New dietary records for croaking lizards of the genus *Aristelliger* (Reptilia: Sphaerodactylidae)

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Associate Editor: Robert W. Henderson. Date of publication: 5 September 2018. Citation: DeBoer JC, Griffing AH, Iyengar VK, Bauer AM (2018) New dietary records for croaking lizards of the genus *Aristelliger* (Reptilia: Sphaerodactylidae). *Caribbean Herpetology*, 62, 1–8. DOI: 10.31611/ch.62

Abstract

Croaking Lizards (*Aristelliger*) are some of the largest geckos occurring in the New World, but knowledge of their basic biology remains limited. Here we present a dietary account of *Aristelliger*. Our results augment existing data by providing new dietary records for seven of the nine species of *Aristelliger*. The first dietary records are reported for three of these species (*A. barbouri, A. expectatus,* and *A. hechti*). We report lithophagy, frugivory, seed dispersal, and ontogenetic variation in the diet of *Aristelliger* and the first instance of molluscivory in the genus. In total, 22 items were added to the dietary records of various species of *Aristelliger* with nine items being new to the genus.

Keywords: Caribbean, frugivory, gecko, lithophagy, molluscivory.

Introduction

Aristelliger is a genus of vocal sphaerodactylid geckos that are distributed throughout the West Indies and sporadically along Central America's Atlantic coast and some satellite islands (Hecht 1952; Schwartz & Henderson 1991; Bauer & Russell 1993). Unlike most New World sphaerodactylids, *Aristelliger* are nocturnal, semi-arboreal, and exhibit a range of body sizes, with most species being relatively large (Schwartz & Henderson 1991; Bauer & Russell 1993; Henderson & Powell 2009). *Aristelliger* are omnivorous and known to eat a diversity of prey items (Henderson & Powell 2009). However, data on natural diets are available for only half of the described species (*A. cochranae, A. lar, A. praesignis,* and *A. reyesi*) and only *A. cochranae* and *A. lar* are represented by more than minimal dietary records (Schwartz & Henderson 1991; Gifford et al. 2000).

Materials and Methods

We examined specimens collected during fields trips to Great Inagua Island, Bahamas, and Jamaica (July 2015 and May 2016, respectively), as well as from a number of specimens in American museum collections (AMB, personal collection of Aaron M. Bauer, Villanova University, Villanova, Pennsylvania; KU, University of Kansas Natural History Museum, Lawrence, Kansas; MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; UCM, University of Colorado Museum of Natural History, Boulder, Colorado).

We made ventral incisions and dissected 59 preserved specimens (four *A. barbouri*, four *A. cochranae*, five *A. expectatus*, five *A. georgeensis*, two *A. hechti*, four *A. lar*, and 35 *A. praesignis*). We recorded sex and measured snout-vent length (SVL) of all inspected specimens with calipers to the nearest 0.1 mm (Appendix 1), examined stomach and intestinal contents under a dissecting scope, and isolated and stored gut contents in

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70% ethanol. We identified dietary items to order or family, although several items could be identified more precisely. We did not count prey items as many were highly fragmented.

Results

Aristelliger examined comprised 23 males, 28 females, and 9 unsexed specimens representing a range of both adults and juveniles (Table 1). Forty-three of the 59 Aristelliger examined contained ingested items in the stomach and/or intestines. We extracted 88 different items allocated to 22 dietary categories (Table 2). Most items in the intestines were digested and could only be identified through hard body parts (e.g., head capsules, mandibles, elytra, and legs).

The majority of prey categories were Arthropoda (16; 76%). Important prey types (found in over 25% of specimens that contained ingested items) an adult male *A. lar* (KU 228785). Scale bars = 1 cm.



Figure 1. Various dietary items of *Aristelliger*. A) Typical lepidopteran larva found in the stomachs of *Aristelliger praesignis*. B) Pleurodontid snail, likely *Thelidomus aspera*, extracted from the stomach of an adult female *A. praesignis* (MCZ R 194565). C) Marcgraviacea fruit, likely *Marcgravia domingensis*, extracted from both the stomach and intestines of an adult male *A. lar* (KU 228785). Scale bars = 1 cm.

were representative of Araneae, Coleoptera, Hymenoptera, Lepidoptera (Fig. 1A), and Orthoptera. Additional dietary items included a species of pleurodontid snail, likely *Thelidomus aspera* (Fig. 1B), and plant material found in three specimens of two species, most notably fruits, likely from Marcgraviacea: *Marcgravia domingensis* (Fig. 1C). We found small stones in three specimens.

