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Occurrence of Carabid Beetles in the Phenological Stages of Weedy Plants

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Abstract

In the current study, we investigated the relationship between the abundance of carabid species (Coleoptera: Carabidae) and the phenological stages of weedy plants growing in edge habitats. A survey of carabid beetles was conducted in edge habitats between forest fragments and soybean/corn crops or orange orchards in five sites located in northeastern São Paulo state, Brazil, from November 2005 to May 2008. Beetles were captured with pitfall traps, and multiple regression analysis was used to determine the carabid species that prevailed on each of the phenological stages of weeds. In total, 1115 individuals, representing 26 genera and 52 species, were captured. *Selenophorus* species, mainly *Selenophorus seriatoporus* Putzeys, *Selenophorus* sp.4, *Helluomorphoides squiresi* (Chaudoir), *Tetragonoderus laevigatus* Chaudoir, *Athrostictus* sp.1 were abundant during the reproductive phenological stages of weedy plants, which suggests that these carabid species might prefer to feed on the seeds of weedy plants.

Keywords

Abundance, Ground Beetle, Phenology, Seed Consumption, Weed

1. Introduction

Several studies of plant phenology and insects have focused on the relationship between plants and the life cycle or population dynamics of phytophagous insects [1] [2] [3] [4] [5]. Published studies on the influence of plant phenology on carabid beetles (Coleoptera: Carabidae) have examined the consumption of weed seeds by carabid species, as well as the role of weeds as a refuge and dispersal aid for carabids in agroecosystems [6] [7] [8]. There are also reports of weedy plants causing changes in the carabid community structure [9] [10].

Feeding habits of carabid beetles range from carnivory to phytophagy, but there are also carabid species with more-specialized feeding behaviors [11]. For example, in terms of phytophagy, carabids can be classified into two groups: 1) those that are carnivorous but supplement their diets with vegetation; and 2) those that are seed consumers [8] [12] [13]. Thus, in addition to being recognized as important biological control agents of crop pests, carabids are also an important group of seed feeders and, thus, can act efficiently to reduce the size of weed populations in agroecosystems [8] [14]. Carabids and crickets dominate the granivorous taxa of temperate regions [7] [8] [15], whereas ants are dominant in the tropics [16]. Among the carabid beetles, the Harpalini and Zabrini tribes contain the most granivores [6] [17].

Despite the rich carabid fauna in Brazilian agroecosystems [18] [19], there are no specific studies from this region on carabid beetles as weed seed consumers or on their relationship with the phenological stages of weedy plants. The only studies published on the feeding habits of Brazilian carabids were by Barbosa *et al.* [20], who evaluated the effect of different diet types on biological aspects of two carabid species, and Matta *et al.* [21], who determined the types of food within the digestive tract of carabids associated with herbaceous plants and colored cotton. It is also worth noting that the life cycle of Brazilian carabids inhabiting agroecosystems is almost unknown; however there is information available about seasonal activity of several dominant carabid species in the state of São Paulo [22].

Therefore, in the current study, a survey of adult carabids was carried out in the edge habitat covered by weedy plants and located between a forest fragment and a soybean/corn crop or an orange orchard in five sites in northeastern São Paulo state, Brazil. The objective was to determine the changes in the density of carabid species in relation to different phenological stages of weeds. We considered the increased number of individuals of a carabid species during the reproductive stages of weedy plants, an indication of preference to feed on seeds of agricultural weeds.

2. Material and Methods

2.1. Sites Description

The study was carried out in five sites in the northeast region of São Paulo state, Brazil, from November 2005 to May 2008. According to the Köppen system, the regional climate is classified as Aw climate, tropical rainy with dry winter [23]. The first site, in the Jaboticabal municipality [Jaboticabal-no-tillage system (NTS)] was located on the campus of the Universidade Estadual Paulista (21˚14'52"S, 48˚16'04"W). The soil is classified as an oxisol. The site comprised 40 ha cultivated with soybean [*Glycine max* (L.) Merrill] rotated with corn [*Zea mays* (L.)], in a NTS, adjacent to 15 ha of a semideciduous broadleaf tropical forest fragment. Two further sites were located in the Guaíra municipality:

