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Cannibalism among *Myrmeleon brasiliensis* larvae (Návas, 1914) (Neuroptera, Myrmeleontidae)

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ABSTRACT. Cannibalism is influenced by various intrinsic and extrinsic factors of the population, such as density, population structure, prey availability, habitat structure and famine. These factors acting either independently or in synergy determine the frequency of cannibalism. The aims of the present study were to evaluate the effect of density and food availability on the occurrence of cannibalism among *Myrmeleon brasiliensis* larvae (Neuroptera, Myrmeleontidae). In the present study, the occurrence of cannibalism among *M. brasiliensis* larvae was greater in the treatments that simulated an absence of food in situations of both high and low density. The search for food makes a larva move about to forage, thereby increasing the risk of falling into the trap of a neighboring larva. Thus, the cannibalistic behavior of *M. brasiliensis* larvae may be associated with opportunity rather than a direct attempt to pray on the same species.

Keywords: trap, density, antlion, food availability.

Canibalismo entre as larvas *Myrmeleon brasiliensis* (Návas, 1914) (Neuroptera, Myrmeleontidae)

RESUMO. O canibalismo pode ser influenciado por vários fatores intrínsecos e extrínsecos à população, tais como a densidade, a estrutura da população, a disponibilidade de presas, a estrutura do habitat e o nível de fome. Todos esses fatores podem atuar independentemente ou de forma sinérgica para determinar a frequência de canibalismo. Os objetivos deste estudo foram avaliar o efeito dos fatores densidade e da oferta de alimento na ocorrência de canibalismo entre as larvas *Myrmeleon brasiliensis* (Neuroptera, Myrmeleontidae). Foi observado que tanto em situações de baixa densidade quanto de alta densidade o canibalismo é maior nos tratamentos que simularam a falta de alimento. A busca pelo alimento faz com que as larvas se desloquem; esse deslocamento contribui para que uma larva *M. brasiliensis* caia na armadilha da larva vizinha. Dessa maneira, o comportamento canibal entre *M. brasiliensis* pode estar associado à oportunidade, e não a uma busca direta pela presa da mesma espécie.

Palavras-chave: armadilha, densidade, formiga-leão, oferta de alimento.

Introduction

Cannibalistic behavior is not uncommon among generalist predators in the animal kingdom (Fox, 1975; Polis, 1981).The advantage of this type of behavior is an increase in the variability and quality of diet, leading to a greater availability of energy and nutrients in comparison to non-cannibalistic animals (Pfennig, Ho, & Hoffman, 1998; Fagan et al., 2002).

Cannibalism is influenced by various intrinsic and extrinsic factors of the population, such as density, population structure, prey availability, habitat structure and famine. These factors, acting either independently or in synergy, determine the frequency of cannibalism (Polis 1981; Wise, 2006). Although the way by which these isolated factors exert an influence on this behavior is well understood, little is known regarding how the interaction of these factors affects cannibalism (Barkae, Golan, & Ovadia, 2014; Mayntz & Toft, 2006).

Antlion larvae of the genus *Myrmeleon* (Neuroptera, Myrmeleontidae) are typical 'sit-and-wait' predators. The larvae build funnel-shaped traps in sandy soil (Farji-Brener, 2003; Hauber, 1999; Scharf, Daniel, Macmillan, & Katz, 2016). Experiments in both the natural environment and laboratory report the occurrence of cannibalism among *Myrmeleon* spp. larvae in response to an increase in density, a lack of food and the destruction of their traps, which leads larvae to actively seek other sites (Griffiths, 1991, 1992; Barkae, Scharf, Subach, & Ovadia, 2010; Barkae et al., 2014). Lima and Faria (2007) found that *Myrmeleon brasiliensis* larvae exhibit the behavior of maintaining a minimum distance from each other.

Lima and Lopes (2016) found that *M. brasiliensis* larvae have a greater frequency of cannibalism in denser populations.

The aims of the present study were to evaluate the effect of density and food availability on the occurrence of cannibalism among *M. brasiliensis* larvae. The frequency of cannibalism was tested in laboratory experiments in which density and food availability were manipulated. An increase in density is expected to lead to an increase in the rate of cannibalism due to the greater interaction among larvae, and this increase is likely greater among non-fed larvae, which are forced to actively seek food, leading to predation of or by neighboring larvae (Gotelli, 1993; Griffith, 1992).