The following paragraphs provide dietary summaries and relevant information by species.

Aristelliger barbouri Nobel & Klingel, 1932. This is a medium-sized (46 mm maximum SVL), secretive, xerophilic species native to Great Inagua Island, Little Inagua Island, and Sheep Cay, Bahamas (Nobel & Klingel 1932; Schwartz & Henderson 1991). No previous dietary records were available for *A. barbouri*. Araneae, Coleoptera, Heteroptera, Lepidoptera, and Orthoptera are reported here as the first dietary records for the species.

Aristelliger cochranae Grant, 1931. This is a medium-sized (63 mm maximum SVL), xerophilic species native to Navassa Island (Schwartz & Henderson 1991). This species has the most extensive dietary records of any member of the genus. Gifford et al. (2000) extracted 50 individual prey items from specimens from Navassa Island. They reported cannibalism, finding both hatchlings and eggs among the stomach contents of multiple adult female *A. cochranae*. The remaining items consisted of Arachnida: Araneida and Pseudoscorpionida; Insecta: Blattodea: Blattelidae; Coleoptera: Anobiidae, Scolytidae, and Tenebriondae; Diptera; Hymenoptera: Formicidae; Isoptera; and Lepidoptera: Gelechiidae. Hemiptera, Odonata, and Orthoptera are new dietary items for *A. cochranae*, increasing the known dietary items from 12 to 15 different prey types.

Aristelliger expectatus Cochran, 1933. This is a medium-sized (55 mm maximum SVL), xerophilic species native to western Hispaniola (Thomas 1966; Henderson & Powell 2009). No previous dietary records were available for *A. expectatus*. Orthoptera: Gryllidae is the first and only dietary record for *A. expectatus*.

Aristelliger georgeensis (Bocourt, 1873). This is a large (115 mm maximum SVL), mesophilic species and the only *Aristelliger* found on the Central American coast and some satellite islands (Dunn & Saxe 1950; Hecht 1952; Bauer & Russell 1993; Lee 1996). Dunn & Saxe (1950) reported locals on Providencia stating that "the screeching lizard live in trees and eat tame lizards [*Anolis*]"; however, this remains unverified. The consumption of other vertebrates is rare among geckos, with most prey items being other geckos and conspecifics (Bauer 1990). Nonetheless, a prey item of this size seems feasible due to the large size of *A. georgeensis. Aristelliger georgeensis* also is known

Species	n	Sex ratio total	Sex ratio with contents	SVL range (mm)	SVL average (mm)	
A. barbouri 4		0:4:0	0:3:0	36.7-41.6	40.6	
A. cochranae 4		1:1:2	0:0:1	26.9-58.2	43.4	
A. expectatus	5	0:3:2	0:1:0	17.2–52.8	35.1	
A. georgeensis	5	2.3:0	1:3:0	33.6-95.6	69.8	
A. hechti	2	1:1:0	1:1:0	46.4-86.4	66.4	
A. lar	4	1:2:1	1:2:0	43.4-129.9	77.1	
A. praesignis	35	18:14:3	14:13:1	23.0-98.0	68.8	
A. reyesi	0	—	—	—	—	
Total	59	23:28:8	17:23:2	17.2-129.9	63	

Table 1. Species, sex ratios, and size of Aristelliger examined. Sex ratio, males:females:unsexed. SVL, snout-vent length.

Table 2. Stomach and intestine contents of 42 specimens of *Aristelliger*. (†), new dietary item for the genus. (*), new dietary item for the species. *A. barbouri*, Ab. *A. cochranae*, Ac. *A. expectatus*, Ae. *A. georgeensis*, Ag. *A. hechti*, Ah. *A. lar*, Al. *A. praesignis*, Ap.

Dietary Item	Ab	Ac	Ae	Ag	Ah	AI	Ар
ARACHNIDA				_			
Araneae	3*	1		1*			8
INSECTA							
Blattoidea		1					1
Coleoptera	1*				1*		9
Curculionoidea†				1*			
Diptera							6
Tephritidae†				1*			
Hemiptera							
Heteroptera†	1*						
Homoptera†		1*					
Hymenoptera							4*
Apocrita†							1*
Formicidae				1*	1*		9*
Lepidoptera							2*
Lepidoptera (larvae)	1*						9*
Odonata†		1*					
Orthoptera	1*	1		3*		1	2*
Acrididae†				1*			
Gryllidae			1*	1*			
GASTROPODA							
Pleurodontidae†							3*
PLANT							
Marcgravia†						1*	
Seeds							1*
Misc. plant material						2	
OTHER CONTENTS							
Stones		1*					2

to eat scorpions in the wild (White et al. 2017) and its own shed skin (i.e., dermatophagy) in captivity (Weldon et al. 1993).