Guaíra-NTS (20˚21'10"S, 48˚14'47"W) and Guaíra-conventional-tillage system (CTS; 20˚19'29"S, 48˚15'08"W), located approximately 2 km from one another. The soil is also classified as an oxisol in both sites. Guaíra-NTS comprised a 90-ha field cultivated with soybean rotated with corn, in a NTS, adjacent to 48 ha of a semideciduous broadleaf tropical forest fragment. Guaíra-CTS was a 15-ha site cultivated with soybean rotated with corn in a CTS, adjacent to 6 ha of a semi-deciduous broadleaf tropical forest fragment. The fourth site, the Gavião Peixoto-orange orchard (21˚49'19"S, 48˚24'46"W), was located in the Gavião Peixoto municipality. The soil is classified as an ultisol. The site comprised 10 ha of an orange orchard [*Citrus sinensis* (L.) Osbeck] adjacent to 19 ha of a semideciduous broadleaf tropical forest fragment. The fifth site, Descalvado-orange orchard (21˚54'09"S, 47˚43'55"W), was located in the Descalvado municipality. The soil is classified as an oxisol. The site comprised 800 ha of an orange orchard adjacent to 2000 ha of a Brazilian savanna fragment.

In Descalvado and both Guaíra sites, the edge habitat was completely covered by weedy plants, whereas, in the Jaboticabal and Gavião Peixoto sites, the edge habitat contained weeds and a 3-m strip of bare ground. Most of weed species were found in all sites, some of them occurred in 1 or 2 sites only (**Table 1**).

2.2. Carabid Beetles and Phenological Stages

Carabids were sampled with pitfall traps installed in the edge habitat between the forest fragment and soybean/corn crop or orange orchard at each study site, with 50 sampling dates in each sites. Traps were 500-ml (80-mm diameter) plastic cups filled with a solution of formaldehyde in water (1%) and detergent [19] [21]. To install each trap, a hole was dug and a plastic cup was inserted so that the lip of each cup was level with the ground. A plastic cover (diameter 135 mm) was used to protect each trap from rain. A total of eight traps were set in two rows 10-m apart, with each row containing four traps that were set 1 m apart (**Figure 1**). Traps were placed in the field twice a month during each cropping season and once per month otherwise. Traps remained in the field for 1 week, at which point the contents were collected. No traps were lost nor destroyed during the sampling period. Beetles were preserved for identification at the Laboratório de Ecologia de Insetos, Universidade Estadual Paulista, Jaboticabal Campus. The carabids were identified to species level by Sérgio Ide, Agência Paulista de Tecnologia dos Agronegócios (APTA), with the help of the keys of Reichardt [24] or 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.

The phenological stages of weeds were determined by visual inspection of plants performed on the same dates as the carabid samplings. Phenological stages included four stages (vegetative growth, flowering, fruiting, and seed dispersal),

Table 1. Weed species found in the edge habitat between forest fragment and agricultural fields of five sites. Weeds are listed based on their occurrence in the sites. NTS = no-tillage system, CTS = conventional tillage system.

Site	Weed species			
	Scientific name	Common name	Family	Life cycle
All sites	*Acanthospermum australe* (Loefl.) Kuntze	sheepbur	Asteraceae	annual
	Alternanthera tenella Colla	-	Amaranthaceae	perennial
	Bidens pilosa L.	beggarticks	Asteraceae	annual
	Cenchrus echinatus L.	sandbur	Poaceae	annual
	Commelina benghalensis L.	dayflower	Commelinaceae	perennial
	Conyza bonariensis (L.) Cronquist	fleabane	Asteraceae	annual
	Cyperus rotundus L.	nutsedge	Cyperaceae	perennial
	Digitaria insularis (L.) Mex ex Ekman	sourgrass	Poaceae	perennial
	Eleusine indica (L.) Gaertner	goosegrass	Poaceae	annual
	Emilia sonchifolia (L.) DC. ex Wight	tasselflower	Asteraceae	annual
	Sida sp. L.	-	Malvaceae	annual
Jaboticabal-NTS	*Acanthospermum hispidum* DC.	bristly starbur	Asteraceae	annual
(soybean/corn crop)	*Digitaria nuda* Schumacher	naked crabgrass	Poaceae	annual
	Panicum maximum Jacq.	guineagrass	Poaceae	perennial
Guaíra-NTS	*Brachiaria decumbens* Stapf	signal grass	Poaceae	perennial
(soybean/corn crop)				
Guaíra-CTS	*Brachiaria decumbens* Stapf	signal grass	Poaceae	perennial
(soybean/corn crop)				
Gavião Peixoto	*Brachiaria decumbens* Stapf	signal grass	Poaceae	perennial
(orange orchard)	*Chamaesyce hirta* (L.) Millsp.	spurge	Euphorbiaceae	annual
	Parthenium hysterophorus L.	ragweed	Asteraceae	annual
Descalvado	*Amaranthus* sp. L.	-	Amaranthaceae	annual
(orange orchard)	*Brachiaria decumbens* Stapf	signal grass	Poaceae	perennial
	Digitaria nuda Schumacher	naked crabgrass	Poaceae	annual
	Panicum maximum Jacq.	guineagrass	Poaceae	perennial
	Rhynchelitrum repens (Willd.) C.E. Hubb	natal grass	Poaceae	annual

