

MOVEMENT, HABITAT USE AND DIET OF
AN INVASIVE SNAKE, *Boa constrictor* (Boidae), IN PUERTO RICO
by

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Abstract

Invasive species are the second threat to biodiversity. Studies have suggested that along with other variables, lack of predators, numerous offspring production, body size and prey availability are some of the reasons for non-native species successful establishment. *Boa constrictor* is very common in the illegal exotic animal pet trade and it is believed that accidental and/or intentional releases of this non-native snake into novel environments has caused the establishment of *B. constrictor* populations out of its native range. In Puerto Rico there is a population of *B. constrictor* established at Mayaguez, on the west side of the Island. I studied movement and habitat use, using radio telemetry to track the snakes. A total of six snakes were radio tracked and for every location, movement patterns, home range area and habitat description were estimated. In addition, I determined sexual dimorphism, body condition and studied the diet of the *B. constrictor* using direct diet description and stable isotopes ratios. The mean total distance moved for all snakes was 431 m (SD= ± 335.91), while mean daily movement every time they were located was 51.62 m (SD= ± 27.19). The average activity range of this species in Puerto Rico for almost three months was 5730.72 m² (SD= ± 4824.80). Snakes were more frequently located on forest edges than in forest. Analysis of habitat use determined a significant selection of habitats with larger rocks, understory trees with low height but bigger DBH, and less shrub coverage when compared with the surrounding available habitat. These data suggest that the habitat selection and movement of *B. constrictor* may be influenced by thermoregulatory needs and possibly by prey availability (not measured in this study). Sexual dimorphism in snout to vent length was not detected, but males had a significant longer tail than females. *B. constrictor* seem to have a good foraging success but they are more corpulent compared to the Puerto Rican boa (*Chilabothrus inornatus*). Both sexes of *B. constrictor* seem to feed mainly upon mammals in Puerto Rico as determined by stable isotopes signals of their muscles. Further studies should be done characterizing thermoregulation sites and prey population, to better understand the biology of this non-native invasive snake in its new established environment.

Resumen

Las especies invasoras son la segunda amenaza a la biodiversidad a nivel mundial que ocurre hoy día. Algunas investigaciones científicas sugieren que algunas variables que determinan el éxito de estas especies no nativas en un nuevo medioambiente son la ausencia de un depredador, la capacidad de tener numerosas crías, poseer un gran tamaño y tener disponibilidad de comida en el nuevo lugar donde se establecen. *Boa constrictor* es una de las serpientes con gran demanda en el tráfico ilegal de animales exóticos y, actualmente, hay poblaciones de esta especie establecidas en el municipio de Mayagüez al oeste de la isla de Puerto Rico. Estudié seis individuos capturados a los que le determiné algunos parámetros como movimiento, uso de hábitat, ámbito doméstico (área que el animal utiliza para llevar a cabo las actividades esenciales y sobrevivir) dimorfismo sexual, condición corporal y dieta utilizando isótopos estables. Para el movimiento y uso de hábitat, utilicé radio transmisores para localizar la serpiente cada 48 horas. Una vez localizadas se describió el hábitat de donde se encontró cada serpiente como también se tomaron medidas para calcular movimiento total y por localización para cada serpiente. En adición, se hizo caracterización de composición de dieta utilizando isótopos estables. En los parámetros calculados para movimiento, la media de la distancia total de todas las serpientes fue de 431 m (SD=335.91), mientras cada vez que se movían, recorrían una distancia de 51.62 m (SD=27.19). El área del ámbito doméstico de la serpiente en Puerto Rico fue de 5730.72 m² (SD=4824.80). Las serpientes bajo estudio fueron encontradas con mayor frecuencia en los bordes de bosque que en los bosques. Luego que se describió el hábitat seleccionados por las serpientes, las serpientes seleccionaron hábitats con rocas de mayor tamaño, menos cobertura de arbustos en el suelo y árboles de sotobosque con menor altura y mayor diámetro. Esto sugiere que la selección de hábitat y el movimiento de la *B. constrictor* pueden estar influidos mayormente por áreas potenciales para la termorregulación de la serpiente al igual que la disponibilidad de alimento (aunque no fue medida en este proyecto). La *B. constrictor* en Puerto Rico carece de dimorfismo sexual pero los machos tienen colas más largas comparado con las hembras. *B. constrictor* tiene éxito en forrajeo y son más corpulentas que la Boa de Puerto Rico (*Chilabothrus inornatus*). La alimentación de la *B. constrictor* es principalmente compuesta de mamíferos, establecido por la señales isotópicas obtenida de sus músculos. Se deben

realizar estudios para caracterizar hábitats de termorregulación y la población de sus presas para poder entender la biología de ésta especie no-nativa invasora establecida en un nuevo medio ambiente.

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Dedication

To:

My dear family and friends, for their patience and support.

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Chapters Introduction

Non-native species introduction have been progressively increasing on the last few years. Studies suggest that before the human's appearance, the introduction of new species was one species per 35,000 years, while the frequency of introduction nowadays has increased to 79 species in 85 years; humans are the primary responsible of species introduction in a novel environment (Beardsley 1962; Lowes et al. 2000; Pimentel et al. 2001; Pimentel et al. 2005; Kraus 2008). The impacts of an introduction of a non-indigenous species to the local fauna, to the community structure and to humans' health have been widely studied in their novel environment and had cost the United States approximately 210 billion dollars in damages (Wilcove et al. 1998; Sakai et al. 2001; Pimentel et al. 2005).

