

## Noteworthy dietary records of the Variable Coral Snake *Micrurus diastema* (Serpentes: Elapidae) in America

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Received: 09. April 2020 / Accepted: 23. March 2021 / Available online: 25. March 2021 / Printed: June 2021

**Abstract.** Diet is an essential component of the natural history and ecology of organisms. Many snake species' trophic ecology is poorly characterized, mainly because predation events are rarely documented in nature. The diet of *Micrurus diastema* has been reported so far to include only other snakes. To obtain further knowledge on the species diet, we performed intermittent field excursions in Veracruz, Mexico, and surveyed published information for this snake in Mexico. Thereby, we report four items of prey in the diet of *M. diastema*, three of which are previously unreported, including a lizard (Sauria: *Holcosus amphigrammus*, Serpentes: *Amerotyphlops tenuis*, and *Drymarchon melanurus*); the fourth prey previously reported is another snake (Serpentes: *Coniophanes imperialis*). Our results extend the knowledge on the Variable Coral Snake's trophic ecology in the northern extreme of its geographical distribution in Mexico.

**Key words:** *Amerotyphlops*, diet, *Drymarchon*, *Holcosus*, predator, prey.

### Introduction

The New World coral snakes are represented by two genera (*Micruroides* and *Micrurus*) and 89 species that inhabit tropical and subtropical regions in the Americas (Castoe et al. 2007, Uetz 2020). The species of this genus are venomous and consume vertebrate and invertebrate prey (Roze 1996, Campbell & Lamar 2004). The diet of some *Micrurus* spp., such as the Eastern Coral Snake *M. fulvius* (Linnaeus, 1766), Texas Coral Snake *M. tener* Baird & Girard, 1853 and Double-Banded Coral-Snake *M. altirostris* (Cope, 1860), is well-documented (Jackson & Franz 1981, Greene 1984, Roze 1996, Reams et al. 1999, da Silva & Aird 2001, Campbell & Lamar 2004). However, little is known about the feeding ecology of many other coral snakes due to their elusive behavior and fossorial habits (Cavalcanti et al. 2010).

The Variable Coral Snake, *M. diastema* (Duméril, Bibron & Duméril, 1854), is a medium-sized snake (average total length: 600–750 mm but can exceed 900 mm); it occurs along the Atlantic Coast from the center of the state of Veracruz in Mexico to northwestern Honduras (Campbell & Lamar 2004). However, a recent molecular study of the species changed its taxonomy, suggesting a separation of species and reducing the number of taxa as well as their geographic distribution for the *M. diastema* group (Reyes-Velasco et al. 2020), restricts its distribution only to the low and moderate elevations of the Atlantic drainage from central Veracruz, Tabasco, and northern Oaxaca, which was formerly the distribution of *M. d. diastema*, *M. d. affinis*, and *M. d. macdougalli* (Campbell & Lamar 2004). The Variable Coral Snake *M. diastema* occurs in the tropical rain forest and deciduous forest at lowlands and cloud forest and mixed forest at highlands (Campbell & Lamar 2004, Reyes-Velasco et al. 2020). The records in the literature about the diet of *Micrurus diastema* are scarce and only include snakes (Rodríguez-García et al. 1998, West et al. 2019). Therefore, the present contribution is relevant because we point out the records of items unreport-

ed in the literature about the diet of *M. diastema*, three of which are previously unreported in this coral snake's diet.

### Material and Methods

#### Study area

We performed intermittent field sampling, specifically for *M. diastema* from 2011 to 2016, in the municipalities of Atoyac and Amatlán de Los Reyes in the region known as "the High Mountains" and in the Actopan municipality in the Coastal Plain of the Gulf, both regions in central Veracruz state, Mexico (Fig. 1). These municipalities are dominated by tropical, subtropical, and semi-temperate vegetation, including cloud mountain forest and tropical deciduous forest; mono- and polycultures are also present, mostly sugar cane and citrus trees (INEGI 2016). The study area encompasses elevations from sea level (e.g., Actopan) to 1600 meters above sea level (m a.s.l.) (e.g., Atoyac). The average rainfall varies between 800 and 1500 mm yearly; the average temperature ranges between 20 °C in the upper part of Atoyac and 28 °C in Actopan (García 2004).