Araneae, Coleoptera: Curculionoidea, Hymenoptera: Formicidae, Orthoptera: Acrididae and Gryllidae, and Diptera: Tephritidae are new dietary items for this species, increasing the known dietary items from 3 to 9. Of particular interest was a specimen (UCM 16183) that contained at least 50 tephritids, several formicids, a curculionoid, and an orthopteran. The tephritids were found intact within the stomach. These tiny insects may be a more prevalent prey item in the diets of *Aristelliger* and other geckos, but may be overlooked due to their minuscule size and rapid rates of digestion. *Aristelliger hechti* Schwartz & Crombie, 1975. This is a large (90 mm maximum SVL), xerophilic species native to the Caicos Islands (Schwartz & Crombie 1975). No previous records of dietary items were available for *A. hechti*. We report Coleoptera (two unidentifiable species both found within KU 228757) and Hymenoptera: Formicidae as dietary items for *A. hechti*.

Aristelliger lar Cope, 1862. This is a large (135 mm maximum SVL), mesophilic species native to Hispaniola (Hecht 1952). The known dietary items of *A. lar* include: spiders, beetles, roaches, true bugs, crickets, ghost crabs, and a flower (Schwartz & Henderson 1991; Burns et al. 1992; Henderson & Powell 2009). *Aristelliger lar* appears to be omnivorous. Schwartz and Henderson (1991) reported seeds and fruits from a fecal examination, "spherical seeds (approx. 6 mm in diameter), and red pulp, also many tiny seeds (like strawberry achenes), and elongate (3/4 in.), many-seeded white fruits" (Henderson & Powell 2009).

Our results are consistent with previous dietary data for *A. lar*. We confirm frugivory by a single individual (KU 228785) containing 11 Marcgraviaceae fruits, likely *Marcgravia domingensis* (Fig. 1C). The large quantity of fruits suggests that the consumption was not accidental. *Marcgravia* nectar and fruits also are consumed by Neotropical bats, opossums, frugivorous and nectivorous birds, and primates, the latter two of which are known seed dispersers (van Roosemalen 1985; Tschapka & Helversen 1999; Zusi & Hamas 2001; Herrera et al. 2003). Geckos, especially insular forms, are known to be important seed dispersers in some ecosystems (Whitaker 1987; Bauer & Sadlier 1994; Wotton 2002; Olesen & Valido 2003) and *A. lar* also might serve in this role.

Aristelliger nelsoni **Barbour**, **1914.** This is a large (235 mm total length; Barbour 1914), mesophilic species native to the Swan Islands, Honduras (Barbour 1914). We did not examine any specimens of this species. No previous records of dietary items were available for *A. nelsoni*. McCranie et al. (2017) found an individual *A. nelsoni* inside a termite nest, suggesting that diet of *A. nelsoni* may include termites.

Aristelliger praesignis (Hallowell, 1856). This is a large (101 mm maximum SVL), mesophilic species native to Jamaica, and the Cayman Islands (Schwartz & Henderson 1991; Griffing et al. 2017). Insects, including cockroaches, and sugar (Garman 1888; English 1912; Grant 1940; Schwartz & Henderson 1991) have been reported in its diet.

We report eleven new dietary items for *A. praesignis*. Arthropodan prey were assignable to Araneae, Coleoptera, Diptera, Hymenoptera: Apocrita and Formicidae, Lepidoptera: adults and larvae, and Orthoptera. A large, unidentifiable seed found in KU 228974 is the second instance of an *Aristelliger* consuming large seeds, the first being *A. lar* (Schwartz & Henderson 1991). Most significant is the first record of molluscivory in any *Aristelliger*. A subadult female *A. praesignis* (MCZ R 194565) contained an entire juvenile pleurodontid snail, likely *Thelidomus aspera* (Fig. 1B), and similar shell fragments were found in two other *A. praesignis* (MCZ R 194568, MCZ R 194587). Molluscivory, although uncommon in gekkotans as a whole (Paluh & Bauer 2016), has previously been documented in several genera of small to miniaturized Neotropical sphaerodactylids (*Coleodactylus, Gonatodes, Pseudogonatodes*, and *Sphaerodactylus*; Daza et al. 2009). We found snail shells only in females, but other dietary items were recovered from both sexes.

