

Research Article

Predatory Behavior of *Canthon virens* (Coleoptera: Scarabaeidae): A Predator of Leafcutter Ants

Luiz Carlos Forti,¹ Isabela Maria Piovesan Rinaldi,²
Roberto da Silva Camargo,¹ and Ricardo Toshio Fujihara¹

¹Laboratório de Insetos Sociais-Praga, Departamento de Produção Vegetal, Faculdade de Ciências Agrônômicas, UNESP, P.O. Box 237, 18603-970 Botucatu, SP, Brazil

²Departamento de Zoologia, Instituto de Biociências, UNESP, 18618-970 Botucatu, SP, Brazil

Correspondence should be addressed to Roberto da Silva Camargo, camargobotucatu@yahoo.com.br

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We present a detailed description of the predatory behavior of the beetle *Canthon virens* Mannerheim, 1829, on the leafcutter ant *Atta* sp. We observed 51 acts of predation, which were also recorded on film and subjected to behavioral analysis. *Canthon virens* exhibited 28 behaviors while predating upon *Atta* sp. queens. Adult beetles search for queens while flying in a zigzag pattern, 15 to 20 cm above the ground. After catching a queen, the predator stands on its back and starts cutting the queen cervix. Once the prey is decapitated, the predator rolls it until an insurmountable obstacle is reached. The distance from the site of predation to the obstacle can vary widely and is unpredictable. The beetle rolling the queen also buries it in a very peculiar way: first, it digs a small hole and pulls the queen inside, while another beetle is attached to the prey. The burial process takes many hours (up to 12) and may depend on the hardness of the soil and the presence of obstacles. In general, one or two beetles are found in a chamber with the queen after it is buried. They make the brood balls, which serve as food for the offspring. This study contributes to the knowledge of the predatory behavior of *Canthon virens*, a predator poorly studied in Brazil and widespread in the country.

1. Introduction

Canthon dives Harold, 1868, and *Canthon virens* Mannerheim, 1829, prey on queens of leafcutter ants, *Atta* spp., after the queen nuptial flight. For this reason, the beetles are considered natural biological control agents of these ants. In 1937, Lichti [1] was the first to report the predation of leafcutter ant queens by *Canthon dives* beetles. Later, Navajas [2] reported that not only queens but also winged forms of both sexes are preyed upon by *Canthon virens*.

Atta queens lose their wings after their nuptial flight and start looking for a place to dig. When searching for a suitable place to build their nests, and during nest digging, ant queens are most vulnerable to their beetle predators. They can be attacked by one to over six individuals simultaneously [3]. The predation rate of *Atta* by *Canthon virens* [4] alone is 7.6%, but when other species of *Canthon* are considered, this proportion can reach more than 50% [3].

Using the tissues of their prey, *Canthon* beetles build two or three brood balls for their larvae. Detailed observations of this behavior have been documented for *Canthon virens*: first, the beetle positions itself, with some difficulty, on the back of the queen. Then, using the clypeus as a lever and the jagged edges of the tibiae as a saw, the predator cuts the prey cervix or neck [5, 6]. Both male and female beetles prey on queens [7], but a relationship between the size of the prey (queen) and the predator (beetle) has not been found. However, there is a positive relationship between the densities of queens and beetles, suggesting that the relationship between *Atta* spp. and *Canthon virens* might be obligatory [3, 6].

The brood balls are buried 7.7 ± 2.3 cm deep. Each female beetle lays one egg in each brood ball, and males and females remain in the burrow until the offspring has developed [3].

Little is known about the predation sequence of *Atta* queens by *Canthon virens*. In view of this gap, we have

investigated and provide a detailed description of the steps from searching for *Atta* queens to the confection of the brood balls.

2. Material and Methods

The behavior of the beetle predator *C. virens* was monitored for 5 years in a natural situation, in several commercial plantations of *Eucalyptus grandis* or natural vegetation (Cerrado) in the municipalities of Botucatu, Itatinga, and Anhembi, in the state of São Paulo, Brazil.