and were established based on Fenner [25]. The inspections were performed using square metal quadrants (0.70 × 0.70 m) for the random removal of 18 samples in the immediate vicinity of the pitfall traps. The phenological stages of plants inside the quadrant were visually determined according to the following criterion: 1) vegetative growth: plant without reproductive structures, 2) flowering or fruiting stages: presence of at least one flower or fruit, respectively, and 3)

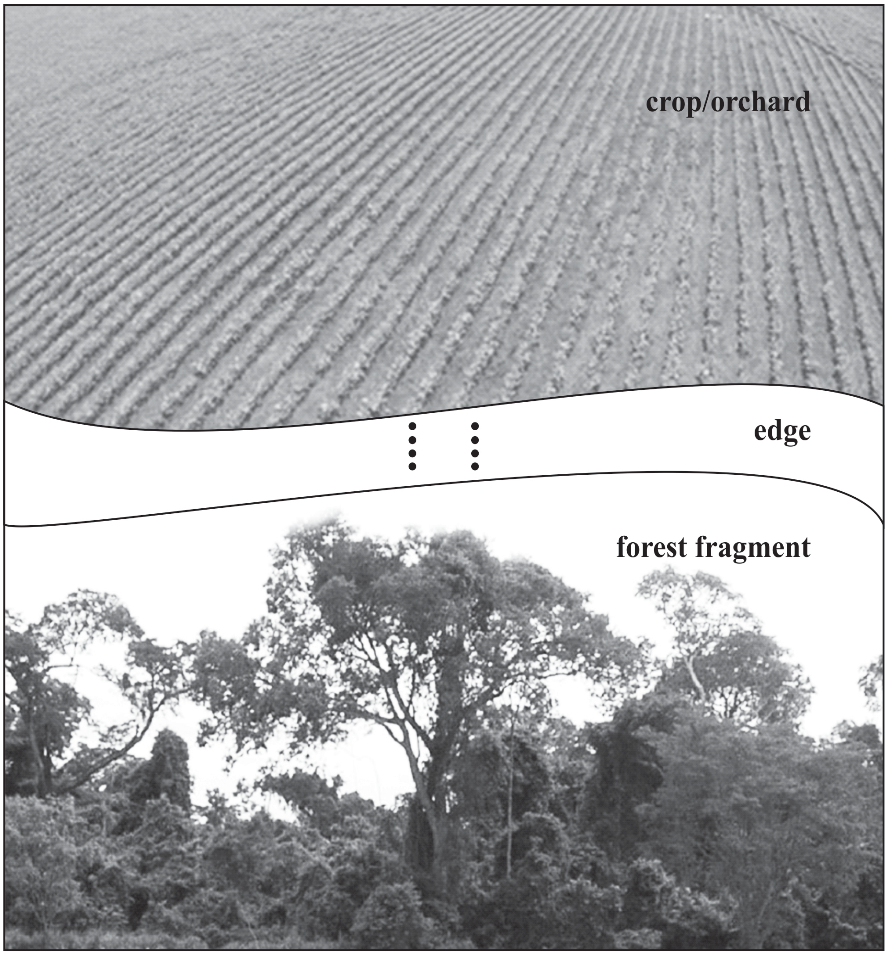

Figure 1. Position of the pitfall traps in the edge between forest fragment and soybean/corn crop or orange orchard. Black dots represent the position of the traps set in two rows 10-m apart, each one containing 4 traps installed at 1-m intervals.

seed dispersal: plant with several seeds. The weed species were identified by Maria do Carmo Morelli Damasceno Pavani, Departamento de Biologia, Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal Campus, according to Lorenzi [26] and Moreira and Bragança [27].

