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Morphology and ecology of *Sibon* snakes (Squamata: Dipsadidae) from two forests in Central America

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Abstract

Morphology and ecology of *Sibon* snakes (Squamata: Dipsadidae) from two forests in Central America. Physical measurements, abundance, and ecological observations were recorded for *Sibon annulatus*, *S. argus, S. longifrenis*, and *S. nebulatus* at two Neotropical habitats: a lowland swamp forest in Costa Rica and a montane cloud forest in Panama. Fourty-four and 58 adult snakes were recorded from Costa Rica and Panama, respectively. Differences in morphology and body condition showed minimal significant differences among species from both geographical locations. Observations of feeding, reproduction, abundance, distribution, and a new size record for *S. annulatus* are discussed.

Keywords: abundance, behavior, body condition.

Resumo

Morfologia e ecologia de serpentes do gênero *Sibon* (Squamata: Dipsadidae) de duas florestas da América Central. Medidas morfométricas foram tomadas, foi estimada abundância e feitas observações ecológicas para *Sibon annulatus*, *S. argus*, *S. longifrenis* e *S. nebulatus* em dois habitats neotropicais: Uma floresta pantanosa de baixada na Costa Rica e uma floresta de neblina no Panamá. Quarenta e quatro e 58 serpentes adultas foram registradas na Costa Rica e no Panamá, respectivamente. Diferenças morfológicas e na condição corporal significativas foram mínimas entre as espécies para ambas as localidades. São discutidas as observações sobre alimentação, reprodução, abundância, distribuição e um registro de um novo tamanho máximo para *S. annulatus*.

Palavras-chave: abundância, comportamento, condição corporal.

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Introduction

Sibon, Dipsas, Sibynomorphus, and *Tropidodipsas* are specialized slug- and snail-eating snake genera found across the Neotropics (Peters 1960, Kofron 1985). The genus *Sibon* contains 16 species distributed from central Mexico, through Mesoamerica to Ecuador and Brazil (Savage 2002, Köhler 2008, Köhler *et al.* 2010, Lotzkat *et al.* 2012, Rovito *et al.* 2012, Uetz 2012).

Previous work on the four species in this study has consisted of studies on systematics, distribution, morphology, feeding, reproduction, and behavior (Kofron 1985, 1987, McCoy 1990, Campbell 1998, Montgomery *et al.* 2007, Lewis 2009, Ray 2009, Köhler *et al.* 2010, Ray *et al.* 2011, Lotzkat *et al.* 2012, Ray 2012, Ray *et al.* 2012, Rovito *et al.* 2012). The conservation status of species in Costa Rica is that *Sibon annulatus* and *S. nebulatus* are IUCN Least Concern, while *S. antracops*, *S. argus*, *S. dimidiatus*, *S. lamari*, and *S. sartori* are all IUCN Data Deficient (Sasa *et al*. 2010). In Panama *S annulatus*, *S. argus*, and *S. nebulatus* are listed as IUCN Least Concern while *S. lamari* and *S. longifrenis* are IUCN data deficient (Jamarillo *et al.* 2010). *Sibon noalamina*, the newly described species (Lotzkat *et al.* 2012), has not yet been assessed.

In this study we report on differences in morphology on four species of *Sibon* recorded at two sites in Central America. We also note observations of feeding, reproduction, abundance, distribution, and a new size record for *S. annulatus*.

Materials and Methods

Study Sites

Herpetological surveys in Costa Rica were conducted annually 2003 to 2012 at Caño Palma Biological Station (CPBS), which is located 8 km north of Tortuguero in the Barra del Colorado Refuge (10.592615 N, 83.527122 W), and the area surrounding Tortuguero National Park and Cerro Tortuguero in the NE region of Costa Rica. CPBS is an area of lowland (0–100 m asl) tropical wet forest dominated by *Manicaria* palm (Myers 1990, Lewis *et al.* 2010b).

Herpetological surveys in Panama were conducted from March to July 2006 at Altos del Maria (ADM), a private retirement community near El Valle de Antón in western Panamá Province (8.6333 N, 80.0666 W). ADM is a mid-elevation (450–1200 m a.s.l.) pre-montane tropical wet forest (Holdridge 1967, Ray 2009).

Study Species

In Costa Rica, six species of *Sibon* occur, three of which, *S. annulatus* (Figure 1A), *S. longifrenis* (Figure 1B) and *S. nebulatus* (Figure 1C), are found in the north-eastern lowlands of Costa Rica (Savage 2002, Guyer and Donnelly 2005, Köhler 2008). All three of these species have been recorded for CBPS. Panama contains seven species, four of which, *S. annulatus, S. argus* (Figure 1D), *S. longifrenis* and *S. nebulatus,* have been recorded at ADM (Ray 2009, Köhler *et al.* 2010).

