Herpetology Notes, volume 10: 335-338 (2017) (published online on 29 June 2017)

Feeding on elongate prey: additional data for the coral snake *Micrurus corallinus* (Merrem, 1820) (Elapidae) and comments on aposematism

Karina Rodrigues da Silva Banci[1,*], Natália F. Torello-Viera[1], Antonio Carlos Freitas[2] and Otavio A. V. Marques[1]

Ophiophagy is widespread and relatively well documented in snakes, being estimated that around 20% of the Alethinophidia feed on snakes (Colston *et al.*, 2010). Among them, the genus *Micrurus* may be highlighted, since they often feed on snakes (Greene, 1984; Roze, 1996). However, many species feed on other elongate prey (Almeida et al., 2016), as fishes, but mainly fossorial caecilians, amphisbanians, and lizards. The coral snake *Micrurus corallinus* (Merrem, 1820), from the Brazilian Atlantic Forest, fits within this pattern, since its diet is composed of fossorial elongate prey, including amphisbaenians (69.3%), lizards (12.7%), caecilians (9.6%), and snakes (8.6%; Marques and Sazima, 1997).

Feeding behavior of *Micrurus* has been observed in captive snakes usually on the ground (Greene, 1984; Marques and Sazima, 1997). Predation events by *Micrurus* are rare to be observed in nature (Maffei *et al.*, 2009). Here we report an underground feeding in the wild, and discuss the possible relationship between eating elongated prey and the aposematism in coral snakes.

A male *M. corallinus* (total length ~ 600 mm) was found in the afternoon of September 21st, 2006, feeding on an amphisbaenian (*Leposternon microcephalum* Wagler, 1824) on the edge of a trail within forest at Reserva Biológica União – IBAMA, Municipality of Casimiro de Abreu, Rio de Janeiro (22.4264°S, 42.0344°W). The anterior part of the snake's body was inside a hole in a ravine (Fig. 1A), where it captured the amphisbaenian, and dragged it out (Fig. 1B) for subsequently swallowing it (Fig. 1C). The tail-first ingestion started at 4:36 p.m. (Fig. 1A), and lasted until 5:18 p.m. (Fig. 1D), after which the animal moved away through the surrounding vegetation. Based on the photos (see Fig. 1D), we estimate, that the relation total prey length / predator snout-vent length was at least 0.5. Tail-first ingestion in *M. corallinus* may be associated with underground feeding, and was observed in 40% of the *M. corallinus* with amphisbaenians in their guts (Marques and Sazima, 1997). In the present observation, the amphisbaenian was in a burrow, a circumstance that probably caused the tail-first ingestion. Ingestion time may be determined by several factors, such as the relation prey mass/predator mass or prey length/predator length, prey type, venom toxicity of the predator, or risk of retaliation offered by the prey (Greene, 1983; De Queiroz, 1984; Rodríguez-Robles and Leal, 1993). It is well known that the kinetic skull of advanced snakes, together with the absence of an anterior symphysis in the lower jaws, allow the ingestion of preys that are large in relation to the predator's head size (Colston et al., 2010). In the case of ophiophagous snakes, which may eat preys as long as, or even longer than, themselves, the head size is not the constraint. However, ingestion time is long due to the prey's length. In the event reported herein, the swallowing lasted at least 42 minutes.

In comparison, some snakes that feed on non-elongate preys, such as *Crotalus durissus* (Linnaeus, 1758), take from 3 to 12 min to subdue and ingest mice which weigh 50% of their own body mass, whether adults or juveniles (Cruz-Neto *et al.*, 1999; 2001). These same authors have also shown that aglyphous snakes, such as *Boa constrictor*, that do not rely on a powerful venom to subdue prey, need from 11 to 35 min to eat

[1] Laboratório de Ecologia e Evolução, Instituto Butantan, CEP: 05503-900 , São Paulo, Brazil
[2] Laboratório de Radioecologia e Mudanças Globais (LARAMG), Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil
* Corresponding author e-mail: karina.banci@butantan.gov.br

Table 1. Species of snakes, their preys, and time required to ingest them.