2.3. Data Analysis

The relationship between the phenological stages of the weedy plants and the abundance of carabid species were examined by stepwise multiple regression analysis [28], which included the phenological stages as independent variables. The model used was:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4,$$

where b_1, b_2, b_3, and b_4 were the coefficients of vegetative growth, flowering, fruiting, and seed dispersal, respectively. The analysis was performed based on the capture of carabids on two distinct dates in relation to plant phenology: 1) carabid sampling and observation of phenological stages performed simultaneously; and 2) carabid sampling 1 month after the phenological observations. The analysis was based on the total number of individuals of the carabid species captured in all traps, and the total number of all weed species in each one of the phenological stages throughout the sampling period. SAS 93 software [29] was used for the analysis. Carabid species represented by fewer than ten individuals were excluded from the analysis.

3. Results

A total of 1,115 individual carabids, representing 26 genera and 52 species, were captured (Table 2). The three most-abundant carabid species were *Abaris basistriata* Chaudoir (20.6% of the total sample), *Selenophorus seriatoporus* Putzeys (15.8% of the total sample), and *Odontocheila nodicornis* (Dejean) (9.6% of the total sample), while *Scarites* sp. 3, *Selenophorus* sp.4, *Athrostictus* sp.1, and *Pentacomia cupricollis* (Kollar) accounted for 6.9%, 5.5%, 4.6%, and 4.0%, respectively, of the total sample.

Multiple regression analysis showed that some carabid populations increased during the reproductive period of the weeds. A population increase was verified in *S. seriatoporus* (Table 3) during the flowering stage of weeds ($b_2 = 0.0941$, $p = 0.0356$) in Jaboticabal-NTS, during both the flowering stage ($b_2 = 0.2510$, $p = 0.0494$) and fruiting stage ($b_3 = 0.1789$, $p = 0.0527$) in Guaíra-NTS, and during the seed dispersal stage in Gavião Peixoto ($b_4 = 0.0103$, $p = 0.0373$) and Descalvado ($b_4 = 0.0212$, $p = 0.0360$). Similar population increases were also verified in *Selenophorus* sp.4 ($b_3 = 0.0347$, $p = 0.0006$; Descalvado) and *H. squiresi* ($b_3 = 0.0267$, $p = 0.0042$; Gavião Peixoto) during the fruiting stage of the weeds, and in *Athrostictus* sp.1 ($b_2 = 0.1765$, $p = 0.0134$; Jaboticabal) and *Tetragonoderus laevigatus* Chaudoir ($b_2 = 0.0681$, $p = 0.0189$; Descalvado) during the flowering stage. The density of these carabid species also increased during the reproductive phenological stages when captured by traps 1 month after the phenological observations (Table 4). This was observed in *S. seriatoporus* ($b_2 = 0.0154$, $p = 0.0192$; Gavião Peixoto), *Selenophorus* sp.1 ($b_2 = 0.0200$, $p = 0.0059$; Jaboticabal-NTS), *Selenophorus* sp.4 ($b_3 = 0.0166$, $p = 0.0011$; Guaíra-CTS), *Helluomorphoides squiresi* (Chaudoir) ($b_3 = 0.0270$, $p = 0.0135$), and *T. laevigatus* ($b_4 = 0.0352$, $p = 0.0362$) in the Gavião Peixoto and Descalvado sites (Table 4).

The number of *Scarites* spp. individuals decreased during the reproductive period of weeds, including individuals captured 1 month after the phenological period had been determined (Table 3 and Table 4). Similar population behavior was found in *Abaris basistriata* Chaudoir captured after a 1-month lag (Table 4). The reverse result was found for *Calosoma granulatum* (Perty) in the Jaboticabal and Guaíra-NTS sites (Table 3 and Table 4), and for *O. nodicornis* and *Galerita brasiliensis* Dejean in the Guaíra-CTS and Descalvado sites, respectively (Table 4). In addition, *O. nodicornis* was abundant in the edge habitats of three of the study sites (Table 2).

