

## TAIL LURING BY THE GOLDEN LANCEHEAD (*BOTHROPS INSULARIS*), AN ISLAND ENDEMIC SNAKE FROM SOUTH-EASTERN BRAZIL

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**ABSTRACT.** Herein, we report on direct and indirect evidence of tail luring by the golden lancehead, *Bothrops insularis* (Viperidae), a threatened snake species endemic to a small island off the coast of South-eastern Brazil. Tail luring was recorded for a juvenile male in nature and circumstantial evidence indicates that it was directed to ectothermic prey. Indeed, *B. insularis* juveniles feed on small lizards and frogs and tail luring is probably an important hunting strategy of this species. Adult golden lanceheads prey mostly on birds. A frequently seen characteristic ambush posture, coiled with the conspicuous tail tip exposed close to the head, indicates that they use tail luring as well. Lured birds may peck at a snake's tail, and the high frequency of tail tip injuries in *B. insularis* (20.9%) compared to a continental sister species that rarely preys on birds (*B. jararaca*, 7.3%) strengthens the view that *B. insularis* adults lure birds.

**KEYWORDS.** Viperidae; Feeding Strategy; Caudal Luring; Prey Capture.

### INTRODUCTION

Caudal luring, the wriggling movements of a conspicuous tail tip supposedly mimicking an active insect larva or other crawling invertebrate, is widespread among several snake species, particularly those that feed on ectothermic prey (Neill, 1960; Heatwole and Davidson, 1976; Greene, 1992; Martins and Gordo, 1993; Sazima and Puerto, 1993). Among the neotropical species of *Bothrops* (*sensu lato*, but see Fenwick *et al.*, 2009) tail luring is believed to occur in most species whose juveniles have a whitish/yellowish tail tip and feed on small lizards and/or anurans (Sazima, 1992; Martins *et al.*, 2002). However, the factual observation of tail luring is reported only for *B. atrox* (but see Heatwole and Davidson, 1976), *B. bilineata* (Greene and Campbell, 1972), *B. jararaca* and *B. jararacussu* (Sazima, 1991, 2006), and is recorded for *B. leucurus* and *B. taeniatus* (Martins *et al.*, 2002), and *B. moojeni* (DVA, unpublished) as well. A darker coloration of the tail tip (instead of the usual whitish color) is rarely found among species of *Bothrops* (Sazima, 1991; Martins *et al.*, 2002), but is especially evident in the golden lancehead, *Bothrops insularis*, for which it was previously suggested to be employed to lure birds (Martins *et al.*, 2002).

Herein, we report direct and indirect data on tail luring by the golden lancehead. Since direct observation on tail luring under natural conditions is fortuitous (e.g. Sazima, 1991, 2006), we complemented our behavioral observations (direct evidence) by looking for signs plausibly resulting from attempts to lure birds (indirect evidence). Accordingly, we considered damaged tail tips of preserved snakes as indicative of caudal luring, since birds that forage for insect larvae and other crawling invertebrates may peck at the tail tip while the snake is luring. To explore this hypothesis, we compared the frequency of tail tip injuries between adults of *B. insularis* (which prey mostly on birds and possibly lure them, Martins *et al.*, 2002; Marques *et al.*, 2002) and of *B. jararaca* (whose diet is based on rodents and which rarely prey on birds and most probably do not lure them, see Sazima, 1991; Martins *et al.*, 2002).

### METHODS

#### Study Animal

The golden lancehead, *Bothrops insularis*, is endemic to a small island off the coast of Southeastern

Brazil, Queimada Grande Island (Amaral, 1921; Marques *et al.*, 2002; Martins *et al.*, 2008). On the island, these snakes dwell in lowland Atlantic rain forest, feeding mainly on medium-sized migratory birds as adults, and on frogs, lizards, and centipedes as juveniles (Marques *et al.*, 2002; Martins *et al.*, 2002). A population estimated in 2,500 individuals (Martins *et al.*, 2008) provides one of the highest snake densities in the world. However, due to the very restricted distribution and the indication that population size is declining (Martins *et al.*, 2008), *B. insularis* is presently considered to be critically endangered in the IUCN Red List of Threatened Species (IUCN, 2008).

Molecular data supports the notion that *B. insularis* is a relatively recent isolated derivative of *Bothrops jararaca* (Wüster *et al.*, 2008), whose total geographic isolation happened during sea level rise after the last glaciation about 11,000 years ago (Duarte *et al.*, 1995). Phylogenetic proximity notwithstanding, both species differ considerably in several anatomical and ecological traits (see also Wüster *et al.*, 2005). For instance, *B. insularis* is highly arboreal, has a dark tail tip, and feeds mostly on passerine birds when adult, whereas *B. jararaca* is terrestrial, has a whitish colored tail tip (juveniles only), and feeds mostly on mammals when adult (Martins *et al.*, 2002).