Introduction of exotic species out of their natural range can be accidental or intentional. The Cuban tree frog (*Osteopilus septentrionalis*), with natural distribution that includes Cuba, Cayman Islands and Bahamas, has been accidentally introduced to numerous states in United States, Puerto Rico and other tropical areas through ornamental plants and other cargo shipment (McGarrity and Johnson 2009). Another accidental introduction example is the Brown tree snake (*Boiga irregularis*), that was introduced into Guam, by military cargo, between 1940 and 1950's (Savidge 1987). On the other hand, intentional introductions have played an important role on invasive species establishment. One example is the cane toad (*Rhinella marina*), introduced to the Caribbean islands as biological control to fight against sugar cane insect pests but which has affected native biota of islands (Wilson et al. 2011).

Reed (2005) discussed that some members of the Boidae family present an attractive skin patterns, colors and their large size which increase their demand on the animal pet trade. Because of their size and lack of people willing to take care of a large animal, this can lead to releasing the animal into a new environment. Some of these released exotic animals, therefore, can turn invasive due to the lack of predation, and sometimes can displace native species. Furthermore, the eradication and control of the invasive species can have economic costs. For example, estimates of damages and losses caused by non-native species in the United States can sum up to \$138 billion in United States (Pimentel et al. 2002). One perfect example to show the economic impacts of exotic species is the Indian mongoose (*Herpestes auropunctatus*) introduced to Puerto Rico and other islands for bio-control of rats. The Indian mongoose preyed on herpetofauna and is a vector for rabies. Consequently, the invasion of Indian mongoose into new territories has had an estimated 50 billion dollars cost on damages in Puerto Rico and Hawaii (Pimentel et al. 2005; Barun et al. 2011).

The illegal wildlife international trade is the second most lucrative black market business after narcotics, and is hypothesized to generate up to U.S. \$20 billion per year (Rosen and Smith 2010). The red tail boa (*Boa constrictor*) is a common species on the exotic animal pet trade and is among the top three boid snakes most traded in the United States (Reed et al. 2005). Because of its wide native distribution, tropical and subtropical areas are suitable for their establishment; therefore, I will address the movement patterns, habitat use, diet, sexual dimorphism, and body condition of the introduced invasive *Boa constrictor* in Puerto Rico.

CHAPTER 1: Movement and habitat use of the invasive snake, *Boa constrictor* (Serpentes: Boidae) on the island of Puerto Rico.

Introduction and background

Invasive species worldwide has been recognized as one of the contributors to extinctions and threats to biodiversity (Clavero and García-Berthou 2005; Wilcove et al. 2008). The Invasive Species Specialist Group defines an invasive species as “animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they establish and disperse, generating a negative impact on the local ecosystem and species” (www.issg.org). Even though, nowadays it is known that the establishment of new organisms can cause negative impacts, it is poorly understood how these species interact within the new environment (Mooney and Cleland 2001; Pimentel et al. 2005; Medina et al. 2011). These species share similar characteristics such as lack of predators, high fecundity, (that allow the production of multiple offspring), and rapid growth that allow dispersion and establishment in novel environments (Reed and Rodda 2009).

Species of snakes from the families *Boidae*, *Colubridae* and *Pythonidae* have been identified as snakes of high demand in the animal pet trade and to herpetoculturists (Reed 2005); therefore, it is believed that accidental escapes and intentional releases of some individuals in novel environments may have contributed to the spread and establishment of these invasive snakes into new places (Reynolds et al. 2013). Furthermore, some non-native invasive snakes have been placed in the top 100 worst invasive alien species that can successfully become established and spread on new environments (Lowe et al. 2000).

One of the snake species that became an invasive in the Caribbean region is *Boa constrictor*. Native to the continental neotropics, including adjacent islands, *B. constrictor*

has one of the largest latitudinal habitat ranges (66°) and can tolerate climates with temperatures ranging from 5°C to 33°C (Reed and Rodda 2009). The *B. constrictor* can be recognized by its hourglass marks on a lighter background color and a black line that appears in the center of the head towards the body. Also, its main identification comes from the round-reddish blotches on the tail. Red tail boas can grow up to 4.4 meters in body length and reach its sexual maturity when spanning 1.5 to 2 meters (Reed and Rodda 2009). When gravid, they give birth from 20 to 64 neonates (Bertona and Chiaraviglio 2003; Reed and Rodda 2009). Even though *B. constrictor* can reproduce sexually, with favorable conditions, females can reproduce by parthenogenesis (Booth et al. 2010). Research data suggest that captive *B. constrictor* can live up to 40 years, but no information is available for wild populations (Greene 1983; Reed and Rodda 2009).

Because of its large size and different color patterns, *B. constrictor* is placed in the top three species with highest demand on exotic animal pet trade in the United States for skin products purposes and also in the top five species of snakes that can turn invasive out of their native ranges and cause irreversible damages (Reed 2005; Schlaepfer et al. 2005). Introduction of *B. constrictor* has been reported in Cozumel (Romero-Nájera and Cuarón 2006), Aruba (Quick et al. 2005), Florida (Snow et al. 2007), Puerto Rico (Reynolds et al. 2013), and St. Croix (Nicole Angeli, personal communication). In Cozumel, *B. constrictor* invasion and spread started after the ending of a Hollywood film, when the crew allegedly set free a few *B. constrictors*, and nowadays they are established all over the island (Romero-Nájera and Cuarón 2006). Today, it is considered responsible of predated on native songbirds, lizards and mammals declining thriving populations and dropping total biodiversity (Quick et al. 2005; Romero-Nájera and Cuarón 2006).