Table 2. Total number of carabid individuals collected in the edge between forest fragment and agricultural field of five sites. NTS = no-tillage system, CTS = conventional tillage system, ORC = orange orchard.

	Species	Jaboticabal (NTS)	Guaíra (NTS)	Guaíra (CTS)	Gavião Peixoto (ORC)	Descalvado (ORC)
1	*Abaris basistriata* Chaudoir, 1873	71	43	66	19	31
2	*Amblygnathus suturalis* Putzeys, 1845	1	0	0	0	0
3	*Apenes marginalis* (Dejean, 1831)	2	0	0	0	0
4	*Apenes plaumanni* (Liebke, 1939)	1	0	4	2	1
5	*Apenes* sp.	0	1	0	0	1
6	*Athrostictus speciosus* Dejean, 1829	2	0	0	1	0
7	*Athrostictus* aff *nobilis* Brullé, 1838	0	0	1	0	0
8	*Athrostictus sulcatulus* Dejean, 1829	2	0	0	3	0
9	*Athrostictus* sp.1	36	4	0	11	0
10	*Barysomus punctatostriatus* Emden, 1949	0	0	0	1	0
11	*Calosoma granulatum* (Perty, 1830)	13	4	1	3	1
12	*Colliuris* sp.	0	0	1	0	0
13	*Cymindis* sp.1	0	1	1	0	0
14	*Cynthidia croceipes* (Perty, 1830)	1	0	0	0	0
15	*Galerita brasiliensis* Dejean, 1826	14	0	0	0	12
16	*Galerita bruchi* Liebke, 1932	2	0	0	0	0
17	*Galerita occidentalis* (Olivier, 1795)	1	2	0	0	0
18	*Helluobrocus negrei* Reichardt, 1974	0	0	0	1	0
19	*Helluomorphoides squiresi* (Chaudoir, 1872)	0	0	0	14	0
20	*Loxandrus catharinae* Tschitschérine, 1900	0	0	0	1	0
21	*Loxandrus* sp.1	1	0	2	0	0
22	*Loxandrus subvittatus* Straneo, 1953	14	10	2	1	0
23	*Microcephalus festiva* Tschitschérine, 1898	0	0	1	0	0
24	*Morion cyclomus* Chaudoir, 1854	0	0	1	0	0
25	*Notiobia amethystinus* Dejean, 1829	0	0	0	1	0
26	*Notiobia chalcites* Germar, 1824	3	0	0	1	0
27	*Notiobia cupripennis* (Germar, 1824)	1	0	0	0	0
28	*Notiobia* sp.1	0	1	0	2	0
29	*Notiobia* sp.2	0	3	1	0	0
30	*Odontocheila nodicornis* (Dejean, 1825)	29	43	30	5	0
31	*Pelecium brasiliense* Straneo, 1962	0	2	0	0	0
32	*Pentacomia cupricollis* (Kollar, 1836)	10	30	2	3	0
33	*Polpochila impressifrons* (Dejean, 1831)	0	0	0	1	0
34	*Pseudabarys* sp.1	3	0	0	16	0
35	*Scarites* sp.1	0	0	2	0	0

Continued

36	*Scarites* sp.2	27	0	0	8	0
37	*Scarites* sp.3	37	20	13	7	0
38	*Scarites* sp.4	0	21	9	0	0
39	*Scarites sulcipes* (Chaudoir, 1855)	0	0	0	8	0
40	*Selenophorus alternans* Dejean, 1829	11	0	0	1	22
41	*Selenophorus discopunctatus* Dejean, 1829	5	1	0	2	1
42	*Selenophorus seriatoporus* Putzeys, 1878	21	98	20	10	27
43	*Selenophorus ventralis* Putzeys, 1878	0	0	0	0	10
44	*Selenophorus* sp.1	6	0	0	1	2
45	*Selenophorus* sp.2	1	0	0	0	0
46	*Selenophorus* sp.4	1	4	15	31	10
47	*Selenophorus* sp.5	1	0	0	0	0
48	*Stratiotes* sp.1	4	0	2	0	0
49	*Tetracha brasiliensis* (Kirby, 1818)	24	5	3	7	0
50	*Tetracha* sp.1	2	0	0	0	1
51	*Tetragonoderus laevigatus* Chaudoir, 1876	0	0	0	0	17
52	*Tetragonoderus* sp.1	0	0	0	0	2
	Number total of individuals	347	292	177	161	138
	Number of species	31	18	20	27	14