Surveys were conducted at night and specimens were located by torchlight visual encounter surveys (Heyer *et al.* 1994, McDiarmid *et al.* 2012) in canal edge areas, deep forest, riparian gallery forest, and pre-montane slope habitat. Surveys in Costa Rica averaged three surveyors and were conducted four nights a week for up to six hours per survey. Surveys in Panama averaged two surveyors and were conducted five or six nights a week for five to six hours per survey.

Morphometric Measurements

For each snake, snout-vent length (SVL) (mm) and total length (TL) (mm) were recorded using measuring tapes and/or a squeeze box (Quinn and Jones 1974). Mass (g) was recorded using electronic or Pesola™ scales (rounded to one decimal place). Sex was confirmed by use of

Figure 1. *Sibon annulatus* (**A**) , *Sibon longifrenis* (**B**), *Sibon nebulatus* (**C**), each photographed at Caño Palma Biological Station, © Alex Figueroa, *Sibon argus* (**D**) photographed at Altos del Maria, © Julie M. Ray.

blunt tipped probes (McDiarmid *et al.* 2012). Only adult specimens (SVL > 300 mm) were used in the analysis. At CPBS, snakes were uniquely marked by cauterizing scales of the first dorsal scale row to the ventral scales in a numerical manner (Winne *et al.* 2006) using a medical cautery unit (Aaron Medical Change-A-Tip cautery units). At ADM, snakes were marked using PIT tags and scale clips. We removed all recaptures from the analyses. Snakes were released at the site of capture after collection of data. Activities were permitted under license number ACTo-GASP-PIN-08-2011 (Costa Rica) and SE/A-44-06 (Panama).

Condition analyses were used to calculate relative health of the snakes. To determine body condition, Fulton's Condition Factor K (Ricker 1975) was utilized, where $K = (W/L^3) \times 10^n$, where the mass of the snake is in kg (W), the length (L) is SVL in cm and '*N*' is chosen so that the mean of K is larger than one, in this case $N = 7$.

Natural History

Observations of natural behavior and location were made before capture. Notes recorded included feeding, behavior, reproduction, and habitat type.

Statistical Analysis

Statistical analysis was conducted in Statistica™ Ver. 10 (Statsoft 2011). One-way

ANOVAs were used to test for significant differences in SVL, TL and mass between the sexes of each species, and size differences among species. One-way ANOVAs also were used to investigate size differences of species occurring at both CPBS and ADM, along with condition factors of all individuals within the two sampling locations.

Results

Surveys at CPBS resulted in the documentation of three species of *Sibon* (*S. annulatus*, *S. longfrenis*, and *S. nebulatus*). From 2003 to 2012, 44 adult specimens (19 *S. annulatus*, eight *S. longfrenis*, and 27 *S. nebulatus*) were encountered at CPBS (Table 1). Additionally, six juveniles (Three *S. annulatus*; two *S. longifrenis* and one *S. nebulatus*) were encountered during this time period.

Surveys conducted at ADM resulted in the documentation of all four species of *Sibon* that were the focus of this study. Between March and July 2006 a total of 58 adult specimens (13 *S. annulatus*, 13 *S. longifrenis*, one *S. nebulatus*, and 31 *S. argus*) were found (Table 1).

Sibon annulatus was the only species to show significant differences between sexes with males having greater SVL ($F = 4.55$; $p = 0.04$) and TL ($F = 8.72$; $p = 0.006$), but not significantly greater mass ($F = 0.37$; $p = 0.54$). Females of *S. nebulatus* tended to be larger slightly than males, but not significantly so, for SVL ($F = 1.15$; $p = 0.29$), TL ($F = 0.49$; $P = 0.049$), and mass ($F = 2.40$; $p = 0.13$). *Sibon argus* females also tended to be larger than their male counterparts, but again, not significantly greater for SVL ($F = 1.90$; $p = 0.18$), TL ($F = 1.04$; $p = 0.31$), or mass ($F = 2.50$; $p = 0.12$). *Sibon longifrenis* showed no significant differences between males and females for SVL ($F = 0.001$; $p = 0.97$), TL ($F = 0.03$; $p = 0.86$), or mass ($F = 1.77$; $p = 0.20$). In terms of interspecific morphological differences, *Sibon* spp. were all fairly similar, with the exception of *S. nebulatus*, which showed significantly greater SVL ($F = 28.53$; $p < 0.001$), TL ($F = 14.08$; $p < 0.001$), and mass ($F = 55.75$; $p < 0.001$).