Since 1990, reports of *B. constrictor* on the island of Puerto Rico have been more frequent and its establishment has been more noticeably in the west side of the island (A. R. Puente-Rolón unpubl.). Reynolds et al. (2013) suggests that the populations of the *B. constrictor* in Puerto Rico have similar genetic markers of individuals previously housed in zoos, captivity, or use for breeding, indicating that individuals established in the island escaped or were freed by humans, accidentally or intentionally. These populations are currently established in the west side of the island, being the municipality of Mayagüez the main introduction source. Today the species is expanding its range, moving from west to the east in Puerto Rico (A. R. Puente-Rolón Unpubl.)(Fig.1.10). Previous studies have taught us that we can experience loss of biodiversity and heterogeneity in the native fauna due to the presence of invasive snakes. This also implies an economic cost for the management and protection of our biodiversity, therefore causing the loss of the ecological balance. Currently, it is unknown if there is a direct threat to humans by the species; however, the *B. constrictor* can be a threat to other animal's health because they can be a vector of the Boid Inclusion Body Disease (BIBD). This disease is a fatal and is caused by arenaviruses that affects snakes' central nervous system, and lead to the animal's death (Hetzl et al. 2013). This novel risk combined with other pathogens can threaten native, endangered snakes such as the Puerto Rican Boa (*Chilabothrus inornatus*). In order to manage the increasing populations of *B. constrictor* in Puerto Rico, it is important to improve our knowledge on the biology and the spatial ecology of this invasive snake.

In pursuance of its survival an organism uses the resources that are available in the environment and the time they spent in a particular place is called habitat use (Krausman 1999; Fagan et al. 2013). For Fagan et al. (2013), habitat use is considered selective if the habitat has been used disproportionately compared with the availability of the resources or

the amount of habitat available to the animal (food, shelter, etc.). The use of a particular area within the habitat can vary and change throughout the organisms' life span including spatial and temporal changes. For example, Northern Watersnake (*Nerodia sipedon*) home range size increases over the rainy season because movement frequencies and distances were greater than in other seasons (Roth and Greene 2006). This also coincides with increasing food availability, vegetation cover and reproductive cycle (Marques et al. 2000). In addition, structural changes in the habitat can also influence the amount of movement of an organism (Aebischer and Robertson 1993). It has been suggested that the presence of heterogeneous habitats can decrease the amount of movement of an organism, possibly because of the availability of critical resources (prey, mate, refuge) within that area (Hoss et al. 2010; Pearson and Shine 2005).

To better understand the biology of *Boa constrictor* in Puerto Rico, we need to find what requirements it needs in order to survive in its new environment. The study of spatial movement and habitat use can help determine where we can search for individuals of an invasive species such as a *Boa constrictor* to improve future management and control. The aims of this study were: 1) calculate the movements of invasive *Boa constrictor*, 2) describe microhabitat and macrohabitat use of the species in its novel habitat and 3) estimate its home range size using Minimum Complex Polygon.

Materials and Methods

Study area- The study was conducted in Mayagüez municipality, located on the west side of the island of Puerto Rico (Figure 1.10). Holdridge's system of classification puts Puerto Rico in the Subtropical latitudinal region and is situated on west of 67° W and south of 18° 15' N (Holdridge 1947; Mattson 1960; Ewel and Whitmore 1973). More than 58% of Puerto Rico is dominated by Subtropical Moist Forest, including Mayagüez. The

subtropical moist forest has an annual rainfall of 100-2200 mm and annual average temperatures ranging from 17.8-31.5 °C (64 to 89 °F) (Malmgren and Winter 1999).

Transmitter implant procedure- Snakes for the study (three males and seven females) were captured by people from the Miradero community in Mayaguez, Puerto Rico and during road cruising surveys. Two types of transmitters were used do to possible inefficient battery life on the Advanced Telemetry Systems transmitters. The first equipment used was an R1500 series model with battery life of approximately 400 days (Advanced Telemetry Systems, Inc., Minnesota, USA) coated with electrical resin. After damaged transmitters, new snake's collected had a new transmitter model. The second equipment used was the SI-2T model (Holohil Systems, Ltd., Ontario, Canada) coated with butyl rubber. Both transmitters operated at frequencies between 164.144-165.147 MHz.

I recorded information in the exact date, time, location and behavior of the snakes captured. After the snakes' captures, transmitters were surgically implanted by Dr. Michelle Trappler, veterinary surgeon at the San Francisco de Asis Clinic in Hatillo, Puerto Rico, and by Dr. Luis Figueroa, a veterinarian working at the time for the Mayagüez Zoo (Juan A. Rivero Zoo). The weight of the transmitter (9 grams) did not exceed 2% of the snake's mass. Before surgical implantation, the snake were locally anesthetized (Lidocaine) on the exact place where the transmitter was going be implanted (approximately 40 cm away from the cloacal, towards the head). After 10 minutes, general anesthesia (Ketamine) was applied to the snake. Using sterile techniques, the radio-transmitter was implanted in the body cavity of the snake. The flexible antenna was placed extended subcutaneously towards the head between the epidermis and the outer body wall. After the surgery, Enrofloxacin® antibiotic was applied to prevent infections post-surgery. After recovery, snakes were held

under observation for three consecutive days in an appropriate clean snake cage before they were released at their capture site.

Data collection

Radiotracking- Snakes were released at their point of capture and located every 48 hours from July 2014 to October 2014 and September 2015 to December 2015 using a R410 radio receiver (Advanced Telemetry Systems Inc., Minnesota, USA) and a three-element Yagi antenna. Each location of the tagged snakes were recorded with a Global Positioning System (GPS, Garmin e-Trex 10) with additional observations like its behavior (basking, moving, coiled); A Kestrel 2500 weather meter was used to document climate variables like wind speed, temperature and humidity.