Fifty-one cases of queen predation by beetles were filmed on VHS, using two Panasonic M-8 cameras. Filming began when the queens came to the ground after their nuptial flight. The videos were labeled and stored for later analysis.

All behaviors were quantified by counting the number of times each occurred during 1 minute, at 2-minute intervals. We then used those results to calculate the frequencies of each behavior. Behaviors were then analyzed for a pattern.

3. Results

3.1. Behaviors during Predation. A total of 28 behaviors was recorded during the predation of *Atta* queens (Figure 1), as follows: (1) A single beetle flies over the queen in a zigzag pattern before capturing it. (2) A single beetle on the ground climbs onto the back of a walking queen. (3) Two beetles fly over a queen, but only one attacks and beheads it. (4) A single beetle flies over a queen and catches it. (5) A single beetle flies over a queen, is momentarily unable to catch it, but ends up succeeding. (6) A single beetle flies over a queen, lands on it, and then abandons it. (7) A beetle positions itself on the thorax of a queen, with its head pointing to the queen cervix. (8) A beetle attaches itself to the thorax of a queen, with its head turned to one side, that is, the time required for the beetle to turn in the direction of the queen head and start beheading it. (9) A beetle attaches itself to the queen thorax, with the head facing the queen gaster; the beetle then points its head towards the head of the walking queen, that is, the time required for the beetle to stand with its head toward the head of the queen and start cutting. (10) A beetle attaches itself to the queen thorax while the queen is digging and then changes position, standing up to kill it. (11) A beetle attaches itself to the queen thorax and then abandons it. (12) A beetle, on the ground, secures the queen abdomen, leaves its prey momentarily, and then comes back to catch it again. (13) A beetle, on the ground, secures the queen abdomen but does not turn its head toward the prey head. (14) A beetle cuts the queen cervix, the time needed to start and finish the process. (15) A beetle walks over a queen that is moving with difficulty. (16) A beetle attempts to cut the queen neck, but does not succeed. (17) After cutting the queen neck, the predatory beetle walks on the back of its prey, examining it. (18) After cutting the queen neck, the predatory beetle walks away. (19) After cutting the queen neck, the predatory beetle examines its prey, walks to the side, and comes back to roll it, that is, the time spent from cutting the queen cervix to starting to roll it. (20) After cutting the neck of the queen, the predator examines it, walks beside it, but does not continue with the

process of predation. (21) Numerous beetles show up and “dispute the prey” by rolling it together. When only two beetles are left, one is attached to the queen and the other one rolls it, that is, the time from the dispute to the burial. (22) Numerous beetles dispute the dead body by rolling it together. When only one beetle is left, it rolls the queen to the burial site. (23) More beetles show up and dispute a live queen (walking), which is being preyed upon by another beetle. When only three beetles are left, one goes away and two remain. (24) More beetles show up and dispute a live, yet immobile queen, which is being preyed upon by another beetle. One beetle goes away and the other stays with the original predator. (25) The beetle that killed the queen rolls it. From time to time it climbs up and down the queen, and then goes back to rolling it, that is, the time spent rolling and going up and down. (26) A beetle, after rolling its prey, begins to excavate the soil to bury it. It goes to the bottom of the hole and comes back to the surface. If two beetles are present, one digs and the other remains on the queen. (27) A beetle, after rolling the queen, digs a small hole in the ground, buries the queen only partially, and remains on the surface with the abdomen facing up, that is, the time spent to dig, to bury the queen superficially, and to position the legs up. (28) A beetle buries the queen very deep and then sits on the surface with the abdomen facing up.

3.2. Descriptive Sequence of Behaviors. Adult beetles showed up for the nuptial flight only. They were seen in greater numbers a little before and during the nuptial flight flying in a zigzag pattern, more or less 15 to 20 cm from the ground, searching for prey. They flew very fast, and periodically interrupted their activity to rest on the ground or on the vegetation.

A total of 92% of the queens (47 beetles) were captured by a beetle that was flying in zigzag and came upon the prey thorax (Figure 3). In 4% of the cases (2 beetles), however, the queen was not captured. One queen (2%) was chased by two beetles, but only one beetle finished the task.