Comparison of species between CPBS and ADM only could be carried out for *S. annulatus* and *S. longifrenis,* which were sufficiently abundant in both locations. Little significant variation occurred between species at the two locations. *S. annulatus* showed no significant differences in SVL ($F = 0.61$; $p = 0.44$) or TL ($F = 0.01$; $p = 0.93$) but did show significantly greater mass at CPBS ($F = 14.34$; $p < 0.001$). *Sibon longifrenis* exhibited greater SVL ($F = 3.51$; $p = 0.07$) and mass ($F = 0.49$; $p = 0.49$) at ADM, but only TL was significantly greater ($F = 4.76$; $p = 0.04$).

While *Sibon* individuals at ADM had marginally higher values of Fulton's Condition Factor K, there was no significant difference in K between the two locations ($F = 0.72$; $p = 0.39$), or among the four *Sibon* species ($F = 1.32$; $p = 0.27$) (Table 1). The results suggest that *Sibon* individuals have relatively similar body conditions, irrespective of species or location.

Discussion

Morphology

Generally, greater length in snakes correlates with increasing mass and, in most, but not all species, females are larger than males (Shine 1994). Our morphometric results showed that males were often longer than females, but that females had greater mass than males. However, this trend in sexual size dimorphism was not constant across our data. For example, the *Sibon longifrenis* male from CPBS was longer and heavier than the females; *S. nebulatus* males were shorter than females and weighed less; for *Sibon annulatus* SVL for both sexes were significantly different with TL of males being longer than females, and females were heavier.

Sibon longifrenis had greater total length at ADM than at CPBS. *Sibon annulatus* showed greater mass at CPBS than at ADM. However, in

Table 1. *Sibon* spp. morphological characteristics (mean ± SD), including snout-vent length (SVL, mm), total length (TL, mm), mass (g), and condition index (K) from Caño Palma Biological Station, Costa Rica (CPBS) and Altos del Maria, Panama (ADM).

Species	Sex	*N*	Morphology	Location	
				CPBS	ADM
S. annulatus	♂	17	SVL	372.6 ± 61.3	385.0 ± 48.0
			TL	562 ± 75.5	608.1 ± 76.0
			Mass	8.6 ± 2.1	6.5 ±2.4
			K	1.8 ± 0.8	2.4 ± 0.5
	♀	11	SVL	354.1 ± 55.2	291.0 ± 50.0
			TL	503.2 ± 98.3	45.4 ± 82.9
			Mass	9.5 ± 3.3	3.7 ± 1.6
			K	2.0 ± 0.2	1.9 ± 0.5
S. longifrenis	♂	12	SVL	337.5 ± 62.5	378 ± 33.8
			TL	485.0 ± 95.0	567.0 ± 55.4
			Mass	9.8 ± 3.3	9.2 ± 1.4
			K	2.4 ± 0.4	2.1 ± 1.1
	♀	7	SVL	355 ± 29.3	383.1 ± 19.5
			TL	512.6 ± 43.9	559.1 ± 25.6
			Mass	10.0 ± 1.2	11.9 ± 2.7
			K	1.9 ± 0.2	1.1 ± 0.1
S. nebulatus	♂	15	SVL	486.3 ± 121.8	519
			TL	649.2 ± 165.1	706
			Mass	25.0 ± 9.1	32.8
			K	1.6 ± 0.3	2.3
	♀	9	SVL	536.7 ± 59.8	–
			TL	713.6 ± 71.2	–
			Mass	33.5 ± 14.1	–
			K	1.8 ± 0.4	–
S. argus	♂	19	SVL	–	322.4 ± 55.6
			TL	–	480.0 ± 89.8
			Mass	–	7.1 ± 3.0
			K	–	2.0 ± 0.6
	♀	12	SVL	–	350.9 ± 48.8
			TL	–	523.0 ± 67.2
			Mass	–	9.0 ± 3.2
			K	–	–

contrast to these dimorphic differences, body condition was similar across all species at both locations. This measurement was desired as snakes of the genus *Sibon* are snakes potentially affected by trophic disruption in areas where amphibian populations have declined (Whiles *et al.* 2006). We attribute these dimorphic anomalies to the small sample size in our data, but also consider that little is known about the genus and that our numbers encountered may reflect the relative abundance of individuals given our efforts in surveying.

For Costa Rican specimens Savage (2002) reported 557 mm TL for *S. annulatus* that at the time was the maximum recorded for the species (Köhler 2008). McCranie (2011) reported a maximum TL of 552 mm in Honduras. More recently a new record of 576 mm TL was recorded from CPBS (Lewis *et al.* 2010a). During this study, the largest specimen we encountered was from CPBS and measured 611 mm TL, representing a new maximum size for the species. The maximum TL for *Sibon argus* is 690 mm and for *S. longifrenis* is 624 mm (McCranie *et al.* 2001, Savage 2002, Solórzano 2004, Köhler 2008, McCranie 2011). *Sibon nebulatus* has been recorded up to 1013 mm TL in Panama (Frazier *et al.* 2006), 830 mm TL in Costa Rica (Savage 2002, this paper), 738 mm TL in Honduras (McCranie 2011) and 550 mm TL at its most northern range extent (Lee 2000). Our data fit within these maximum figures, however, it is interesting to note that the species' maximum size seems to increase on a southward geographic gradient.