Habitat data- For each snake's recorded location, I characterized the microhabitat after the snake had abandoned the area so as to minimize stress and disturbance. I used structural variables described on Table 1.0 (Blouin-Demers and Weatherhead 2001). In order to determine habitat preference by the snakes, I repeated the same habitat descriptions (Table 1.10) by selecting random points as described on Blouin-Demers and Weatherhead (2001).

Table 1.0. Variables for microhabitat recorded at each location used by radiotagged *B. constrictor* in Puerto Rico.

Variable	Description
Substrate species	Species of substrate where snake was found
Substrate DBH	DBH of substrate where snake was found
Substrate Height	Height of substrate of substrate where snake was found
Canopy Height	In meters
Canopy closure	Percent of close and open canopy where snake was found
Aspect	Direction the ground slopes
Slope	Degrees
Litter depth	1 meter from site in four cardinal points
Distance to Rock	Distance (m) to nearest rock within a 30 meter radius. Record length (cm)
Distance to Log	Distance (m) to nearest log within a 30 meter radius. Record DBH (cm).
Distance to overstory tree	Distance (m) to nearest overstory tree within a 30 meter radius. Record DBH (cm).
Distance to understory tree	Distance (m) to nearest understory within a 30 meter radius. Record DBH (cm).
Distance to Snag	Distance (m) to nearest snag within a 30 meter radius. Record DBH (cm).
Snag Decay	State of decay in a scale of 1-7
Trees plot	Species of trees within 10 meters radius.
Rock	Coverage (%) of rocks within plot in a 2 m radius.
Litter	Coverage (%) of litter within plot in a 2 m radius.
Log	Coverage (%) of logs within plot in a 2 m radius.
Grass	Coverage (%) of grass within plot in a 2 m radius.
Shrub	Coverage (%) of shrub within plot in a 2 m radius.
Bare	Coverage (%) of bare ground within plot in a 2 m radius.
Herbs	Coverage (%) of herbs within plot in a 2 m radius.
Wood	Coverage (%) of wood within plot in a 2 m radius.
# Woody	Number of woody stems within a 2 m radius
Height of ground vegetation	Height (m) of ground vegetation
Vegetation Clump Height	Nearest vegetation clump height (m)
Vegetation Clump Width	Nearest vegetation clump width (m)
Snake to Edge	Distance (m) from snake to nearest large (>3) canopy opening
Snake to Vegetation	If snake was in an open field, distance (m) to nearest vegetation clump

Analyses

Movement- The coordinates of all snakes' locations were plotted on a satellite image of the study area using ArcMap® (Version 10, ESRI, Redlands, CA). I used the ArcMap® measurement tool to measure the total distance moved per each snake along with mean daily movement per fix as described by Wunderle and Mercado (2004).

Home range is defined as the area that an organism uses to satisfy its needs in order to survive (Burt 1943). Home range size was determined via the Minimum Convex Polygon estimator, using all locations for each snake. To calculate home range with Minimum Convex Polygon I used ArcMap® (version 10, ESRI, Redlands, CA) employing the Minimum Bounding Geometry tool that creates polygons by using the coordinates of each snakes to measure the home range of the snakes that moved more than two times while they were under the study.

Habitat use- For habitat use characterization I conducted a multivariate analysis of variance (MANOVA) for quantitative values and a Chi-square for qualitative variables. I started by doing a random forest in RStudio® to see which variables were important for the coordinates of habitat selection of the snakes and the random coordinates (to confirm that snakes select a specific habitat). Followed by this analysis, I performed a non-parametric MANOVA and a Kruskal-Wallis because variables did not passed the normality tests and the constant variance parameters. In addition, for macrohabitat preferences I performed a Chi-Square (contingency table) to see if there was a preference of snake selection between forest and forest edge. Then, I did a t-test to see if there was a statistical difference in distances of snakes located to the nearest road and building and if they preferred open- or closed-canopy areas.

Results

Even though I had ten *B. constrictor* with transmitters, only six (four females and two males) of them were located more than two times during the study period. During the radio-tracking period, snakes were in areas ranging from 23 to 254 meters elevation above sea level, with temperature ranging from 26.8 to 32.2°C and humidity ranging from 89.3 to 100%. The largest *B. constrictor* was a female that measured 216 cm (SVL+TL) and weighed 6441.01 grams (Table 1.1). Snout-vent length, tail length and weight of snakes with transmitters ranged from 135.3-195.54 cm, 15.5-26.5 cm, 3674.10-6441.012g, respectively (Table 1.1). Also, the number of days under radio tracking activities ranged from 24 to 68 days (Table 1.2).

Movement and Home Range- All *B. constrictor* under study had a mean total movement of 431.21 ± 335.90 m (range of 113.34 to 1,084.56 m). A male *B. constrictor* (BOCO 8) had the largest total distance moved (1084.54 m) and mean daily movement per fix (180.76 m) and BOCO 2, a female *B. constrictor*, had the least total distance moved (113.34m) (Table 1.3). The mean daily movement per fix for all six snakes was 51.62 ± 27.19 m (Table 1.3) and the mean home range (Minimum Complex Polygon) for all six snakes was 5730.71 ± 4824.80 m². The snake BOCO 1 had the biggest home range (15,144.83 m²) and BOCO 2 had the smallest home range (1,316.97 m²) (Table 1.5). I found no relationship between size (snout-vent length) of snake and home range area (m²) for all snakes under study (Constant Variance test; Area= $6976.73 - (8.048 \cdot \text{SVL})$; R=0.0364; P=0.06).

