudobarys* sp., *Selenophorus* sp.4, and *S. seriatoporus* are orchard associated. The remaining species show no clear preference and may be regarded as widespread.

Carabids can be classified according to the habitat where they are observed in the agroecosystem (Fournier & Loreau 1999; French & Elliott 1999). In Brazil, *T. brasiliensis* and species of

TABLE 2. NUMBER (MEAN ± STANDARD ERROR) OF CARABIDAE AND STAPHYLINIDAE CAPTURED IN FOREST FRAGMENT, ORANGE ORCHARD AND EDGE.

Family/species	Orchard	Forest	Edge	*F*
Carabidae				
Abaris basistriata Chaudoir	1.8 ± 0.50 a	1.6 ± 0.31 a	0.1 ± 0.07 b	7.67*
Athrostictus sp.1	2.1 ± 0.50 a	0.06 ± 0.03 b	0.3 ± 0.13 b	11.06**
Tetracha brasiliensis (Kirby)	0.8 ± 0.24 a	0.06 ± 0.02 a	0.3 ± 0.10 a	2.72NS
Pseudabarys sp.1	0.5 ± 0.19 a	0.2 ± 0.05 b	0.1 ± 0.06 b	4.54*
Scarites sp.2	0.2 ± 0.07 a	0.3 ± 0.11 a	0.2 ± 0.05 a	0.07NS
Selenophorus seriatoporus Putzeys	1.0 ± 0.27 a	0.0 ± 0.00 b	0.0 ± 0.00 b	12.20*
Selenophorus sp.4	3.8 ± 1.11 a	0.1 ± 0.06 b	0.2 ± 0.17 b	10.78**
Staphylinidae				
Xenopygus sp.2	1.2 ± 0.83 a	0.1 ± 0.07 a	0.03 ± 0.02 a	1.67NS

Values followed by different letters in same line are different by Tukey test ($P < 0.05$).
NSnon-significant.

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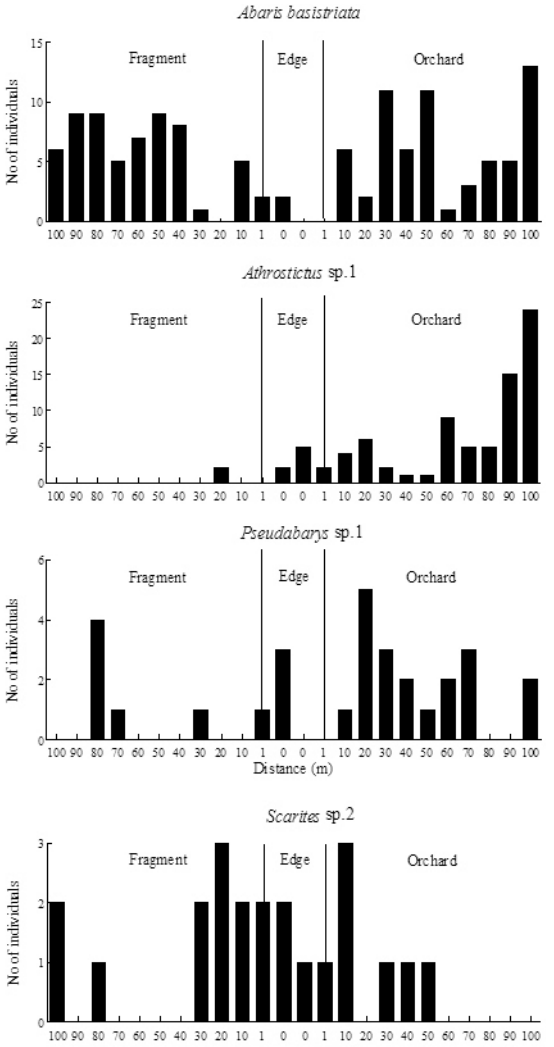


Fig. 2. Catch frequency of individual species of Carabidae plotted against position on the transect. The vertical lines indicate the position of the edge.