An alternative, rarer capture method observed in 4% of the cases did not involve a zigzag flight. In that case, a beetle walking on the soil surface tried to climb on the back of a queen to kill it. In some instances, a beetle that failed to succeed using this method tried again, but seldom (2%) on the same individual.

An interesting result of our study is the observation that female beetles are those that capture and behead *Atta* queens. When a female beetle sits on the thorax of its prey, it often has the head turned to one side (40% of cases, 20 beetles) of the queen body. The predator then turns its head toward the head of the queen. Often, the female beetle sits in the correct position to cut the queen neck (Figures 1, 2(a), and 2(b)), but sometimes the female has its head turned toward the queen gaster (27% of cases, 14 beetles) (Figure 2(d)). Once the predator is positioned correctly (Figure 2(b)), it immediately begins to cut the queen neck. After a queen is killed, many beetles join the killer (Figure 2(e)), but only two are left to bury the prey (Figure 2(f)).

Division of labor according to sex in *C. virens* is well defined. The female catches, kills, rolls, and buries the prey.

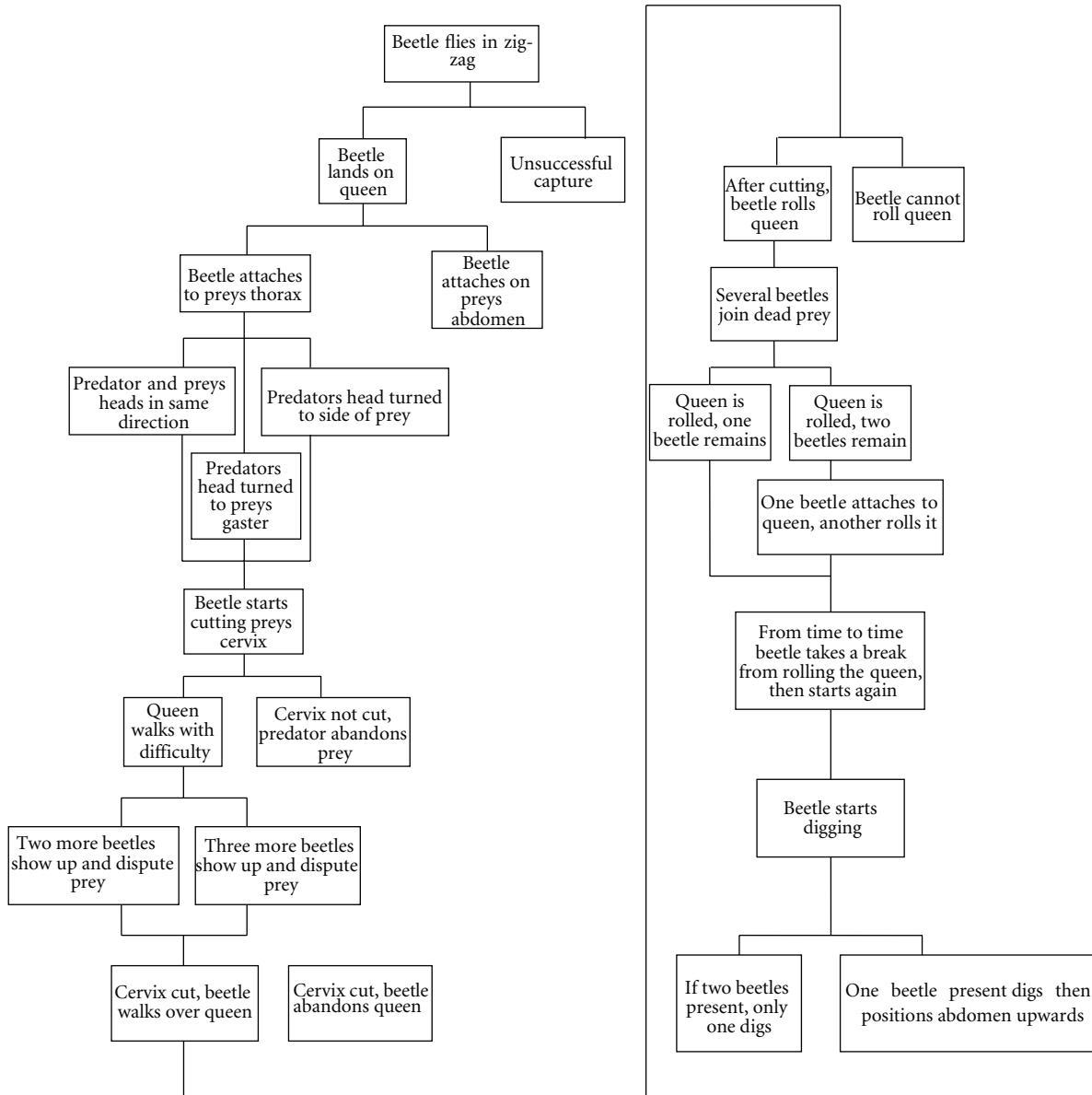


FIGURE 1: Fluxogram showing the behavior of *Canthon virens* preying on leafcutter ants (*Atta* spp.).

The male joins the female after the murder. In some cases, we observed females burying without a male, with her abdomen facing upward and her body partially buried in the tunnel under construction (Figure 2(g)).

A beetle can roll a queen for distances of 2 to 3 m. Some beetles that roll in push feces up to 9 m. *Canthon virens* individuals roll their prey until they find an insurmountable obstacle. The distance between the site of predation and the obstacle can vary widely and is unpredictable. Usually a beetle rolling a queen will stop from time to time, go away a few inches, then return, climb on the dead body, and start rolling it again.