Activity- When snakes were located, they were visible only 15.38 % of the time. On one occasion, a snake (BOCO 4) was on a tree branch while at the same spot I observed a gravid Puerto Rican Boa (*Chilabothrus inornatus*) (Appendix 3). When *B. constrictor* were

visible, 90% of the time they were basking, and while they were basking, 70 % of the time they were stretched, and 30% of the time they were coiled.

Habitat use- Snakes were located 76% of the time on forest edges and 24% in forest interiors (Fig. 1.2). While they were in forest edges, we found no statistical difference between being nearer to roads or buildings but on average they were closer to buildings than to roads (Mann-Whitney U Statistics; T=371.00, n=19, P=1.000) (Fig. 1.3).

Boa constrictor were on open canopy areas 65 % of the time and 35% on closed canopy areas (Fig. 1.2). However, I observed no statistical difference on preference between open and closed canopy (T=4642.00 n (small)=66, P=0.245). I observed *B. constrictor* more frequently on open canopy areas (Fig. 1.4). Snakes were 59.09% of the time in open canopies with greater than 50% of openness; while in closed canopies, 51.51% of the time snakes used areas with a close canopy with less than 50% leaf coverage.

There was no statistical difference in selection of forest versus forest edge when compared with random points ($X^2=0.008895$; $df=1$; $P=0.9249$) but snakes were found more frequent in forest edges. After a Random Forest test was performed, and compared with variables of random habitat descriptions, the variables with significant difference were rock length (KW $X^2=6.3891$; $df=1$; $P=0.01148$), percentage ground cover by shrubs (KW $X^2=9.6279$; $df=1$; $P=0.001916$), under story tree height (KW $X^2= 7.1251$; $df=1$; $P=0.007601$), and under story tree DBH (KW $X^2=13.268$; $df=1$; $P=0.00027$) (Table 1.6).

Table 1. 1. Description of radio-tagged *Boa constrictor*.

Snake ID	Weight (g)	Sex	SVL (cm)	TL (cm)	Frequency
BOCO 1	2902.99	Female	155.6	19.7	164.808
BOCO 2	2812.27	Female	144.0	17.9	164.170
BOCO 3	3674.10	Male	159.9	26.5	164.144
BOCO 4	2086.52	Female	139.2	15.5	164.844
BOCO 5	2630.84	Female	135.3	15.6	164.158
BOCO 6	2494.76	Female	154.9	19.1	164.082
BOCO 7	6441.01	Female	195.0	21.0	165.098
BOCO 8	1587.57	Male	148.5	21.5	165.018
BOCO 9	1859.73	Female	140.0	16.5	165.098
BOCO 10	2726.09	Male	161.5	19.1	165.147

SVL: Snout to vent length in snakes (distance from the snout to the cloaca). **TL:** Tail length (distance from the cloaca to the tip of the tail).

Table 1.2. Release dates and days tracked for all snakes that had transmitters.

Snake ID	Released date	Days tracked	Number of fixes
BOCO 1	14/07/2014	63	9
BOCO 2	15/07/2014	24	10
BOCO 3	14/07/2014	48	13
BOCO 4	14/07/2014	68	21
BOCO 5	08/08/2014	29	8
BOCO 6	30/09/2014	0	0
BOCO 7	01/10/2015	0	0
BOCO 8	29/09/2015	50	6
BOCO 9	24/11/2015	0	0
BOCO 10	24/11/2015	0	0

Table 1.3. Total distances moved and mean daily movement per fix for radio tagged *Boa constrictor* that moved more than two times. Stars (*) represent missing values due to the lack of information.

Snake ID	Total distance moved (m)	Mean daily movement per fix (m/fix)	Mean days Inmobile
BOCO 1	303.36	75.84	2.33
BOCO 2	113.34	15.25	3
BOCO 3	302.76	7.22	*
BOCO 4	403.31	14.24	*
BOCO 5	379.94	15.46	*
BOCO 8	1084.56	180.76	*
Mean	431.21 ± 335.91 SD	51.62 ± 27.19 SD	

Table 1.4. Comparison of movement of the invasive *Boa constrictor* in Puerto Rico with other studies.

Study	Movement calculations
Movement of <i>Boa constrictor</i> in Puerto Rico. (M. Vega-Ross Unpubl. data)	Mean Distance per movement = 129.38 ± 555.54 m Mean Daily Movement per Move = 41.29 ± 185.55 m
Spatial Ecology of <i>Boa constrictor</i> imperator in Nicaragua (Holtzman et al. 2007)	<p style="text-align: center;"><u>Mean Distance per Movement</u></p> Displaced snakes = 241 ± 63 m Resident snakes = 72.99 ± 21.38 m