#### Diet data review

Considering the new reclassification of the species (Reyes-Velasco et al. 2020), we carried out a literature review for the diet of *M. diastema*, excluding cases for taxa previously included in the species. We focused on the search terms "*Micrurus diastema* + diet + feeding + Variable Coral Snake + diet + serpiente coralillo del sureste + dieta + alimentación"; we used three online sources: ResearchGate ([www.researchgate.net](http://www.researchgate.net)), BioOne (<https://bioone.org/>), and Google Scholar (<https://scholar.google.com/>). The information was compiled in a table and projected on a map to spatially locate the studies in a geographic context. For visualization purposes, we used specific coordinates when available or we estimated a centroid using the spatial references of the studies, through the software Google Earth™ platform. We used the *M. diastema* distributions maps generated by Campbell & Lamar (2004) and Acevedo et al. (2020) to geographically locate contributions, which allowed us to identify geographical gaps in the diet study of the species. All information was processed and projected in geographic coordinates in ArcMap 10.3 (ESRI 2014), to help us identify geographical gaps in the diet study of the species.

**Sampling methods**

In October 2011, were carried out surveys in the municipality of Amatlán de Los Reyes; in October 2013, other surveys were carried out in the municipality of Atoyac; finally, in March 2016, field surveys were carried out in the municipality of Actopan, very close to the coast of the Gulf of Mexico.

We carried out in each of the three municipalities two days random tracks snake visual encounter surveys. The same tracks were surveys during the day (10:00 to 16:00 h) and then at night (19:00 to 22:00 h), for a total of six days and 12 km sampled in the three sites, by five persons to document visual encounters. The tracks frequently crossed various plant associations of tropical and subtropical forests, rural roads, secondary vegetation, grasslands and pastures, crops, and even without vegetation areas.

During the surveys, we captured the coral snakes that we located alive; each was weighed (using a digital scale, to the nearest g), photographed with a delineated ruler (for subsequent measure mm), and palpated to identify if it contained food in the stomach, and finally released at the capture site. Nevertheless, when dead snakes (e.g., roadkill) were located, they were collected and processed for deposit in collections (see below). We also recorded the coordinates with a GPS Garmin eTrex 30®, the type of vegetation, and the substrate (i.e., rocky, sandbanks, shrub, asphalt, fallen trees) of each individual. The photographs were used to perform morphometric measurements on the individuals using ImageJ 1.46 software (Broeke et al. 2015), widely used in the field of herpetology (Astley et al. 2017).

Furthermore, where possible, we recorded the sex of the individual and identified their developmental stage (juvenile, adult), based on aspects of its natural history (Lee 2000; Pérez-Higareda et al. 2007). In rural areas of Latin America, farmers frequently end up killing encountered snakes (Hernández & Bravo 2009, Gutiérrez 2011); therefore, we searched for such dead snakes (i.e., on roads and around human settlements). Located dead specimens were fixed in 70% alcohol and deposited in the Colección Herpetológica del Instituto de Investigaciones Biológicas (CHIIB) (Xalapa) and of the Facultad de Biología (CH-FACBAC) (Córdoba) at Universidad Veracruzana, in Veracruz, Mexico.

**Results**

The bibliographic review provided scarce information on the Variable Coral Snake diet because the recent taxonomic change proposed by Reyes-Velasco et al. (2020) substantially decreased the number of documented records of their diet. We were able to collect only records of the diet of *M. diastema* from two references (Greene 1973, West et al. 2019) that report four species of snake consumed from 1973 to 2020 (Table 1).

The sampling effort at the three collection sizes was 270 person-hours for 12 kilometers, with a low capture success,