SNAKE SPECIES	TYPE OF PREY	FEEDING TIME (min.)*	FEEDING STAGES	REFERENCE
Thamnophis sirtalis	earthworm	2.22–8.34	subjection + ingestion	(Burghardt and Krause, 1999)
Dipsas indica	snail	1.17–5.42	subjection + ingestion	(Sazima, 1989)
Nerodia fasciata	fish	0.20–2.39	ingestion	(Vincent *et al.*, 2006)
Thamnophis sirtalis	fish	2.59–8.87	subjection + ingestion	(Burghardt and Krause, 1999)
Alsophis portoricensis	frog	13.14	subjection + ingestion	(Rodríguez-Robles and Leal, 1993)
Nerodia fasciata	frog	2.33–9.47	ingestion	(Vincent *et al.*, 2006)
Thamnodynastes strigatus	frog	10	ingestion	(Bernarde *et al.*, 2000)
Boa constrictor	mouse	11–35	subjection + ingestion	(Cruz-Neto *et al.*, 2001)
Crotallus durissus (adult)	mouse	3–12	subjection (negligible) + ingestion	(Cruz-Neto *et al.*, 2001)
Crotallus durissus (juvenile)	mouse	3–12	subjection (negligible) + ingestion	(Cruz-Neto *et al.*, 1999)
Elaphe climacophora	mouse	4.91–9.15	ingestion (head-first and tail-first, respectively)	(Diefenbach and Emslie, 1971)
Elaphe helena	mouse	3.33–14.17	subjection + ingestion	(Mehta, 2003)
Pituophis melanoleucus	mouse	5.93	subjection + ingestion	(De Queiroz, 1984)
Pituophis melanoleucus	rat	2.2	subjection + ingestion	(De Queiroz, 1984)
Bothrops jararaca	mouse and rat	2.08–5	ingestion	(Sazima, 1989)
Alsophis portoricensis	lizard	12.64	subjection + ingestion	(Rodríguez-Robles and Leal, 1993)
Masticophis flagellum	lizard	2.9–8.8	subjection + ingestion	(Jones and Whitford, 1989)
Micrurus frontalis	lizard	17	ingestion (interrupted)	(Maffei *et al.*, 2009)
Drymarchon corais	amphisbaenian	40	ingestion	(Campos *et al.*, 2010)
Clelia equatoriana	snake	26	subjection + ingestion	(Rojas-Morales, 2013)
Erythrolamprus aesculapii	snake	4–180	ingestion	(Marques and Puorto, 1994)
Lampropeltis getula	snake	18–90	ingestion	(Jackson *et al.*, 2004)
Micrurus albicinctus	snake	40	ingestion	(Souza *et al.*, 2011)
Micrurus corallinus (juvenile)	snake	35.5–37.8	ingestion	present work
Micrurus corallinus (adult)	snake	42	ingestion	present work

* Times were all converted to minutes, in order to facilitate comparison.

mice weighing 40% of their own weight. Concerning *Micrurus*, even though they have a very powerful neurotoxic venom, such as *Micrurus corallinus* (Brazil, 1987), the necessary time for subduing and ingesting prey is longer. Like the adult male observed in the present episode, two captive juveniles of *Micrurus corallinus* required a long time for directing and swallowing the preys (pers. obs.). One of them took 35:30 min for eating a *Sibynomorphus mikanii* (Schlegel, 1837) 40% of its own weight, and the other, 37:50 min for eating a *Erythrolamprus miliaris* (Linnaeus, 1758) 50% its own weight. This data, together with other information available from the literature, evince that ophiophagy and ingestion of elongate prey in general require a longer time, especially when compared to other venomous species of snakes which feed on non-elongate prey, such as *C. durissus* (see Table 1).

Accordingly, an overview of the time required to ingest different kinds of prey suggests that more time is required in the case of elongate prey items, such as snakes or amphisbaenians (Table 1). This suggestion is even more concise when the relation prey/predator weight is considered. The long time necessary to swallow elongate prey, as well as its postprandial condition (which may hinder locomotion) may decrease the defensive ability of the snake (Garland Jr. and Arnold, 1983; Ford and Shuttlesworth, 1986; Mehta, 2006). Thus, we may consider that there is a higher risk of predation on those snakes that consume elongate prey.