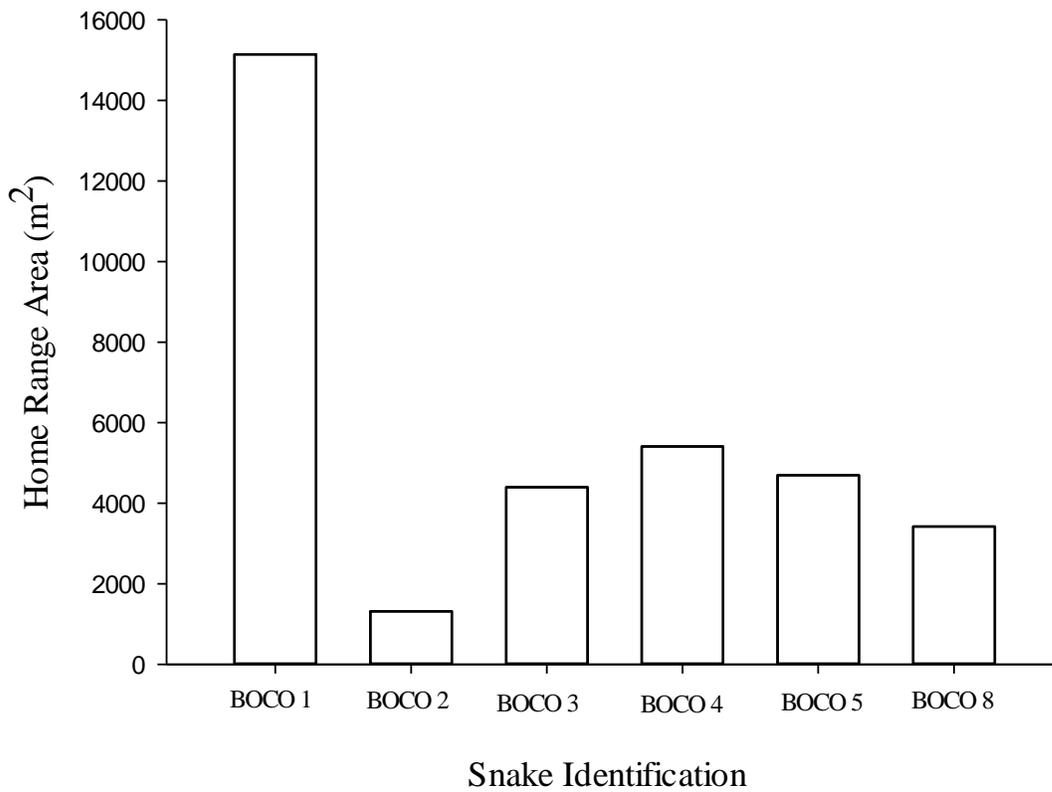


Figure 1. 1. Home range for all *Boa constrictor* that moved more than three times. We used minimum convex polygon using 100% of the data. Bars represent the area in square meters (m²) for each snake.

Table 1.5. Home range area used by all *Boa constrictor*.

BOCO ID	Home range area (m²)
BOCO 1	15144.83
BOCO 2	1316.97
BOCO 3	4396.47
BOCO 4	5409.89
BOCO 5	4693.79
BOCO 8	3422.34
Mean	5730.72 ± 4824.80 SD

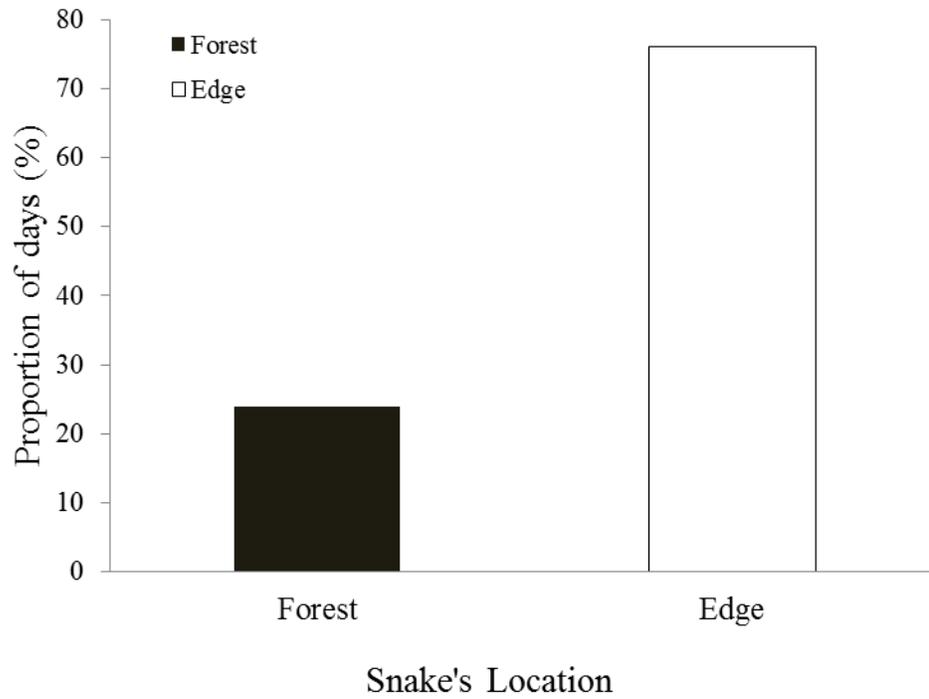


Figure 1. 2. Proportion of days that *Boa constrictors* were found on the forest or forest edge. To see which criteria were used to establish forest and forest edge, see methodology.