Our data suggest ontogenetic variation in the diet of *A. praesignis*. Smaller *A. praesignis* consume smaller and slower moving prey, such as ants and lepidopteran larvae, whereas larger individuals consume larger prey items such as large Blattodea, Gryllidae, and Lepidoptera: adults (Appendix 1).

Aristelliger reyesi Díaz & Hedges, 2009. This is a medium-sized (63.6 mm maximum SVL), largely xerophilic species endemic to Cuba (Díaz & Hedges 2009). We did not examine any specimens of this species. Díaz & Hedges (2009) reported ants (*Camponotus* sp.), neuropterans (adult), beetles, shed skin, and small stones from fecal material. Most of the dietary items are similar to those of other species of *Aristelliger*. Their report of shed skin is the first note of *Aristelliger* dermatophagy outside of captivity; however, dermatophagy is common among the majority of geckos (Bustard & Maderson 1965; Welden et al. 1993).

Discussion

Twenty-two new dietary items were identified for individual *Aristelliger* species and nine were new to the genus: Gastropoda: Pleurodontidae: *Thelidomus aspera*; Ericales: Marcgraviaceae: *Marcgravia domingensis*; Insecta: Coleoptera: Curculionoidea; Diptera: Tephritidae; Hemiptera: Heteroptera, and Homoptera; Hymenoptera: Apocrita; Odonata; and Orthoptera: Acrididae (Table 2).

This is the first published record of molluscivory in *Aristelliger* and the first to identify the genus of a fruit in the diet of *Aristelliger*. The large-bodied *A. lar* likely is a seed disperser for the *Marcgravia* plant. Indeed, large body size often is considered a factor that facilitates frugivory (e.g., Schoener et al. 1982; Cooper & Vitt 2002; Herrel et al. 2004). Further, our finding that *A. lar* eats plant material (KU 228785, KU 228792) and several fruits (KU 228785) and *A. praesignis* eats seeds (KU 228974) demonstrates that these species are using plant parts as an alternative food source to arthropods, which apparently is mediated by their large size.

Our large sample size of *A. praesignis* stomach contents revealed a possible ontogenetic shift in diet. Furthermore, our data suggest that a larger body size allows for a greater range of dietary items (Appendix 1). The relationship between body size and dietary items likely explains how the island of Hispaniola can support the sympatric species *A. lar* and *A. expectatus* (maximum 135 and 55 mm SVL, respectively). Further stomach content examination of *A. expectatus* is essential to determine if differences in diet contributed to dietary niche specialization between the Hispaniolan species.

Lastly, we extracted small stones from *A. cochranae* and *A. praesignis*. Individuals contained single or multiple stones. Ingested stones can indicate lithophagy, intentionally consuming small stones to aid in digestion. Sokol (1971) reported lithophagy in several lizard species and other reptiles that apparently ingest stones to macerate plant materials, such as fruit. Johnson (1966) indicated that stones in the stomachs of *Sceloporus* and *Aspidoscelis* were for the maceration of chitinous exoskeletons of arthropods. Three of nine *Aristelliger* species have records for ingesting stones, but robust dietary reports on *A. barbouri, A. expectatus,* and *A. nelsoni* are lacking. Díaz & Hedges (2009) reported *A. reyesi* ingesting small stones, although they did not attribute it to accidental consumption or lithophagy. With a diet largely consisting of chitinous arthropods but also containing hard fruits and plant material, *Aristelliger* might be intentionally ingesting stones to aid in digestion.

Acknowledgements

We thank Drs. Gary Rosenberg (Academy of Natural Sciences at Drexel University) and Pedro Acevedo (Smithsonian Institution) for assistance in identifying mollusk and plant remains, respectively. We thank all institutional collections and associated curators and collection managers who loaned specimens to complete this study. Field collection of *Aristelliger barbouri* and *A. praesignis* was made possible by the Gerald Lemole Endowed Chair (Villanova University), Bahamas National Trust, Randolph Burrows, Jamaican National Environment and Planning Agency, and Dr. Byron Wilson (University of West Indies, Mona, Jamaica).