The aposematism of *Micrurus* snakes has long been noticed (Wallace, 1867) and the effectiveness of their coral pattern to avoid predators has been verified by several experiments with replicas (Brodie III, 1993; Pfennig et al., 2001; Buasso et al., 2006; Kikuchi and Pfennig, 2010). Additionally, it might be taken into account the protectiveness that the *Micrurus*-like pattern may provide even to other species, that are considered their mimics, and that also feed on elongate preys. This may be the case for *Erythrolamprus aesculapii*, *Phalotris mertensi*, *Boiruna maculata*, and juveniles of *Clelia* spp. (Marques, 1992; Savage and Slowinski, 1992; Marques and Puorto, 1994; Pinto and De Lema,

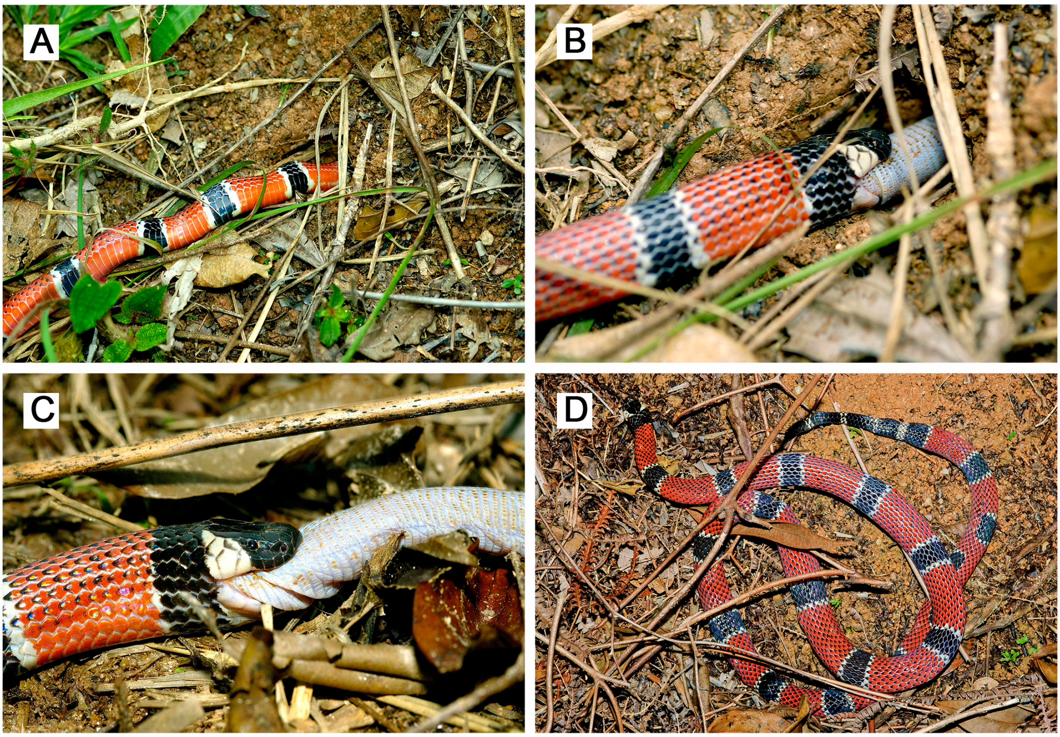

Figure 1. Male of *Micrurus corallinus* capturing the amphisbaenian inside a burrow (A), dragging the prey out of the burrow (B), swallowing the amphisbaenian, tail-first (C), and after finishing ingesting the amphisbaenian (D). Photos by: Antonio Carlos Freitas.

2002; Duarte, 2006; Delia, 2009), among many others. The ophiophagous *E. aesculapii*, for instance, is a diurnal species (Torello-Viera & Marques, in press) which may take up to 180 min to ingest a prey of 80% its own size (Marques and Puorto, 1994). This represents a long time during which the snake is highly vulnerable to predators. Thus, it seems plausible to suppose that bearing a coral pattern is highly adaptive for snakes that feed on elongate prey.

Acknowledgements. We thank Cristiene Rodrigues Martins, for helping with photo edition.