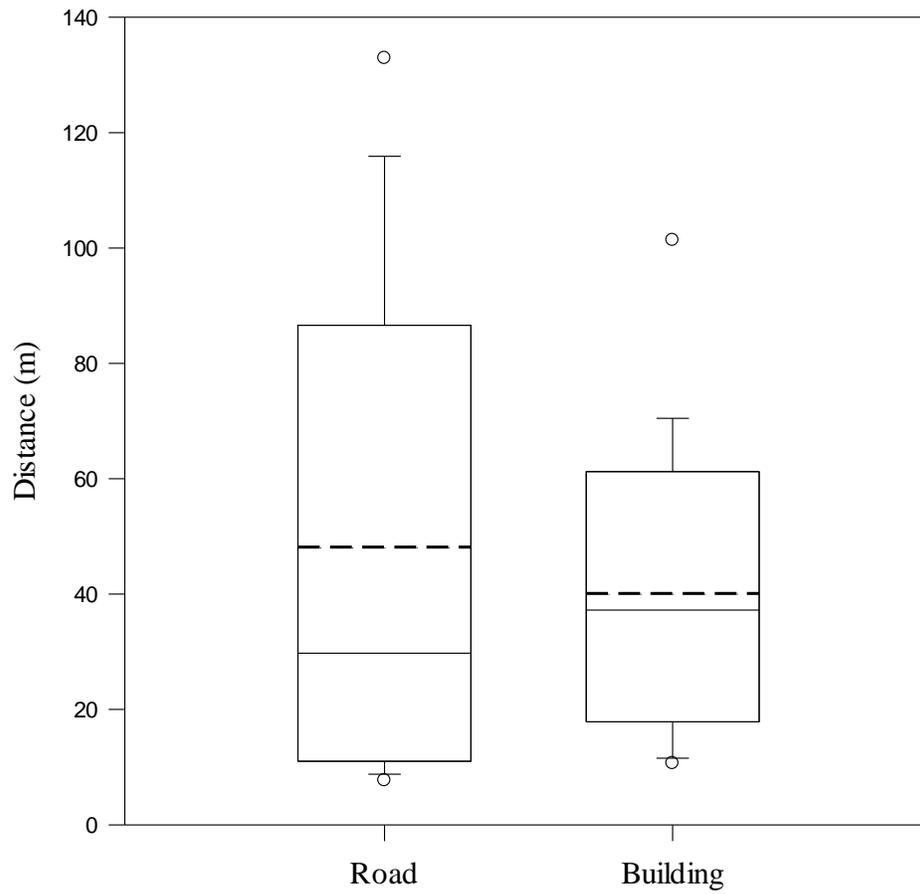


Figure 1. 3. Distance to the nearest roads and buildings for all *Boa constrictor*'s location. Dashed lines represent the mean.

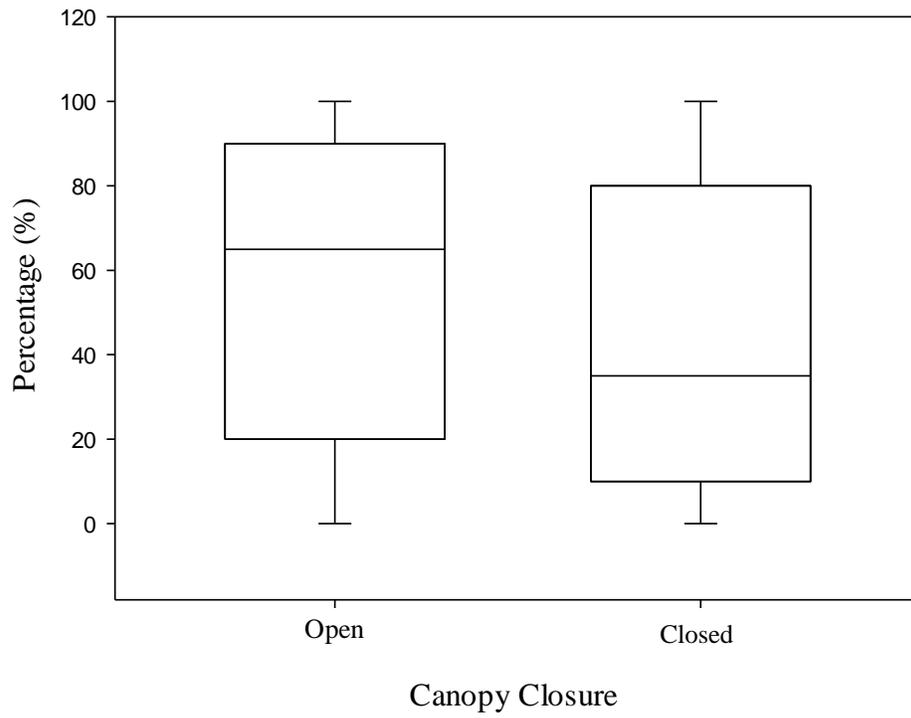
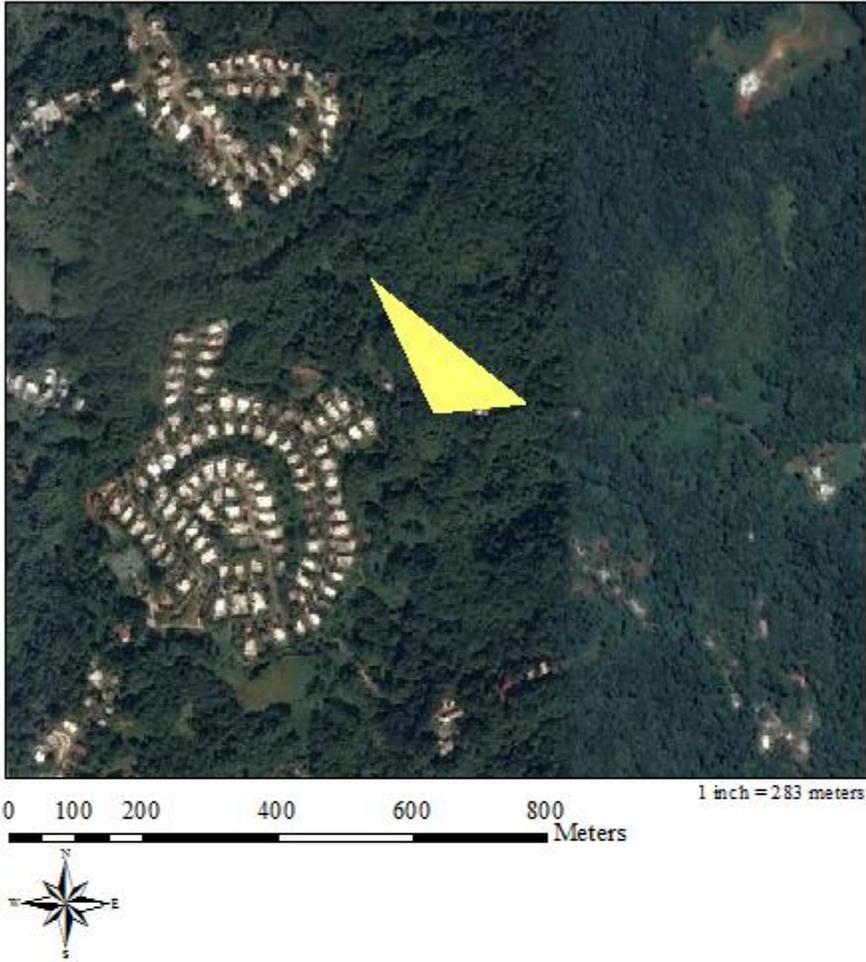