Table 3. Regression coefficients and the standard errors for phenological phases of weedy plants and carabids captured in the edge between forest fragment and agricultural field of five sites. NTS = no-tillage system, CTS = conventional tillage system.

Sites	Regression coefficients and standard errors					
	Species	Vegetative growth	Flowering	Fruiting	Seed dispersal	F
Jaboticabal-NTS	*Abaris basistriata*	-	0.2537 ± 0.08	-	-	9.79**
(soybean/corn crop)	*Athrotictus* sp.1	-	0.1765 ± 0.07	-	-	6.69*
	Calosoma granulatum	-	-	0.0373 ± 0.02	-	4.63*
	Selenophorus seriatoporus	-	0.0941 ± 0.04	-	-	4.73*
Guaíra-NTS	*Selenophorus seriatoporus*	-	0.2510 ± 0.12	0.1789 ± 0.08	-	4.18*
(soybean/corn crop)	*Scarites* sp.3	−0.0621 ± 0.02	-	-	−0.0406 ± 0.02	4.97**
	Scarites sp.4	-	-	−0.0597 ± 0.03	-	4.08*
Guaíra-CTS (soybean/corn crop)	No variable was included in the regression model					
Gavião Peixoto	*Helluomorphoides squiresi*	-	-	0.0267 ± 0.01	-	9.09**
(orange orchard)	*Selenophorus seriatoporus*	-	-	-	0.0103 ± 0.01	4.60*
Descalvado	*Selenophorus seriatoporus*	-	−0.0334 ± 0.02	-	0.0212 ± 0.01	4.44*
(orange orchard)	*Selenophorus* sp.4	-	-	0.0347 ± 0.01	-	14.14**
	Tetragonoderus laevigatus	-	0.0681 ± 0.03	-	-	6.04*

*, **Indicate significance at the P < 0.05 and P < 0.01 levels, respectively.

Table 4. Regression coefficients and the standard errors for phenological phases of weedy plants and carabids captured with a one-month lag in the edge between forest fragment and agricultural field of five sites. NTS = no-tillage system, CTS = conventional tillage system.

Sites	Regression coefficients and standard errors					
	Species	Vegetative growth	Flowering	Fruiting	Seed dispersal	F
Jaboticabal-NTS	*Selenophorus* sp.1	-	0.0200 ± 0.01	-	-	8.58**
(soybean/corn crop)	*Scarites* sp.3	-	-	−0.0841 ± 0.03	−0.0461 ± 0.03	4.13*
Guaíra-NTS	*Abaris basistriata*	0.0450 ± 0.02	−0.1508 ± 0.07	-	-	3.69*
(soybean/corn crop)	*Calosoma granulatum*	-	−0.0163 ± 0.01	0.0207 ± 0.01	-	11.03**
	Scarites sp.4	0.0657 ± 0.02	-	−0.0983 ± 0.03	-	8.01**
Guaíra-CTS	*Apenes aenea*	0.0102 ± 0.01	-	−0.0231 ± 0.01	-	6.16**
(soybean/corn crop)	*Odontocheila nodicornis*	-	0.0783 ± 0.04	-	-	4.36*
	Selenophorus sp.4	-	-	0.0166 ± 0.01	-	12.71**
Gavião Peixoto	*Abaris basistriata*	−0.0166 ± 0.01	-	-	−0.0286 ± 0.01	3.57*
(orange orchard)	*Helluomorphoides squiresi*	-	-	0.0270 ± 0.01	-	6.64*
	Selenophorus seriatoporus	-	0.0154 ± 0.02	-	-	5.92*
Descalvado	*Abaris basistriata*	−0.0437 ± 0.02	−0.1175 ± 0.04	-	−0.0947 ± 0.03	6.01**
(orange orchard)	*Galerita brasiliensis*	−0.0042 ± 0.01	-	0.0107 ± 0.01	-	6.68**
	Tetragonoderus laevigatus	-	-	-	0.0352 ± 0.02	4.71*

*, **Indicate significance at the P < 0.05 and P < 0.01 levels, respectively.

