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Predation by the Opossum *Didelphis marsupialis* on the Rattlesnake *Crotalus durissus*

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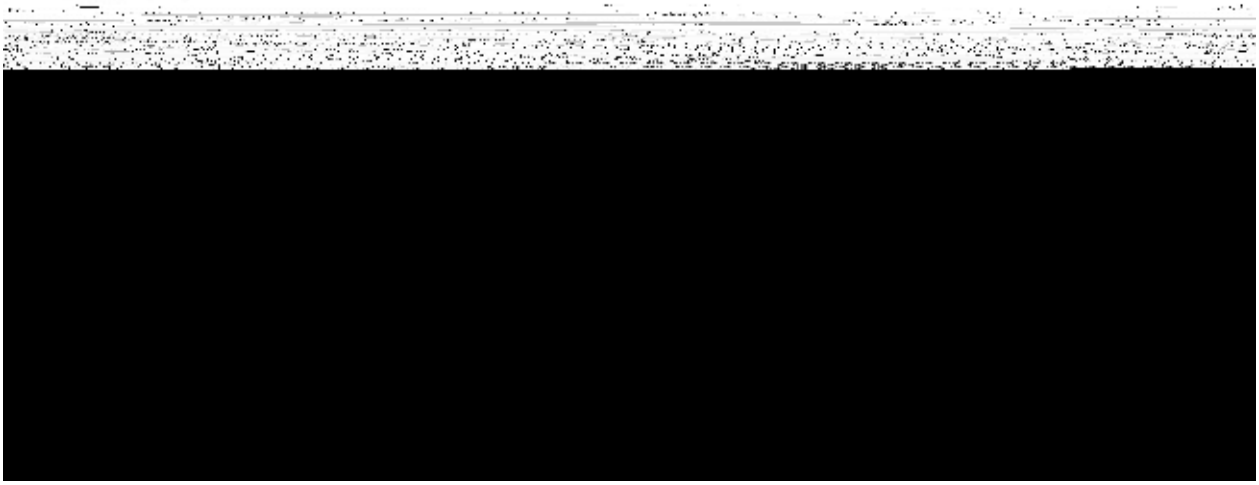
Abstract: **Opossums are considered natural predators of snakes and possess resistance to the venom of some viperids. The resistance of *Didelphis* to *Crotalus* venom has been demonstrated through biochemical and immunological assays. However, systematic observations on the behavior of adult *Didelphis* preying on venomous snakes have never been conducted. In this study the predatory and defensive behaviors of *Didelphis marsupialis* and *Crotalus durissus*, respectively, were analyzed in captivity. Defensive strategies showed by snakes included immobility, flight attempts, coiling, cocking, rattling, and counterattack with strikes and bites. The most common defensive behavior of the rattlesnakes was immobility. The way the opossums attacked was classified in three categories, depending on the defensive reactions presented by the snakes. On all occasions when the opossums were bitten, the injection of venom apparently did not affect the predation. The great ability in capturing and handling *Crotalus durissus* together with the apparent great tolerance to the venom shown by *Didelphis marsupialis* when preying on these snakes confirms the existent biochemical and immunological data about the resistance of opossums to crotalic venoms. In this way our data strongly reinforce the supposition that this species is an effective snake predator in nature.**

Key words: Marsupialia; Behavior; *Didelphis*; Venom; *Crotalus*



1986; Sazima, 1992). In addition, Brodie III (1993) observed attacks of opossums towards snake replicas in the field. At the park of Butantan Institute, São Paulo, Brazil, attacks by native opossums on the outdoor enclosure snakes have been often reported (W. Fernandes, pers. commun.).