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Appendix

Specimens examined. Abbreviations: SVL, snout-vent length; M, male; F, female. Numbers correspond to the following ingested items: Arachnida: 1-Araneae. Gastropoda: 2-*Thelidomus aspera* (Pleurodontidae). Insecta: 3-Blat-todea; 4-Coleoptera; 5-Curculionoidea (Coleoptera); 6-Diptera; 7-Tephritidae (Diptera); 8-Heteroptera (Hemiptera); 9-Homoptera (Hemiptera); 10-Hymenoptera; 11-Apocrita (Hymenoptera); 12-Formicidae (Hymenoptera); 13-Lepi-doptera; 14-Lepidoptera, larva; 15-Odonata; 16-Orthoptera; 17-Acrididae (Orthoptera); 18-Gryllidae (Orthoptera). Ericales: 19-*Marcgravia domingensis* (Marcgraviceae). Miscellaneous: 20-seeds; 21-miscellaneous plant material; 22-stones.

Catalogue Number	Species	SVL (mm)	Sex	Stomach contents —	
KU 228575	A. barbouri	36.7	F		
AMB 9354	A. barbouri	38.4	F	1, 4, 14, 17	
AMB 9352	A. barbouri	41.6	F	1, 8, 16	
AMB 9355	A. barbouri	46.0	F	1	
KU 228605	A. cochranae	26.9	_	—	
KU 228603	A. cochranae	41.6	_	1, 3, 9, 15, 16, 22	
KU 228597	A. cochranae	46.7	F	_	
KU 228585	A. cochranae	58.2	М	_	
KU 228722	A. expectatus	17.2	_	_	
KU 228730	A. expectatus	25.5	—	_	
KU 228734	A. expectatus	38.5	F	_	
KU 228702	A. expectatus	41.6	F	_	
KU 228686	A. expectatus	52.8	F	18	
UCM 16183	A. georgeensis	33.6	F	5, 7, 12, 16	
UCM 16184	A. georgeensis	52.7	F	16	
KU 070030	A. georgeensis	78.9	F	17	
KU 070036	A. georgeensis	88.1	М	1, 16, 18	
KU 070027	A. georgeensis	95.6	М	_	
KU 228758	A. hechti	46.4	F	12	
KU 228757	A. hechti	86.4	М	4	
KU 228760	A. lar	43.4	_	_	
KU 228795	A. lar	64.2	F	16	

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KU 228792	A. lar	70.9	F	21
KU 228785	A. lar	129.9	М	19, 21
MCZ R 194571	A. praesignis	23.0	—	—
MCZ R 194573	A. praesignis	23.8	—	_
KU 228974	A. praesignis	46.2	F	20
MCZ R 194600	A. praesignis	46.2	_	14
MCZ R 194590	A. praesignis	52.3	М	10, 14
KU 228978	A. praesignis	52.5	F	4
MCZ R 194574	A. praesignis	52.6	F	22
MCZ R 194567	A. praesignis	54.0	F	4
MCZ R 194581	A. praesignis	57.9	М	1, 12, 13
MCZ R 194582	A. praesignis	58.1	F	12
MCZ R 194566	A. praesignis	60.3	М	14
MCZ R 194591	A. praesignis	60.7	F	2, 4, 6, 12
MCZ R 194587	A. praesignis	60.8	F	2, 14
MCZ R 194588	A. praesignis	60.8	М	6, 14
MCZ R 194577	A. praesignis	64.8	F	_
MCZ R 194599	A. praesignis	64.9	F	1, 4, 6, 22
MCZ R 194585	A. praesignis	67.3	F	1, 12
MCZ R 194568	A. praesignis	68.1	F	1, 2, 12, 14
MCZ R 194580	A. praesignis	69.7	F	14, 16
MCZ R 194596	A. praesignis	71.2	F	4, 10
MCZ R 194757	A. praesignis	74.9	М	1, 6, 10, 14
MCZ R 194583	A. praesignis	78.5	F	4, 12
MCZ R 194578	A. praesignis	83.2	М	14
MCZ R 194579	A. praesignis	86.5	М	4
MCZ R 194584	A. praesignis	87.5	М	_
MCZ R 194576	A. praesignis	86.5	М	4
KU 228995	A. praesignis	87.5	М	11, 12
MCZ R 194595	A. praesignis	88.2	М	_
MCZ R 194597	A. praesignis	88.3	М	_
MCZ R 194586	A. praesignis	89.6	М	_
MCZ R 194593	A. praesignis	93.4	М	4, 10
MCZ R 194592	A. praesignis	96.6	М	4, 12, 13, 16
MCZ R 194591	A. praesignis	96.9	М	1, 12
MCZ R 194598	A. praesignis	97.5	М	1, 3, 6
MCZ R 194594	A. praesignis	98.0	М	1,6