## Study Site

Queimada Grande Island is located about 33 km off the coast of São Paulo state, southeastern Brazil (46°40'W; 24°29'S) within the Environmental Protection Area of Cananéia-Iguape-Peruíbe. The island itself has been attributed the status of Area of Significant Ecological Interest (ARIE) and no other activity, besides scientific research and the regular maintenance of the lighthouse by the Brazilian Navy, are carried out on the island. The total area of Queimada Grande Island is about 0.43 km<sup>2</sup> covered with Atlantic rainforest, typical coastline low vegetation, and secondary grassy fields in process of recovering. The forest covers about 55% of the island area (Martins *et al.*, 2008) and is the main habitat of *B. insularis*. According to the Köppen-Geiger's system (Peel *et al.*, 2007), the climate at Queimada Grande Island is wet tropical "Af" type. Mean air temperature varies from 27°C (21 to 38°C, min-max) during the warm summer months to 18°C (15 to 27°C, min-max) during the cold winter months (Bovo *et al.*, unpublished data).

## Data Collection

Behavioral observations were made during field expeditions to Queimada Grande Island, which happened regularly over the last few years (ten excursions from 2007 to 2009) and typically lasted 3-5 days. These expeditions were aimed toward the study of broad aspects of the biology of the golden lancehead by a diverse group of researchers. In general, snakes were searched for along a main transect (~ 1300 m; a description of this trail is provided by Martins *et al.*, 2008), at different times of the day. For every snake found, we recorded biometrical data (snout-vent length – SVL, tail length – TL, body mass), sex, reproductive status, stomach content, microhabitat use, time of day, and body temperature. Before handling, we recorded posture and behavior (defensive and predatory), whenever the snakes remained undisturbed after spotted. The whole behavioral dataset obtained will not be treated here in any detail since the present study will focus on the record of caudal luring by *B. insularis*.

Data on tail injury frequency were obtained from preserved specimens of *B. insularis* (n = 110) and *B. jararaca* (n = 110) housed at the herpetological collection of the Instituto Butantan (IBSP) in São Paulo, Brazil. The specimens were randomly selected from the collection and included adult snakes only. For each individual we recorded SVL, TL to the nearest millimeter, sex, and the state of tail tip (as either intact or mutilated). Preserved specimens of *B. insularis* were from Queimada Grande Island while those of *B. jararaca* came from various localities along the geographic distribution of the species (see Campbell and Lamar, 2004), mainly south and southeastern Brazil. Only specimens preserved without having been kept previously in captivity (and that could have had their tail injured under this condition) were examined. We compared the difference in the proportion of snakes with mutilated tails between *B. jararaca* and *B. insularis* using a Chi-square test with Yates correction for continuity. Differences were considered to be statistically significant at  $P \leq 0.05$  (Sokal and Rohlf, 1995).

## RESULTS

In the ten field expeditions we found a total of 406 snakes in typical ambush posture (see Oliveira and Martins, 2002) in various microhabitats, including on the forest floor, over fallen tree trunks or rocks, and



FIGURE 1. An adult female *Bothrops insularis* coiled in ambush posture on the forest floor, possibly ready to lure with its tail (note the exposed dark tip close to the head; Photo by M. Martins).

over tree branches at heights varying from few centimeters to about 10 m at different times of the day. Ambush posture was characterized by the snake's snout or anterior part of the head held away from the body coils, and in four instances we found snakes in a posture suggestive of caudal luring (Figure 1), with the conspicuous tail tip held close to the head (see Sazima, 2006 for both ambush and tail-luring postures in *B. jararaca*). Natural predation was observed only four times toward birds. In these occasions, the snake was swallowing the prey on vegetation ( $n = 2$ ) or on the forest floor ( $n = 1$ ) or it was inspecting the bird on the ground, flicking its tongue and touching the prey ( $n = 1$ ). In four instances, juvenile snakes found in ambush posture were offered (staged encounters) live frogs, *Haddadus binotatus*, which occur on the island and have been recorded in the diet of *B. insularis*. In all instances the snakes moved towards the prey, struck the offered frog and tried to swallow it (two individuals completed ingestion), but in no case did they display caudal luring.