A number of studies is available demonstrating that opossums are immune to the venom of some viperids (Domont et al., 1991). Besides the well-known immunity against *Bothrops* venom (Moussatché et al., 1979, 1990; Perales et al., 1994; Neves-Ferreira et al., 1997), resistance of *Didelphis* to the venoms of *Crotalus durissus* (Vellard, 1945; Moussatché et al., 1979, 1990) and *C. atrox* (Werner and Vick, 1977; Perez et al., 1979) has been observed. All these data were obtained from biochemical and immunological assays. Studies about the zoo-

procrypsis (immobility associated with a cryptic coloration pattern), flight, body coiling, cocking (retracting of the coiled body and intimidation with strikes), rattling, head hiding, strikes and bites, and finally emptying of the anal glands. This set of behaviors or, in most cases, the combination of some of them, is sufficient to prevent the snakes from being killed by predators.

This paper describes a behavioral experiment in the laboratory where *Crotalus durissus* was offered to *Didelphis marsupialis*. It aims to understand the defensive and attack strategies of both animals. It also has the intention of comparing the obtained behavioral data with the existent biochemical and immunological information about the resistance of *Didelphis* to *Crotalus* venom. Drawing on these results, this work finally tries to make a few inferences about the predatory and defensive behaviors of these animals in nature.

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METHODS

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ina (1992) made a single observation on the behavior of *Didelphis* toward its prey; his work, however, was not specific to predation. Jared et al. (1998) made a few preliminary observations on young opossums attacking and killing young *Bothrops jararaca* in captivity. Despite the strong supposition about opossums being effective predators of viperids, experimental results demonstrat-

logical implications of this re
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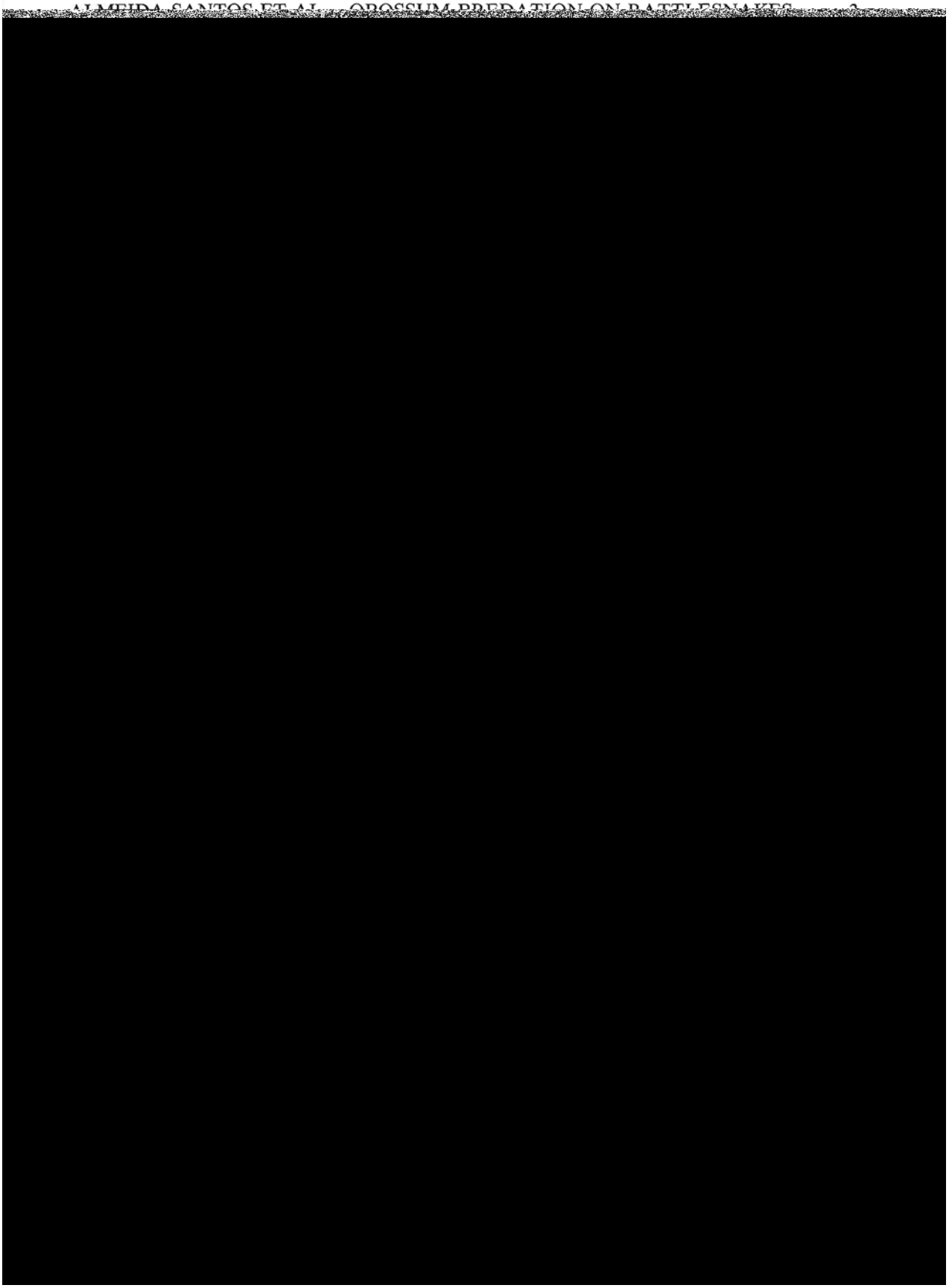