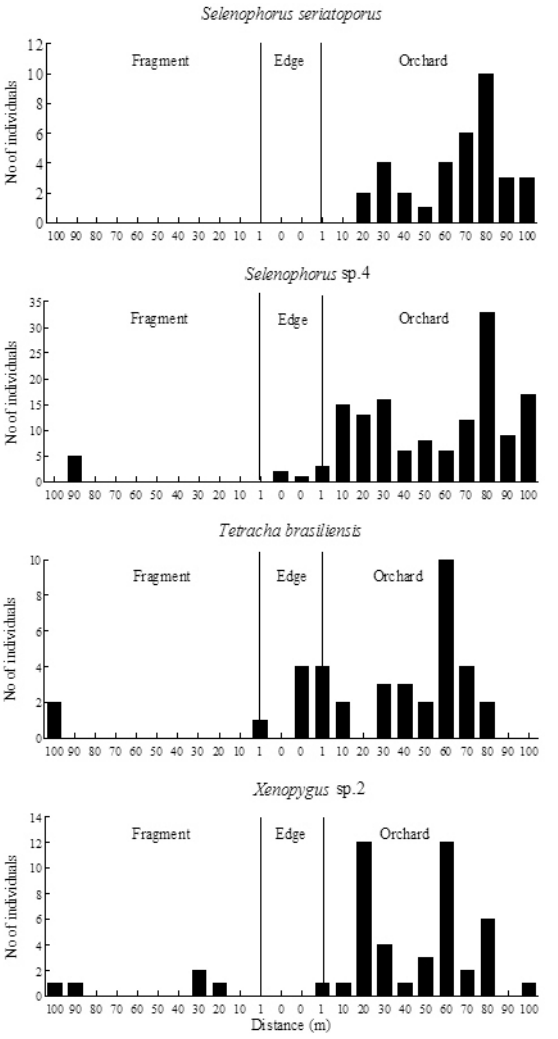


Fig. 3. Catch frequency of individual species of Carabidae and Staphylinidae (*Xenopygus* sp.2) plotted against position on the transect. The vertical lines indicate the position of the edge.

genus *Selenophorus* were found in cotton (Ramiro & Faria 2006), maize (Araújo et al. 2004), sugar cane (Macedo & Araújo 2000; Araújo et al. 2005), and vegetables (Cividanes et al. 2003). These findings corroborate the results of the present study, indicating *S. seriatoporus,* and *Selenophorus* sp.4 as crop inhabiting species.

Although the abundance distribution of carabids might potentially be affected by many factors (Thomas et al. 2002), the distribution frequency of selected species gave some indication of their response to the transition zone (edge) between the fragment and the orchard (Figs. 2 and 3). *Abaris basistriata* showed a gradual decline in catch frequency from inside the orchard/fragment toward the edge. *Scarites* sp.2 was most abundant at the edge to at least 30 m into the orchard and fragment, whereas *T. brasiliensis* was abundant from the edge to 80 m into the orchard. Among the orange-orchard species, the catch frequency of *Athrostictus* sp.1 declined abruptly from inside the orchard to the edge, whereas *S. seriatoporus*, *Pseudabarys* sp.1 and *Selenophorus* sp.4 showed a more gradual drop in abundance toward the edge. The staphylinid *Xenopygus* sp.2 was abundant in the orange orchard, with a clear decrease in abundance near the edge.

This study indicated low similarity between the carabid and staphylinid communities in the orange orchard and forest fragment, but, on the other hand, we observed high species diversity of carabids in the orchard where most of the domi-

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nant species also prevailed. Low similarity between communities can indicate low rate of movement of the ground-dwelling beetles between the fragment and orchard (Kajak & Lukasiewicz 1994). Therefore, the high diversity of carabids and the presence of dominant species in the orchard are due probably to no soil disturbance and the presence of ground vegetation on the orchard soil. These characteristics of the orchard favored the establishment of ground-dwelling beetles that may be acting to control important pests such as the fruit flies *C. capitata* and several species of *Anastrepha*, the citrus borer, *E. aurantiana* and the beetles *M. pumilio*, *N. cervinus* and *N. rivulosus*. As most of Brazilian orange orchards employ the same agricultural practice of keeping ground vegetation, further studies are needed to clarify the actual role of these ground-dwelling beetles as biological control agents of pests in orange orchards. Considering that dominant species have the potential to be used in biological control programs (Ellsbury et al. 1998), research in an orange orchard aiming to improve biocontrol should consider the dominant species determined in this study.

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