Material and methods

Second-instar *M. brasiliensis* larvae were collected from a permanent protection area (20º26'25"S, 55º39'21"W) belonging to the *Universidade Estadual do Mato Grosso do Sul* in the municipality of Aquidauana, in the State of Mato Grosso do Sul, Brazil. The experiments were conducted in the General Biology Laboratory of the Biology Department of the Campo Grande campus of the university. In the laboratory, the larvae were sorted and kept in plastic boxes measuring 35 cm x 22 cm x 7 cm filled with sand from the collection site. The specimens of *M. brasiliensis* in each plastic box were monitored through observation direct for ten consecutive days, during which the number of traps and occurrence of larval carcasses around the traps were recorded.

In the experiment, the following treatments were employed: I) low density/without food; II) low density/with food; III) high density/without food; IV) high density/with food.

To test the effect of food availability on cannibalism, *Drosophila melanogaster* (Meigen, 1830) larvae were offered as prey. The prey was only offered on the first and fifth day of the experiments due to the fact that the prey capture rate of antlion larvae is low in the natural environment (Hauber, 1999). *Drosophila melanogaster* were used due the demonstration of laboratory findings that antlion larvae feed efficiently on fruit fly larvae with no nutritional loss throughout development (Missirian, Uchôa-Fernandes, & Fischer, 2006).

High (20 larvae per box) and low (five larvae per box) population densities were simulated to test the effect on cannibalism. These simulations were based on data from a study conducted in the natural environment demonstrating that *M. brasiliensis* density ranges from one to 43 individuals per m^2 (Lima & Faria, 2007).

Each treatment was replicated 10 times, totaling 40 plastic boxes and the use of 500 *M. brasiliensis* larvae. The number of cannibalism events was compared using the Kruskal-Wallis test followed by Dunn's post hoc test with the aid of the BioEstat 5.0 program (Ayres, Ayres Júnior, Ayres, & Santos, 2007).

Results and discussion

A total of 42 cannibalism events were recorded. Four larvae were found dead in treatment I (low density/without food), in which the cannibalism events occurred in two out of ten replicas mounted (two different plastic boxes). In treatment II (low density/with food) three larvae were killed by the neighboring larvae, in this case the cannibalism events occurred in three replicates. In treatment III (high density/without food) was observed a mortality of 26 larvae, and in this case the cannibalism events occurred on all replicas. In the treatment IV (high density/with food) was observed a mortality of nine larvae in six of the ten replicas mounted (Kruskal-Wallis, GL = 3, $p < 0.005$). Dunn's post hoc test revealed that differences occurred between treatments I and III as well as between treatments II and III (Figure 1).

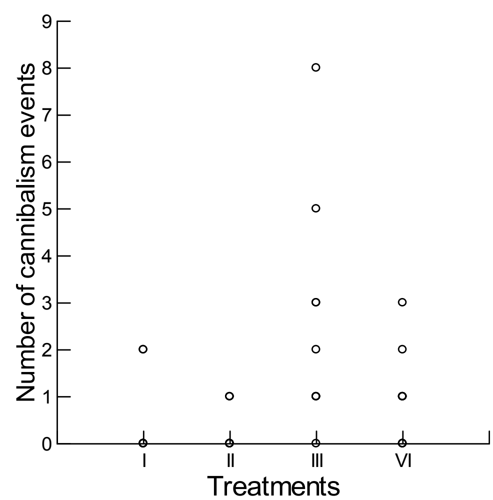

Figure 1. Number of cannibalism events among *Myrmeleon brasiliensis* larvae (Kruskal-Wallis, GL = 3, $p < 0.005$).

A high frequency of movements was found during the first days of the experiment, especially among larvae in situations of high population density and the absence of food. The number of predated larvae was concentrated in the first two days in treatment I (low density/without food) and treatment II (low density/with food). Cannibalism among *M. brasiliensis* larvae was concentrated between the first and eighth days of the experiment in the treatments with high density (Table 1).

Table 1. Percentage of predated *M. brasiliensis* larvae according to day of experiment (Treatment I: low density/without food; Treatment II: low density/with food; Treatment III: high density/without food; Treatment IV: high density/with food).