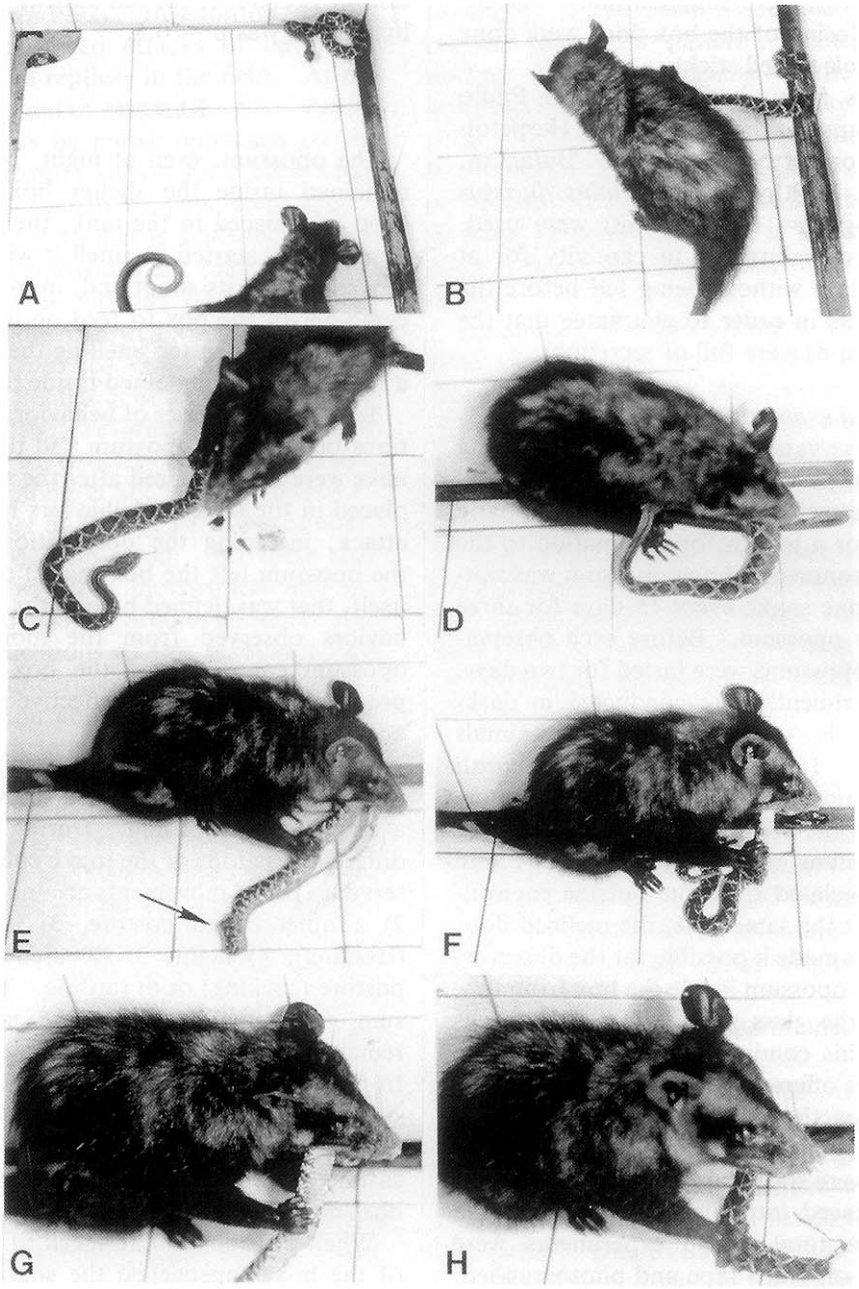

FIG. 1. One of the possible sequences of predatory behaviors of the opossum on the rattlesnake. A: The opossum directly approaches the snake, which remains immobile. B: The opossum captures the snake by the tail. The snake remains passive, flicking the tongue. C: The opossum continues eating the snake from the tail. The snake still flicks its tongue. D: The snake suddenly bites the opossum. E: The opossum reacts, kills the snake by chewing its head (arrow) and bites the rest of the body. F to H: The opossum continues eating the snake from the anterior end. While eating, it remains in the same position (F, G) until it finishes the whole snake (H).

2 summarizes the feeding tactics of the opossums, which depended on the reactions exhibited by the snakes after the initial approach:

(1) The snakes showed an erratic behavior, moving the body by chance in a disoriented manner. In this case, the opossum immobilized them with successive bites along the whole body. Then it consumed them from either the tail or the head.
(2) The snakes were immobile. In this case the opossum consumed them alive, preferentially from the tail (Fig. 1C). Usually the snakes stayed immobile throughout predation. Sometimes, however, the snakes counterattacked with part of their bodies already eaten.
(3) The snakes counterattacked with strikes and bites either just before being captured or having already part of its body eaten from the tail (Fig. 1D). In both cases the opossum killed them by chewing the head, and then immediately consumed them beginning from one of the extremities (Fig. 1E).

Besides these three types of interactions, a few encounters were observed where the opossum and the snake faced each other