The burial is always conducted by the beetle that pushed the queen: first, the beetle digs a small hole and pulls the queen into the pit, while the other beetle remains on the prey. The burial process takes up to 12 hours and may be

dependent on soil compaction and/or the presence of obstacles. As the queen is buried, the soil is deposited on the surface in the form of small pellets.

Up to three beetles were found buried with the queen during the first 24 hours, but the most common is to find one or two beetles per chamber with the queen (Figures 2(h) and 2(i)).

4. Discussion

Predation is an unusual form of specialization in Scarabaeinae beetles because the majority of them are coprophagous. Some species of *Canthon* specialize in the predation of *Atta* queens. Other authors have described [2, 3, 5] the specialized predatory behavior of these beetles, beginning after the nuptial flight: first the beetle approaches the queen,



FIGURE 2: (a) A beetle flies zigzag over prey and lands on its back. (b) The beetle cuts the neck of the queen and is attached to it by its legs. (c) The queen has been killed: the beetle examines the prey, before rolling it. (d) Sometimes the beetle may attach itself to the thorax of the queen, having the head turned toward the queen abdomen. (e) When the queen is dead, many other beetles may join. (f) After a few minutes only two beetles remain to bury the queen. (g) The beetle is partially buried and has its abdomen and hind legs facing up and is partially buried; this phenomenon is observed when the beetle buries its prey by itself. (h) The nest of *Canthon virens*, with a channel about 1 cm in diameter and 15 cm deep. (i) Chamber at the end of the canal, with the brood balls.

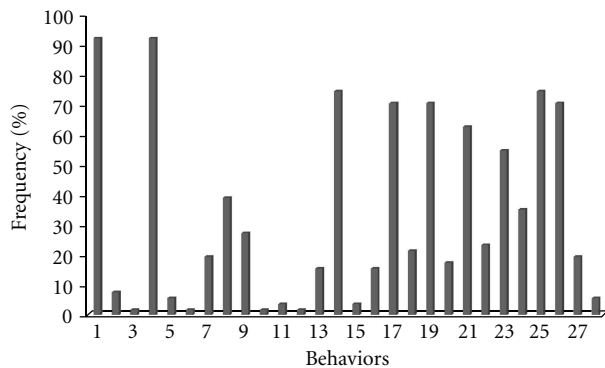


FIGURE 3: Frequency of predatory behaviors of *Canthon virens*.

lands on its back, and then beheads it. However, previous descriptions of the predation sequence were insufficient in view of the amount of information that can be obtained. In our study, we found that 28 behaviors are performed,

showing the complexity of the sequence of predation events (Figure 1).