References

Almeida, P.C.R., Prudente, A.L.C., Curcio, F.F., Rodrigues, M.T.U. (2016): Biologia e história natural das cobras-corais. In: As Cobras-Corais do Brasil - Biologia, Taxonomia, Venenos e Envenenamentos, p. 169–215. Da Silva Jr., N.J., Ed., Goiânia, Brazil, PUC–Goiás.

Bernarde, P., Moura-Leite, J.C., Machado, R.A., Kokobum, M.N.C. (2000): Diet of the colubrid snake, *Thamnodynastes strigatus* (Günther, 1858) from Paraná State, Brazil, with field notes on anuran predation. Revista Brasileira de Biologia **60(4)**: 695–699.

Brazil, O.V. (1987): Coral snake venoms: Mode of action and pathophysiology of experimental envenomation. Revista Do Instituto De Medicina Tropical De Sao Paulo **29(3)**: 119–126.

Brodie III, E.D. (1993): Differential avoidance of coral snake banded patterns by free-ranging avian predators in Costa Rica. Evolution **47(1)**: 227–235.

Buasso, C.M., Leynaud, G.C., Cruz, F.B. (2006): Predation on snakes of Argentina: Effects of coloration and ring pattern on coral and false coral snakes. Studies on Neotropical Fauna and Environment **41(3)**: 183–188.

Burghardt, G.M., Krause, M.A. (1999): Plasticity of foraging behavior in garter snakes (*Thamnophis sirtalis*) reared on different diets. Journal of Comparative Psychology **113(3)**: 277–285.

Campos, V.A., Oda, F.H.; Curcino, A.F.; Curcino, A. (2010): An unusual prey item for the yellow tail cribo *Drymarchon corais* Boie 1827, in the Brazilian Savannah. Herpetology Notes **3**: 229–231.

Colston, T.J., Costa, G.C., Vitt, L.J. (2010): Snake diets and the deep history hypothesis. Biological Journal of the Linnean

Society **101(2)**: 476–486.

Cruz-Neto, A.P., Andrade, D.V., Abe, A.S. (1999): Energetic cost of predation: Aerobic metabolism during prey ingestion by juvenile rattlesnakes, *Crotalus durissus*. Journal of Herpetology **33(2)**: 229–234.

Cruz-Neto, A.P., Andrade, D.V., Abe, A.S. (2001): Energetic and physiological correlates of prey handling and ingestion in lizards and snakes. Comparative Biochemistry and Physiology A-Molecular and Integrative Physiology **128(3)**: 515–533.

De Queiroz, A. (1984): Effects of prey type on the prey-handling behavior of the bullsnake, *Pituophis melanoleucus*. Journal of Herpetology **18(3)**: 333–336.

Delia, J. (2009): Another crotaline prey item of the Neotropical snake *Clelia clelia* (Daudin 1803). Herpetology notes **2**: 21–22.

Diefenbach, C.O., Emslie, S.G. (1971): Cues influencing the direction of prey ingestion of the Japanese snake, *Elaphe climacophora* (Colubridae, Serpentes). Herpetologica **27(4)**: 461–466.

Duarte, M.R. (2006): *Phalotris mertensi* (False coral snake) and *Amphisbaena mertensi* (NCN). Predation. Herpetological Review **37**: 234.

Ford, N.B., Shuttlesworth, G.A. (1986). Effects of variation in food-intake on locomotory performance of juvenile garter snakes. Copeia **4**: 999–1001.

Garland Jr., T., Arnold, S.J. (1983): Effects of a full stomach on locomotory performance of juvenile garter snakes (*Thamnophis elegans*). Copeia **4**: 1092–1096.

Greene, H.W. (1983): Dietarey correlates of the origin and radiation of snakes. American Zoologist **23(2)**: 431–441.

Greene, H.W. (1984): Feeding behavior and diet of the eastern coral snake, M*icrurus fulvius*. In: Vertebrate ecology and systematics: a tribute to Henry S. Fitch, p. 147–162. Seigel, R.A., Hunt, L.E., Knight, J.L., Malaret, L., Zuschlag, N.L., Ed., Kansas, Museum of Natural History, University of Kansas.