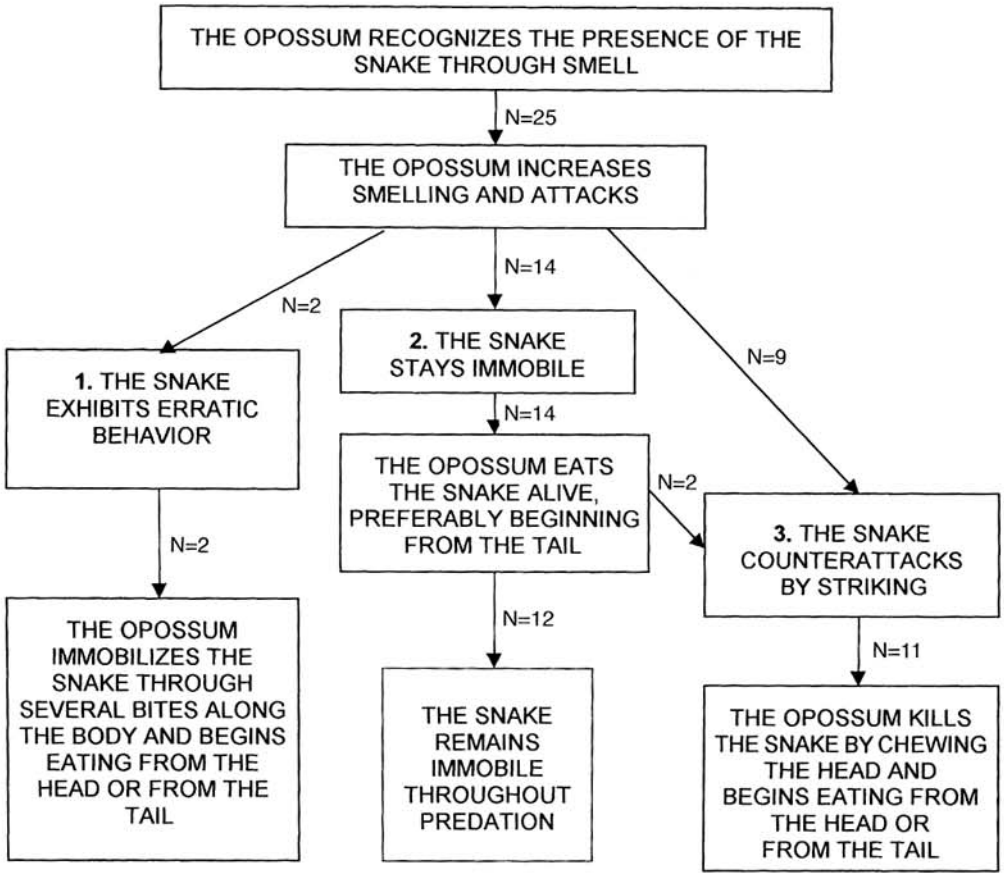

FIG. 2. Scheme of attack and defense strategies in the encounters of opossums and snakes. Three different types of reaction are observed in the rattlesnakes after the first attack by the opossum. N = number of filmed events.

without moving for a long time. The two animals remained in this position until the snake slowly moved backwards.

During predation, the prey handling behavior was quite regular: the opossum remained in a sitting position while holding the snake with one of the forelimbs (Figs. 1F, 1G). One of the ends of the snake was introduced into the mouth laterally and was chewed with the lateral teeth (Figs. 1F, 1G). The other forelimb supported the animal (Figs. 1F, 1G). The forefeet were used alternately but for short periods of time were used together to tear apart the harder parts of the snake. Generally the whole snake was eaten uninterruptedly (Fig. 1H) with an average duration of 12 min.

The opossums killed and ate approximately 80% of the offered rattlesnakes. Taking into account the filmed captures where the attack was directed to the tail or to the head ($N = 22$), the opossums seemed to direct the attack significantly to the tail ($N = 16$; $p < 0.05$, $df = 1$). In three filmed captures the opossums directed the attack to the middle of the body.

During all experiments no observable effects of envenomation were recognized.

Discussion

The way the opossums behaved while eating the snakes was very regular. The opossums were always in the same posture when observed. They used only one forelimb at a time to hold the snake and introduce it into the mouth. Ivanco et al. (1996) also verified the use of a single limb in another opossum species, *Monodelphis domestica*, when feeding or preying, and suggested that this behavior is fixed and species-typical.

During the time preceding the effective predation, when the encounter between opossum and rattlesnake took place, great behavioral variations were noted in both animals.

Before the attack by the opossum, the differences in reaction presented by the rattlesnakes indicated that some times they were not able to notice the opossum, moving calmly around the tank or remaining quietly coiled. Most times, however, the rattlesnakes demonstrated by their behavior that they could recognize the opossum as a predator; in these cases some of the typical behaviors of the defensive escalation of the rattlesnakes were observed, such as immobility, coiling, cocking, and rattling. Among these defensive behaviors, the strategy of immobility in nature can be very valuable when associated with a cryptic coloration pattern and may constitute an efficient defense used by these animals against predators (Greene et al., 1978; Herzog and Drummond, 1984; Cloudsley-Thompson, 1994). Rattling many times occurred despite the snake not being able to see the opossum inside the box. Since it was not observed in any of the control experiments, rattling indicates that most times the snakes seemed to identify somehow the danger, possibly by chemical signs, as proposed by Weldon et al. (1992).