On 29 October 2009, we recorded a juvenile male (SVL = 481 mm, tail = 87 mm, conspicuous dark portion of the tail = 31 mm) displaying tail luring behavior. The snake was first located at 14:30 h coiled on the branches of a small tree about 30 cm above the ground (total height of the tree about 4 m) on a cloudy day, with intermittent periods of light rain. The same individual was sighted again at 22:40 h, in the same general posture and condition (air temperature = 19°C), but this time the whole tail was resting on top of the head, which was positioned over and away from the body coils. The tail was held straight and the tail tip was pointing toward the snake's snout.



FIGURE 2. A juvenile male *Bothrops insularis* coiled on vegetation wiggles the darker tip of its tail to lure prey (droplets on snake are raindrops; Photo by D. V. Andrade).

A few frogs (*Haddadus binotatus*) were noticed calling nearby. Upon indirect illumination with a headlamp, the snake started to wriggle the tail laterally, waving the very tip of the conspicuously dark portion of the tail ( $< 5$  mm) from one side to the other. The tail was kept most of the time on the top of the snake's head (Figure 2). Occasionally, wider movements brought the tail laterally to the head where the wriggling movements were resumed over the body coils until the tail tip was back to its initial position. After we ended the observations, we offered a freshly dead frog (*H. binotatus*), which was successfully struck but then dropped to the ground. However, after the strike, the snake displayed SICS behavior (Strike Induced Chemosensory Search, see Chiszar *et al.*, 1982), scanning the surroundings while tongue flicking. The frog was offered to the snake again, but the snake was clearly disturbed and fled.

Out of the 220 examined snakes (110 *B. insularis*, 110 *B. jararaca*), 23 specimens of *B. insularis* (20.9%) had the tail tip missing and/or scars from healed wounds. In contrast, tail tip mutilation was recorded for only eight specimens of *B. jararaca* (7.3%). The frequency of tail mutilation was significantly different between the two species ( $\chi^2 = 7.36$ ;  $P = 0.007$ ).

## DISCUSSION

Tail luring behavior by the golden lancehead, *B. insularis*, is herein documented for the first time, although its occurrence was anticipated by Martins *et al.* (2002). Indeed, tail luring is expected to be



displayed by all *Bothrops* species that have a conspicuous tail tip, probably an ancestral trait for this group (Sazima, 1992; Martins *et al.*, 2002) and our observation strengthens this view. The luring movements of the golden lancehead's tail were stereotyped and similar to those described for *B. jararaca* and other *Bothrops* species (Sazima, 1991, Martins *et al.*, 2002). Moreover, similarly to what is usually reported for juveniles of other *Bothrops* species, we believe that tail luring by the golden lancehead was directed to ectothermic prey, since it was observed at night with potential prey (frogs and geckos) present in the neighborhood and, when offered a frog, the snake tried to feed on it. Additionally, frogs and small nocturnal lizards (geckos) are found in the diet of juvenile and adult golden lanceheads (OAVM, unpublished) and their capture could be facilitated by tail luring. Nonetheless, we note that in four staged encounters with frogs, *B. insularis* juveniles did not display tail luring. Thus, this behavior is not always used for prey capture by juvenile *B. insularis*, similarly to what has been reported for juvenile *B. jararaca* under natural conditions (Sazima, 2006), and observed for *B. moojeni*, *B. jararaca*, and *B. jararacussu* in captivity (DVA personal observation).

Besides *B. insularis*, adults of two additional pitviper species, *B. bilineata* and *B. itapetiningae*, also retain the distinctly colored tail tip of juveniles (Greene and Campbell, 1972; our unpublished observations). However, in these two species the colored tail tip of adults (and probably caudal luring behavior) is likely associated with high proportion of ectothermic prey (Martins *et al.*, 2002). In contrast, the conspicuous dark tail tip of the golden lancehead adults is thought to be used to attract passerine birds that compose the bulk of their diet (Martins *et al.*, 2002). We failed to obtain a direct evidence of tail luring by *B. insularis* adults, but the ambush posture with exposed dark tail tip close to the head in some individuals strengthens the view that adults of this species also lure their prey. The fortuitousness of such behavior and the fact that it is displayed only by some individuals (see Reiserer and Schuett, 2008) makes the documentation of this behavior by *B. insularis* adults a challenge.