Jackson, K., Kley, N.J., Brainerd, E.L. (2004): How snakes eat snakes: the biomechanical challenges of ophiophagy for the California kingsnake, *Lampropeltis getula californiae* (Serpentes : Colubridae). Zoology **107(3)**: 191–200.

Jones, K.B., Whitford, W.G. (1989): Feeding behavior of free-roaming *Masticophis flagellum*: an efficient ambush predator. Southwestern Naturalist **34(4)**: 460–467.

Kikuchi, D.W., Pfennig, D.W. (2010): Predator Cognition Permits Imperfect Coral Snake Mimicry. American Naturalist **176(6)**: 830–834.

Maffei, F., Do Nascimento, G.R., Neto, D.G. (2009): Predation on the lizard *Ameiva ameiva* (Sauria: Teiidae) by a coral snake *Micrurus frontalis* (Serpentes: Elapidae) in Brazil. Herpetology Notes **2**: 235–237.

Marques, O.A.V. (1992): História natural de *Micrurus corallinus* (Serpentes, Elapidae). Master Dissertation, Univesidade de São Paulo, São Paulo, 89 pp.

Marques, O.A.V., Puorto, G. (1994): Dieta e Comportamento alimentar de *Erythrolamprus aesculapii*, uma serpente ofiófaga. Revista Brasileira de Biologia **54(2)**: 253–259.

Marques, O.A.V., Sazima, I. (1997): Diet and feeding behavior of the coral snake, *Micrurus corallinus*, from the Atlantic forest of Brazil. Herpetological Natural History **5(1)**: 88–93.

Mehta, R.S. (2003): Prey-handling behavior of hatchling *Elaphe helena* (Colubridae). Herpetologica **59(4)**: 469–474.

Mehta, R.S. (2006): Meal size effects on antipredator behavior of hatchling trinket snakes, *Elaphe helena.* Ethology **112(7)**: 649–656.

Pfennig, D.W., Harcombe, W.R., Pfennig, K.S. (2001): Frequency-dependent batesian mimicry - Predators avoid look-alikes of venomous snakes only when the real thing is around. Nature **410 (6826)**: 323–323.

Pinto, C..C., De Lema, T. (2002): Comportamento alimentar e dieta de serpentes, gêneros *Boiruna* e *Clelia* (Serpentes, Colubridae). Iheringia. Série Zoologia **92**: 9–19.

Rodríguez-Robles, J.A.; Leal, M. (1993): Effects of prey type on the feeding behavior of *Alsophis portoricensis* (Serpentes, Colubridae). Journal of Herpetology **27(2)**: 163–168.

Rojas-Morales, J.A. (2013): Description of ophiophagy in *Clelia equatoriana* (Amaral, 1924)(Serpentes: Dipsadidae) in captivity. Herpetology Notes **6**: 425–426.

Roze, J.A. (1996): Coral snakes of the Americas: biology, identification, and venoms, 1st Edition. Florida, Krieger Publishing Company.

Savage, J.M.; Slowinski, J.B. (1992): The coloration of the venomous coral snakes (Family Elapidae) and their mimics (Families Aniliidae and Colubridae). Biological Journal of the Linnean Society **45(3)**: 235–254.

Sazima, I. (1989): Comportamento alimentar da jararaca *Bothrops jararaca*: encontros provocados na natureza. Ciência e Cultura **41(5)**: 500–505.

Souza, S.M., Junqueira, A.B., Jakovac, A.C.C., Assunção, P.A., Correia, J.A. (2011): Feeding behavior and ophiophagous habits of two poorly known amazonian coral snakes, *Micrurus albicinctus* Amaral 1926 and Micrurus paraensis Cunha and Nascimento 1973 (Squamata, Elapidae). Herpetology Notes **4**: 369–372.

Torello-Viera, N.F., Marques, O.A.V. (*in press*): Daily activity of Neotropical Dipsadid Snakes. South American Journal of Herpetology.

Vincent, S.E., Moon, B.R., Shine, R., Herrel, A. (2006): The functional meaning of "prey size" in water snakes (*Nerodia fasciata*, Colubridae). Oecologia **147(2)**: 204–211.

Wallace, A.R. (1876): Mimicry, and other protective resemblances among animals. Westminster and Foreign Quarterly Review **32**: 1–43.

Accepted by Mirco Solé