On a significant number of occasions the attack of the opossum was directed to the tail. That was observed more frequently when the rattlesnakes remained immobile, a strategy that at first view is difficult to interpret. On the other hand, during the approach, it was observed on a few occasions that the opossum, when noticing the snake coiling and preparing to strike, rapidly killed it by attacking and chewing its head. The same happened in the few cases when the rattlesnakes were able to bite the opossum even after being captured by the tail. In other cases, when the snake reacted to the attack by exhibiting erratic behavior, it was immobilized through bites along the whole body. The analysis of these different situations observed during the attack indicated that any type of active reaction presented by the snake caused an immediate fatal attack by the opossum. Although in our experimental conditions attacks directed to the tail did not prevent the snake from

being killed by the opossum, in nature they may confer an advantage to the snake, that by remaining immobile has a chance of escaping without being severely injured, as has been already observed for lizards by Greene et al. (1978). These data seem to be in accordance with Herzog and Burghardt (1974), who affirmed that for many predators, prey movement is a critical factor in mediating attack.

In contrast to our results indicating some preference of the opossums for capturing the snakes by the tail, Sazima (1992) reported that *D. marsupialis* when attacking *Bothrops jararaca* usually goes first to the head or neck region. In our experiments with *Crotalus durissus*, in many cases, *Didelphis* grasped the tail first, giving the snakes a chance to bite. This observation, at first view, seems to be contradictory since the predatory behavior of ophiophagous animals (mammals or birds) usually consists in attacking the head or the region just behind the head (Kaufmann and Kaufmann, 1965; Perez et al., 1978). However, ophiophagous animals such as *Conepatus sp.* and *Galicts sp.* have been observed attacking snakes at the tail (Ribeiro, 1940; Jackson, 1979).

It is possible that in our study the apparent preference of *D. marsupialis* for attacking the tail of *C. durissus* may be caused by an attraction of the opossums to cloacal odors of the rattlesnakes that can misdirect the attack. In nature, such attraction of the predator to the tail, which is a more disposable portion of the body, could help the prey to escape or counterattack (Greene, 1988; Alcock, 1993).

Two species of opossums of the genus *Didelphis* occur in Brazil: *D. albiventris* and *D. marsupialis* (Cerqueira, 1985). The former lives in open fields such as "cerrado" and "caatinga" and the latter is distributed in forests (Cerqueira, 1985; Emmons, 1990). On the other hand, *Crotalus durissus* is a species typical of open fields while *Bothrops jararaca* is distributed in forests (Sazima, 1992; Campbell and Lamar, 1989). In this way, one would expect the opossums to have resistance only to snake venoms from the same habitat. In fact, Moussatché et al. (1990) have demonstrated that *D. marsupialis* remains unharmed by *B. jararaca* venom. In addition, they mentioned that this marsupial has partial resistance to *Crotalus durissus* venom. On the basis of this information, our experiments aimed at comparing behavioral results with the biochemical data of Moussatché et al. (1990). Although *D. marsupialis* and *C. durissus* are not sympatric in nature, we observed that, at least in captivity, predation was effective. The injection of venom by snakebites apparently did not affect the predation as has already been observed for other predators, including mammals and birds (Duvall et al., 1985).

In spite of the limitations imposed by a behavioral experiment conducted in captivity, the present observations strongly suggest that *D. marsupialis* is an effective snake predator in nature. This supposition is mainly based on the great interest and ability shown by *D. marsupialis* in capturing *Crotalus durissus*, which were comparable to the interest they showed when presented with different types of food. This idea is also reinforced by the great tolerance these animals showed to the snake venom.

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