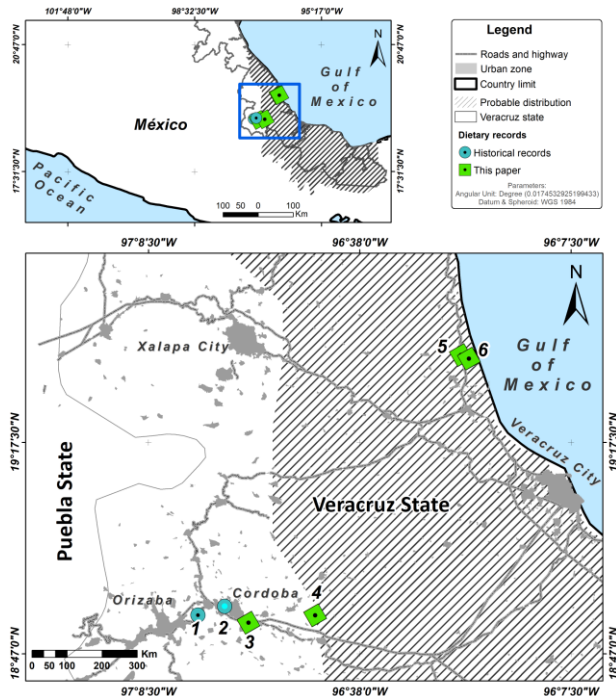


Figure 1. *Micrurus diastema* diet records in Veracruz, Mexico (published and this study). Observations: #1 - *Geophis semidoliatus*, #2 - *Chersodromus liebmanni*, #3 - *Holcosus amphigrammus*, #4 - *Drymarchon melanurus*, #5 - *Amerotyphlops tenuis*, #6 - *Coniophanes imperialis*).

and only three specimens located. The first individual we found and collected was on 21 October 2011 at 15:00 h, 1.5 km northeast of Amatlán de Los Reyes, Veracruz, Mexico (datum WGS84; 18.8584° N, 96.9007° W; 737 m a.s.l., Fig. 1). The adult male *M. diastema* (snout-vent length, SVL = 900 mm; tail length = 105 mm) was found dead with many injuries on the body (likely inflicted by local farmers) in a sugar cane field near a group of trees (Fig. 2A). The examination of the stomach contents revealed an adult female Rainbow Ameiva, *Holcosus amphigrammus* (Smith & Lafe, 1945) (SVL = 101 mm; Fig. 2B). Both specimens were conserved with the same catalog number (CH-FACBAC-000667). We recorded the second snake next to the village of Caballo Blanco in the municipality of Atoyac in Veracruz, Mexico (datum WGS84; 18.8760° N, 96.7404° W; 423 m a.s.l.). An adult female, *M. diastema* (SVL = 686 mm; tail length = 80 mm), was captured by local farmers during the surveys on 06 October 2013 at 01:02 h on a path near a tropical dry forest and "aca-

Table 1. Prey species recorded in the diet of the Variable Coral Snake (*M. diastema*) in Mexico.

Prey type	Cat. Number	Record site (coordinates)	References
Lizards			
<i>Holcosus amphigrammus</i>	CH-FACBAC-000667	18.8584°N, 96.9007°W	This study
Snakes			
<i>Amerotyphlops tenuis</i>	IIB-UV H00598	19.5019°N, 96.3897°W	This study
<i>Chersodromus liebmanni</i>	UIMNH 19194	18.8840°N, 96.9260°W	West et al. 2019
<i>Coniophanes imperialis</i>	UCM 49376	Locality unspecified	Greene 1973, West et al. 2019
	IIB-UV H00598B	19.5019°N, 96.3897°W	This study
<i>Drymarchon melanurus</i>	IIB-UVR 0053f IIB-UVR 0054f	18.8760°N, 96.7404°W	This study
<i>Geophis semidoliatus</i>	UIMNH 19193	18.8770°N, 97.0230°W	West et al. 2019
<i>Ninia sebae</i>	UIMNH 48822	Locality unspecified	



Figure 2. (A) An adult male *Micrurus diastema* collected in Amatlán de Los Reyes, Veracruz. (B) A Rainbow Ameiva (*Holcosus amphigrammus*) was found as part of the stomach contents of *M. diastema*.

hual" area (secondary vegetation). The individual was photographed by the locals (Fig. 3A) and placed in a cotton bag. The snake's belly was distended with prey (Fig. 3A); while in the bag for about 30 minutes, the snake regurgitated a likely immature Western Indigo Snake, *Drymarchon melanurus* (Duméril, Bibron, & Duméril, 1854) with an SVL = 605 mm, tail length = 120 mm (Fig. 3B). The Variable Coral Snake was released at the capture site; however, the prey (*D. melanurus*) was prepared in a bottle with alcohol (70% concentration) and was preserved by local farmers as a souvenir; they could not donate it to herpetofauna collections. We inspected the prey and identified lesions on its left side of the Western Indigo; the marks on the parietal scale could be coral snake teeth marks (Fig. 3C). The pictures were deposited at the Photographic Collection of Vertebrates "Alvar González Christen" of the Universidad Veracruzana (catalogue numbers IIB-UVRe 0053f and 0054f).