First, *Canthon* beetles were observed flying at about 15 to 20 cm from the soil surface in search of prey. They fly extremely fast and periodically stop to rest on the ground or on the vegetation. Because queens are located by their beetle predators regardless of whether they remain still or move, we believe that individuals of *Canthon virens* use their sight to locate them. However, because vision is generally poorly developed in Scarabaeinae beetles, whereas their tactile sense is sharp [5], we cannot rule out the possibility that smell, such as that produced by allelochemicals, plays a role in prey location. It is well known that, when an odor current is detected by dung beetles, they take flight and perform a short-distance search [5]. The same could apply to *Canthon virens* beetles.

Once a queen is found walking on the ground, the predator flies in a zigzag fashion, lands on it, and later beheads it. In this study, we found that female beetles are responsible for catching the ant queens. This result contrasts with those

of Navajas [2] and Silveira et al. [7], who found that both males and females prey on the queen and that only the males attack it.

After landing on the queen, the female beetle proceeds to decapitate it, as shown in Figure 1. According to Halffter and Matthews [5], the beetle cuts the queen cervix with the aid of its front legs and clypeus, a fact we also observed. When a female beetle lands on the thorax of its prey, it most often positions itself with the head facing sideways. The predator then turns to face the queen cervix. Frequently a beetle will land on the queen thorax with its head pointing to the head of its prey. In rare cases, the predator stands on the queen thorax with its head pointing to the queen gaster.

The queen keeps walking for a while as the predator proceeds to behead it. At a certain moment, the queen stops and assumes a position in which her body is sideways, arched, and immobile. Infrequently, two or three other beetles may join before the queen has been beheaded and while it is still walking. Most often, however, beetles will group around a victim that is already dead. In some cases, we have observed up to 11 beetles surrounding a single queen. Apparently, some are there to compete for the female beetle. In the end, usually one or two beetles remain at the scene.

Forti and Rinaldi [3] reported that a queen may be attacked by up to six beetles when it is looking for an ideal place to start digging its nest. We believe that their reports actually describe what happens after the queen is already dead. Normally one beetle rolls the queen, while the other is attached to it.

Most Scarabaeini make balls from vertebrate feces and have developed specialized ways to roll them. The balls are rolled either by one or two beetles [5, 8]. When two beetles are involved, they usually belong to different sexes, and the roles taken by each member of the couple differ from one genus to another. In some species of *Canthon*, for instance, the male always rolls, while the female remains on the top of the ball. However, in *C. virens*, the female rolls the queen while the male is rolled along with it.

As soon as the beetle finds an insurmountable obstacle, it starts digging. Similarly, Silveira et al. [7] observed that beetles roll the headless queen until they find a dead leaf and, from that moment on, start digging.

In other coprophagous species of *Canthon*, for instance *C. lituratus*, either the male or the female, or both, prepares fecal balls. However, the female is the one to bury the ball, even when a male is present [9, 10]. In *C. virens*, the queen is buried by the beetle that was rolling it. First, the beetle digs a small hole and pulls the queen into the pit, while the other beetle remains stuck on the prey. The same behavior was observed in *C. lituratus*: the female buries the fecal ball while the male, when present, sits on it [9].

When a beetle excavates alone, it returns to the surface with the abdomen and hind legs facing up, remaining partially buried (Figure 2(g)). Silveira et al. [7] also noted that the beetle remains with the hind legs pointing up and suggested that this may be an indication that it is emitting sex pheromones to attract the opposite sex to the nesting site [11].

Finally, the soil is deposited on the surface at the same time that the queen is being buried. Within 24 hours, the beetles, usually one or two individuals, are buried in the chamber next to the brood ball (Figures 2(h) and 2(i)). This study contributes to the knowledge of the predatory behavior *C. virens*, a predator poorly studied in Brazil.

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