Treatment	Day/Percentage of predated larvae									
	1	2	3	4	5	6	7	8	9	10
Treatment I	50	50	-	-	-	-	-	-	-	-
Treatment II	100	-	-	-	-	-	-	-	-	-
Treatment III	42	31	15	4	4	-	-	4	-	-
Treatment IV	44	34	11	-	-	11	-	-	-	-

As expected, an increase in the density of *M. brasiliensis* larvae, together with the absence of food, led to an increase in the rate of cannibalism. In situations in which the larvae were fed, a lower rate of cannibalism was found. This suggests that, although density is a preponderant factor for the occurrence of this behavior, food availability also exerts an influence.

The effect of density on the spatial distribution of antlion larvae has been studied. According to Wilson (1974), larvae are distributed in such a way as to maximize prey capturing efficiency, thereby reducing intra-specific competition for food sources. In experiments involving the artificial increase in population density, MacClure (1976) found a clear trend toward a uniform distribution pattern, which is believed to minimize the effects of competition.

Simberloff et al. (1978) found that spatial distribution was affected by the act of one larva tossing sediment into the funnel trap of a neighboring larva, leading the latter to move in search of a different site. Other authors report similar findings (e.g. Matsura & Takano, 1989; Griffiths, 1991). Day and Zalucki (2000) found that the minimum distance between *Myrmeleon acer* Walker larvae under conditions of high density was similar to the distance that grains of sand reached during the building of a funnel trap (30 mm). The attempt to create distance from a neighboring funnel trap is limited in a laboratory experiment in which *M. brasiliensis* larvae are kept in a box, which contributes to a greater frequency of cannibalism. This was confirmed in the present investigation, as larvae in situations of high density gradually established a situation of lower density, which led to less movement. The larvae were moving constantly at the beginning of the study, whereas the funnel traps were generally in the same place during the last days of the study.

Antlion larvae *M. brasiliensis* in the natural environment tends to regulate a random distribution with increasing density (Lima & Faria, 2007). The spatial arrangement of the larvae should be at first the reflection of female oviposition, which selects a protected from direct sun and rain action environment. In the course of development the larvae begin to distance themselves in the search for food and to minimize the effects of competition with neighboring larvae (Gotelli, 1997; Scharf & Ovadia, 2006). This pattern of distribution makes the natural environment with sufficient space to dry, and sandy soil larvae are found in low densities, however in the absence of these spaces ant dandelion larvae can be found in high density, which increases occurrence of cannibalism (Barkae et al., 2014). In the laboratory this behavior has been observed in *M. brasiliensis* larvae attempt to move away from each other, but due to space limitation the cannibalism was favored.

The offer of food had a negative effect on the occurrence of cannibalism. Fed larvae moved less in the plastic cages, which led to a reduction in predation among *M. brasiliensis* larvae. Thus, the offer of food in a given area stimulates the maintenance of funnel traps at such sites. The larval duration of antlions ranges from three months to two years, depending on the availability of prey (Furunishi & Masaki, 1981, 1982). Thus, remaining in an area with an abundant food supply may accelerate the maturation of *M. brasiliensis* larvae, and such larvae are therefore less exposed to risk prior to reproduction. The size of adults is another consequence of the diet of *M. brasiliensis* larvae. Missirian et al. (2006) found that larvae fed with leafcutter ants (*Atta* spp.) were smaller upon reaching adulthood in comparison to those fed with fruit fly (*Anasthepha* spp. and *Ceratitis capitata*) larvae, possible due to the higher energy value of the latter food source. As size is related to fecundity in the majority of insect groups (Honek, 1993; DeClercq & Degheele, 1997), it is advantageous for larvae to remain in areas with an abundant food supply, since better fed larvae can lead to larger and possibly more fecund adults.

Conclusion

The cannibalism among *M. brasiliensis* larvae was influenced by the high density and lack of food. The density causes the larvae to move up in an attempt to minimize the effects of competition with neighboring larvae, in addition, the lack of food leads the larvae move for area where there is the offer of resource. Given the fact that cannibalism occurred in direct response to the displacement of *M. brasiliensis*, and indirectly to increased density and lack of food, cannibalistic behavior between *M. brasiliensis* may be associated with opportunity rather than a direct attempt to pray on the same species.

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