Possibly introduced by Rand (1954), tail injury frequency is largely used as an indication of predation pressure in herpetological studies (see Arnold, 1994). However, this estimate is based on a number of important assumptions, and injury frequency can be misleading to indicate intensity of some injury-producing processes such as predation. Herein, we found a significantly higher proportion of *B. insularis*

individuals with mutilated tails when compared to its continental sister species, *B. jararaca*. This could indicate that: 1 = Absolute predation intensity is higher at Queimada Grande Island compared to the habitats occupied by *B. jararaca*; 2 = Predation intensity is similar for both species, but predator efficiency is higher for *B. jararaca* (therefore leaving less survivors bearing injuries in the population); 3 = Predation is similar (in both intensity and efficiency) for *B. jararaca* and *B. insularis*, but snakes differ in age structure (as tail injury frequency determined at adulthood will depend on the accumulation of failed predation attempts, differences in age structure will affect tail injury frequencies) (see Schoener, 1979; Arnold, 1994). Finally, everything being equal, tail injury frequency will differ depending on the conspicuousness of this body part, which provides the rationale of our argumentation on the use of tail injury frequency as an indication of tail luring (see Arnold, 1994, for a discussion about a similar approach). It seems beyond doubt that a conspicuous colored wriggling tail will be more attractive to other animals – which is, indeed, the meaning of the behavior itself – than a non-conspicuous, still tail. In fact, luring snakes are known to stop this behavior in the presence of a potential predator (see also Reiserer and Schuett, 2008). Thus, while acknowledging the fact that differences in tail injury frequency are likely to involve all the factors commented above in complex combinations, we raise the possibility (amenable to tests in the future), that the higher frequency of tail injuries observed in *B. insularis*, as compared to *B. jararaca*, may be related to the fact that lured birds peck at the snakes' tails.

The presence of tail luring in *B. insularis* implies that this behavior was conserved during the differentiation of this insular species following its isolation from the continental sister species, *B. jararaca*, in the last 11,000 years (Marques *et al.*, 2002, see also Marques and Sazima [2009] for discussion on conservatism of prey handling behavior by this species). The caudal luring behavior was preserved during the coloration changes that lead to the inversion of the general/ancestral color pattern of the skin (dark to pale) and the tail (pale to dark) (see also Martins *et al.*, 2002). Tail coloration, however, seems to be less important than tail movements for the attraction of potential prey items (Nelson *et al.*, 2010) and experimental manipulation of tail coloration did not affect growth rate and, possibly, luring efficiency in pigmy rattlesnakes (Farrell *et al.*, in press). Thus, it remains debatable whether a darker tail tip in contrast to pale skin coloration (pale gold in *B. insularis*)

would be more effective in attracting diurnal prey, such as birds, whereas a pale tail tip would be more effective in attracting nocturnal prey such as anurans. If that is the case, then the darker coloration of *B. insularis* tail tip may represent a change in tradeoffs and/or differences in the sensory and neural recognition of the signal (tail luring) by the receivers (prey), as its diet becomes more specialized in birds at adulthood (see Reiserer and Schuett, 2008; Nelson *et al.*, 2010). Although adaptive factors involved in the determination of animal coloration are complex and difficult to untangle, differences in tail luring efficiency under different conditions and toward different prey types (e.g., Sazima, 2006) should be considered in the discussion of tail/body color and luring behavior in snakes.

# RESUMO

O presente estudo registra evidências diretas e indiretas da ocorrência de engodo caudal na jararaca-ilhoa, *Bothrops insularis* (Viperidae), espécie criticamente ameaçada e endêmica de uma pequena ilha do litoral sudeste do Brasil. O engodo caudal foi registrado na natureza em um macho jovem em situação que indica seu emprego para atração de presas ectotérmicas. De fato, jovens de *B. insularis* alimentam-se de pequenos anuros e lagartos, cuja captura é facilitada pelo engodo caudal. Adultos da jararaca-ilhoa apressam principalmente aves. A postura de caça observada para adultos, enrodilhados com a ponta conspícua da cauda exposta próxima à cabeça, indica que o engodo caudal também é empregado para atração de aves. As aves atraídas por engodo caudal devem bicar a cauda das serpentes. A alta frequência de mutilação registrada na cauda de *B. insularis* (20.9%), comparada com a espécie-irmã continental (*B. jararaca*, 7.3%) que raramente apressa aves, fortalece a idéia de que os adultos de *B. insularis* usam engodo caudal para a atração de aves.

# ACKNOWLEDGMENTS

We thank M. Martins for the photo of an adult lancehead in ambush posture; R. Bovo, K. Kasperoviczus, A. Mendes, S. Serrano Filho, and M. Rodrigues for valuable help in the field. This study was supported by grants from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (DVA), from the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) (DVA, RSBG, and OAVM), and Fundação para o Desenvolvimento da Unesp (FUNDUNESP) (DVA).

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- Submitted 19 May 2010  
Accepted 29 November 2010