A third *M. diastema* was found dead on the road near a sugar cane field on 08 March 2016, at 09:00 h, at Paso del Cedro locality in the municipality of Actopan, Veracruz, Mexico (datum WGS84; 19.5019° N, 96.3897° W; 21 m a.s.l.; Fig. 4A). The adult female snake (SVL = 802 mm; tail length = 83 mm) was taken to the laboratory, where the stomach content was examined, and we found the remains of a Coffee Blind Snake, *Amerotyphlops tenuis* (Salvin, 1860), and a Black-striped Snake, *Coniophanes imperialis* (Baird & Girard, 1859) (Fig. 4B). The specimens were deposited as IIB-UV H00598 (*M. diastema*) and IIB-UV H00598B (prey).

## Discussion

Literature reviews provide us with invaluable compendiums of a particular topic, helping to condense important information for decision making (Snyder 2019). In this sense, the literature review of what is published about the diet of the Variable Coral Snake *M. diastema* is no exception as it helps substantially to understand a part of the trophic ecology of this species. Our literature review shows that from 1973 to 2020, at least 28 species have been reported in the diet of what was previously identified as the Variable Coral Snake *M. diastema*, including fishes and specimens of *M. diastema* (Blaney & Blaney 1978, Campbell 1998, Carbajal-Márquez et

al. 2019, Greene 1973, Köhler et al. 2016, Roze 1996, Seib 1985, West et al. 2019). However, the contemporary taxonomic changes in the *M. diastema* group (Reyes-Velasco et al. 2020), significantly modify the results on prey data reported previously for this species. We identified seven species in the Variable Coral Snake diet (*H. undulatus*=*H. amphigrammus*, *Pseudoelaphe phaescens* (Dowling, 1952), *Ficimia publia* Cope, 1866, *Ninia sebae* (Duméril, Bibron, & Duméril, 1854), *Sibon sanniolus* (Cope, 1866), *Stenorrhina freminvillei* (Duméril, Bibron, & Duméril, 1854), and *Tantillita canula* (Cope, 1875). Thus, the number of prey species in the diet of the Variable Coral Snake (as per Reyes-Velasco et al. 2020) has been reduced by 77% (from 28 prey species to 7) with the new taxonomic arrangement.

Our results show that locating these snakes is difficult, probably due to their abundance but also dependent on the collectors' expertise and other factors, leading to sampling effort with high costs (e.g., economic resources and time) and low success of capture (Rodríguez et al. 2018). Thus, we suggest combining methods to increase detection and thus obtain the much-needed data on the trophic ecology of this snake with secretive habits.

Given the eight prey items recorded so far, the diet of *M. diastema* includes seven vertebrate taxa: one lizard and six snakes (Table 1; without considering prey consumed in captivity; Rodríguez-García et al. 1998). Our results suggest that *M. diastema* prefers other snakes (ophiophagy); this is not conclusive and further studies are necessary to support or reject our statement. However, the genus *Micrurus* has been documented to consume a wide variety of prey (i.e., Campbell & Lamar 2004, West et al. 2019), such as Yellow-spotted Night Lizard *Lepidophyma flavimaculatum* Duméril, 1851 (Roze 1996), West Forest Caecilian *Gymnopsis syntrema* (Cope, 1866) (Campbell 1998), and the Blind Swamp Eel *Ophisternon infernale* (Hubbs, 1938) (Köhler et al. 2016).

In this sense, the diet of *M. diastema* resembles those of other North American elapids such as *M. fulvius* and *M. tener*; 70 to 80% of the 25 reptile species documented in their diet were snakes (*M. fulvius* diet: Loveridge 1938, Obrecht 1946, Myers 1965, Jackson & Franz 1981, Greene 1984, Heinrich 1996, Roze 1996, Campbell & Lamar 2004, Wallin et al. 2013, Engé & Mays 2016; *M. tener* diet: Strecker 1908, Ruik 1948, Curtis 1952, Greene 1984, Roze 1996, Reams et al. 1999,



Figure 3. (A) A female *Micrurus diastema* captured by a group of locals in Caballo Blanco, Atoyac, Veracruz. (B) A young Western Indigo Snake (*Drymarchon melanurus*) regurgitated by *M. diastema*. (C) Probable marks infringed by coral snake teeth on the left side of the head of *D. melanurus*.