4. Discussion

Most carabids feed on a variety of invertebrates, but there are some species that consume weed seeds [8] [11]. In a previous study that evaluated the predatory potential of adult carabid beetles [30], *Athrostictus* sp.1, *H. squiresi*, *T. laevigatus*, and *Selenophorus* spp. demonstrated low predatory potential on *A. gemmatalis* larvae, a major soybean pest in Brazil. Thus, the increase in abundance of *Athrostictus* sp.1, *H. squiresi*, *S. seriatoporus*, *Selenophorus* sp.1, *Selenophorus* sp.4, and *T. laevigatus* during the reproductive stages of weeds recorded in the current study might be related to their preference to feed on seeds from weeds. *Selenophorus* spp. are recognized for feeding on seeds of weeds [6]. For example, *S. seriatoporus* was reported to consume seeds of signal grass, *Brachiaria decumbens* Stapf [20]. In addition, the genera *Athrostictus* and *Selenophorus* belong to the Harpalini tribe, which is one of the tribes with the most granivores [6] [17]. *Helluomorphoides squiresi* and *T. laevigatus* belong to the Helluinini and Cyclosomini tribes, respectively, which, together with Harpalini, are included in the Harpalitae supertribe [31]. It is also noted that the population increase verified in *S. seriatoporus*, *Selenophorus* sp.1, *Selenophorus* sp.4, *H. squiresi*, and *T. laevigatus* 1 month after the phenological observations could also be an evidence of their preference for weed seeds, given that the fruiting and seed-dispersal stages of these plants lasted for up to 6 months in each of the study sites. As carabids are important weed biological control agents [8], further studies are required to confirm whether *Athrostictus* sp.1, *H. squiresi*, *T. laevigatus*, and species of *Selenophorus* feed on weed seeds in this region.

The low number of *A. basistriata* and *Scarites* spp. individuals during the reproductive period of weeds, and the previous finding that these carabids demonstrate great predatory potential on *A. gemmatalis* larvae [30], suggest that such species have a low preference for weed seeds. By contrast, the presence of *C. granulatum*, *G. brasiliensis*, and *O. nodicornis* in the edge habitats suggests that these habitats act as temporary refuges for these species [32] [33]. This is also supported by reports that *C. granulatum* prefers soybean/corn crops and is rarely observed in forest fragments and that *O. nodicornis* behaves as a forest species [19], whereas *G. brasiliensis* occurs mainly in corn crops rather than in rubber tree plantations (*Hevea brasiliensis* Muell Arg) or soybean crops [34].

The abundance of carabid beetles usually increases throughout the growing season, with multiple drivers responsible for this increase. In the current study, 52 carabid species were found in the edge habitats between forest fragments and soybean/corn crops or orange orchards. The carabid populations in this environment are likely to have been exposed to similar temperatures and types of food across each study site. However, those carabid species showed different behaviors in relation to the phenological stages of the weedy plants. Some carabids (*Athrostictus* sp.1, *H. squiresi*, *T. laevigatus*, and species of *Selenophorus*, mainly *S. seriatoporus* and *Selenophorus* sp.4), increased in abundance during the reproductive stages of weeds and showed low or no preference for *A. gemmatalis* larvae [30]. Such behavior might suggest that those carabid species prefer to feed on weed seeds. By contrast, the populations of *A. basistriata*, *C. granulatum*, *G. brasiliensis*, *O. nodicornis*, and *Scarites* spp. decreased during the reproductive period of weeds and/or demonstrated high predation of *A. gemmatalis* larvae [30]; such findings suggest that those carabid species had a low preference for weed seeds. Finally, it should be emphasized that all weed species observed in the present study were only found in the edge of all five sites; however these weeds are commonly found in the interior of most Brazilian agricultural fields. Here, the weeds did not penetrate the studied fields/orchards because they were controlled by herbicides in the crop fields while the presence of spontaneous vegetation covering the soil surface of the orchards prevented the development of these plants.

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