Diet and Behavior

At CPBS we observed *Sibon annulatus* feeding on mollusks. At ADM a *S. longifrenis* was observed feeding on eggs of the glassfrog *Cochranella albomaculata* (Montgomery *et al.* 2007) and a *S. argus* found nearby in the community of El Valle de Antón was feeding on eggs of the hylid red-eyed treefrog (*Agalychnis callidryas)* (Ray *et al.* 2011). In fact, Ray *et al.* (2012) showed that the diet of snakes of the genus *Sibon* at two montane sites in Panama, including ADM, was not necessarily obligate snail feeding, and that *Sibon* consume both shelled and unshelled mollusks, annelids, other soft-bodied invertebrates, and amphibian eggs. In captivity *Sibon carri* (Motagua Valley, Zacapa, Guatemala) also readily consumed earthworms (R. Daguerre pers. comm.).

In December 2003, one of us (TRL) observed three *Sibon annulatus,* two males and one female, in the same *Manicaria saccifera* palm tree. The first male was feeding on a small cluster of *Helicinia* sp. snails that were grazing on a palm frond. The second male was mating with the female. To observe three *S. annulatus* in such close proximity (< 800 mm) was unusual. We surmise that this kind of sexual interaction may be assisted by prey resource and distribution (i.e., *S. annulatus* may congregate in areas with abundant prey resource and then utilize close physical proximity for opportunistic mating). Such opportunistic breeding behavior could be reliant on the distribution of females and prey resources. It is known that for some snake species female distribution has a pronounced effect on males and their behavior patterns (Madsen and Shine 1993, Brown and Weatherhead 1999, Seigel *et al.* 2002). That *S. annulatus* or other *Sibon* spp. could be influenced spatially by prey resources is not established by this sole observation but invites further investigation. We concur with Ray *et al.* (2012) that *Sibon* may interspecifically compete for the same food resource.

Abundance and Habitat

Our results show that the composition of *Sibon* spp. varies in different types of forests. Given that data at ADM covered a five month period within a single year and that the CPBS data spanned a decade, we tentatively surmise that *Sibon* spp. were more prolific at ADM with similar totals of snakes being encountered at both sites across respective data collection periods. Notwithstanding, survey effort between

the two sites was not comparable. *S. annulatus, S. longifrenis,* and *S. nebulatus* were all found at both CPBS and ADM. *S. argus* was only found at ADM, and although it is known from the Caribbean versant of Costa Rica, it has not been recorded as far north as CBPS. *S. annulatus* was found in similar abundance at both sites, but *S. longifrenis* was found in higher numbers at ADM than CPBS. The largest contrast in abundance was *S. nebulatus,* which was found more frequently at CPBS than ADM (24 specimens compared to one, respectively). At both sites, *Sibon* specimens were more commonly encountered in riparian habitat, with the exception of *S. longifrenis* at CPBS, which mostly occurred in *Manicaria* swamp forest.

Differences among *Sibon* compositions also exist among types of habitat in the same country. For example, at CPBS *S. longifrenis* was always detected in low abundance. However, this species was found more frequently at the pre-montane site Rara Avis Biological Station (700 m), Braulio Carrillo National Park, Heredia, Costa Rica (D. Filipiak pers. comm.). That *Sibon* spp. are more common at mid to high elevations is further corroborated by the higher numbers observed at ADM (800 m). This postulation invites further comparative work among sites across the Neotropics where *Sibon* spp. occurs. We also speculate that differences in climate may influence *Sibon* composition and abundance. CPBS climate has drier conditions from March to September and a pronounced wet season in November to January. Average daily temperatures are 26ºC and 70 % relatively humidity. Its rainfall is unpredictable and may exceed 5000–7000 mm annually. Flooding can also occur as the area is a catchment zone. ADM is in cloud forest and has a more stable climate and is cooler with average temperatures of 24ºC and 70% relative humidity with annual rainfall between 3000–5000 mm.

Recent research by Whiles *et al.* (2006) has suggested that when a forest is affected by amphibian decline this could present a threat to populations of snakes from the reduction of available prey. *Sibon, Dipsas, Sibynomorphus,* and *Tropidodipsas* are genera potentially affected by this trophic disruption and because of this we recommend that herpetologists collaborate further on the snakes' population ecology and continue to monitor their presence and health across all Neotropical countries.

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