Figure 4. (A) An adult female *Micrurus diastema* found dead on the road at Paso del Cedro, Actopan, Veracruz. (B) Remains of a Coffee Blind Snake (*Amerotyphlops tenuis*) and a Black-striped Snake (*Coniophanes imperialis*) extracted from the digestive cavity of the *Micrurus*.

Campbell & Lamar 2004).

Regarding the items reported in this study, the Black-striped Snake (*C. imperialis*) was previously recorded (Greene 1973) in *M. diastema* diet. However, we found novel prey species for the Variable Coral Snake, such that Coffee Blind Snake (*A. tenuis*) might be an ordinary component of the coral snake diet for its fossorial habits (Pérez-Higareda et al. 2007). The discovery of a Western Indigo Snake (*D. melanurus*) in the stomach of *M. diastema* also suggests that

this coral snake can hunt and consume prey approximately its length. Although this is the first record of interaction between these two species, another coral snake species (*M. distans* Kennicott, 1860) has been reported to prey on *D. melanurus* (Warfel et al. 2015). In both cases, the coral snakes were adult females that consumed juvenile *D. melanurus*.

The Variable Coral Snake *M. diastema* seems to capture and consume prey of different body sizes, from small blind snakes like *A. tenuis* to snakes nearly as large as the predator

(e.g., juvenile *D. melanurus*). This behavior has also been recorded in the Eastern Coral Snake (*M. fulvius*; Greene 1984); this seems to suggest that coral snakes have a preference for small prey and can occasionally capture and consume prey that may exceed its body mass (Cundall & Greene 2000), a situation that probably characterizes the feeding behavior of the *Micrurus* genus.

Similarly, the Rainbow Ameiva (*H. amphigrammus*) we recorded for the first time in the diet of *M. diastema*, and the first record of lacertids in its diet, was reported for *M. apiatus* (Greene 1973), a member of the *M. diastema* group, and supporting their close relationship (Reyes-Velasco et al. 2020).

The bibliographic review showed that the diet of the *M. diastema* group (*M. apiatus* and *M. diastema*) is poorly known, being most evident with the recent taxonomic changes (Reyes-Velasco et al. 2020). The available records on the diet of *M. diastema* (before taxonomy changes) were located at the extreme of its geographic distribution, in the Petén region, Huehuetenango and Alta Verapaz in Guatemala, in the Yucatán Peninsula area in the state of Quintana Roo, and in the Gulf Coastal Plain and the High Mountains in Central Veracruz, Mexico (see Fig. 1). However, with the current taxonomic changes (Reyes-Velasco et al. 2020), the diet records for *M. diastema* were reduced to only three reports, including the present contribution; therefore, a geographic gap in the knowledge of the diet of the species is detected, which includes the states of Oaxaca, Tabasco, and Veracruz. This is not yet conclusive since there is no updated model of the geographic distribution of *M. diastema* that includes the new taxonomic changes. In this context of proposed species change, it is necessary to delimit the geographic distribution of *M. diastema* using novel tools such as ecological niche models (e.g., Kass et al. 2018, Osorio-Olvera et al. 2020).

Our results update and extend the knowledge on the trophic ecology of the Variable Coral Snake in the northern extreme of its geographical distribution in Mexico and refine its place in the food web mainly as a snake-eating predator throughout its geographical distribution, but they also emphasize the lack of information on this taxonomic group. Thus, we urge that such research be continued to provide additional information about the genus *Micrurus* natural history.

**Acknowledgments.** We are grateful to the reviewers (Dr. Uri García and Dr. Larry David Wilson) and the editor Yuri Kornilev for improving the manuscript; additionally, we thank the inhabitants of Caballo Blanco for the support during the surveys in the field and for the photographs and the staff at Facultad de Biología Campus Córdoba and the Laboratorio de Zoología at the Instituto de Investigaciones Biológicas de la Universidad Veracruzana for vouchering the specimens in their collection. Eduardo Morteo, Yadira Peralta, Dominic Olver, and Alvaro Villafañe assisted with the preparation of the manuscript. Field equipment and logistical support (e.g., GPS, vehicle, and others) were provided by the Project "PRODEP: 40857 DSA/103.5/14/10595/PTC-749".

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