Figure 1. 4. Mean percentage of open and close canopy that were used by *Boa constrictor*.

Table 1.6. Important variables on habitat selection for *Boa constrictor* for selected snake habitat N=62 and for random coordinates description N=12.

Habitat selection			Random point		
<u>Variable</u>	<u>Mean</u>	<u>SD ±</u>	<u>Variable</u>	<u>Mean</u>	<u>SD ±</u>
Rock Length (cm)	54.11	45.11	Rock Length (cm)	28.12	25.39
Under Story DBH (cm)	12.36	11.52	Under Story DBH (cm)	3.00	2.6
Under Story Height (m)	5.31	2.33	Under Story Height (m)	8.47	17.26
Ground Cover_Shrubs (%)	2.73	6.16	Ground Cover_Shrubs (%)	30.83	39.65

Reference Scale: 1:0



Coordinate System: NAD 1983 StatePlane Puerto Rico Virgin Islands FIPS 5200
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 200,000.0000
False Northing: 200,000.0000
Central Meridian: -66.4333
Standard Parallel 1: 18.0333
Standard Parallel 2: 18.4333
Latitude Of Origin: 17.8333
Units: Meter

Figure 1.5. Minimum Complex Polygon for snake BOCO 1.

Reference Scale: 1:0



Coordinate System: NAD 1983 StatePlane Puerto Rico Virgin Islands FIPS 5200
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 200,000.0000
False Northing: 200,000.0000
Central Meridian: -66.4333
Standard Parallel 1: 18.0333
Standard Parallel 2: 18.4333
Latitude Of Origin: 17.8333
Units: Meter

Figure 1. 6. Minimum Complex Polygon for snakes BOCO 2 and BOCO 3.

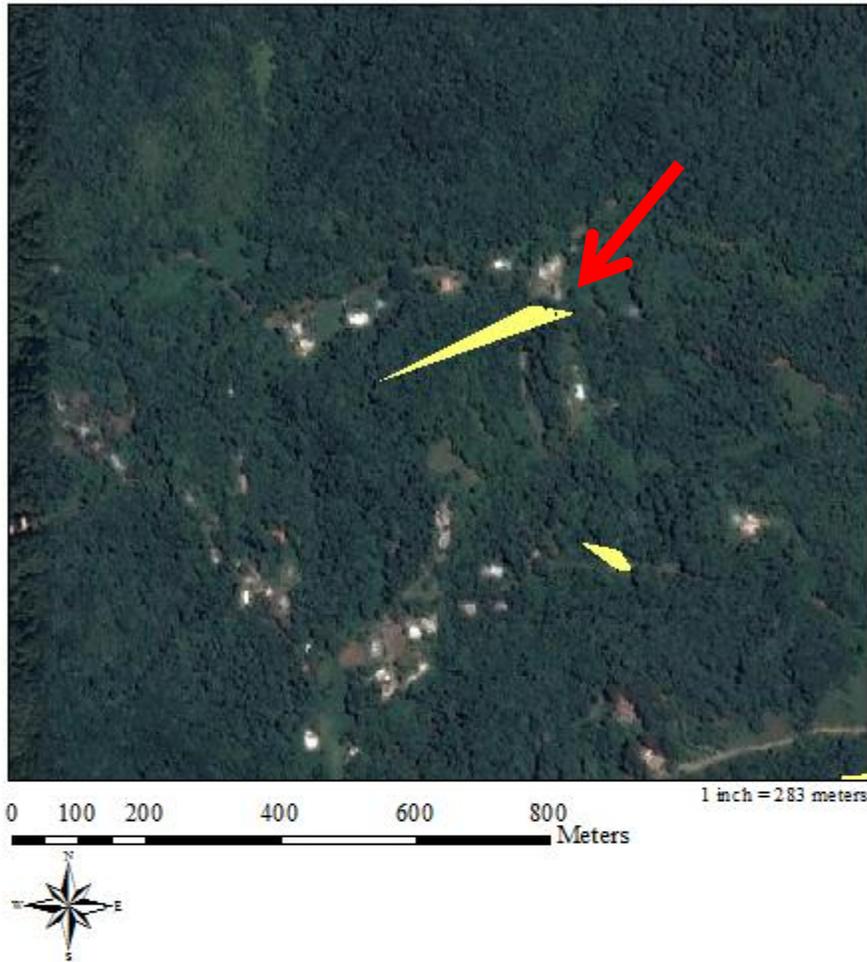
Reference Scale: 1:0



Coordinate System: NAD 1983 StatePlane Puerto Rico Virgin Islands FIPS 5200
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 200,000.0000
False Northing: 200,000.0000
Central Meridian: -66.4333
Standard Parallel 1: 18.0333
Standard Parallel 2: 18.4333
Latitude Of Origin: 17.8333
Units: Meter

Figure 1. 7. Minimum Complex Polygon for snake BOCO 4.

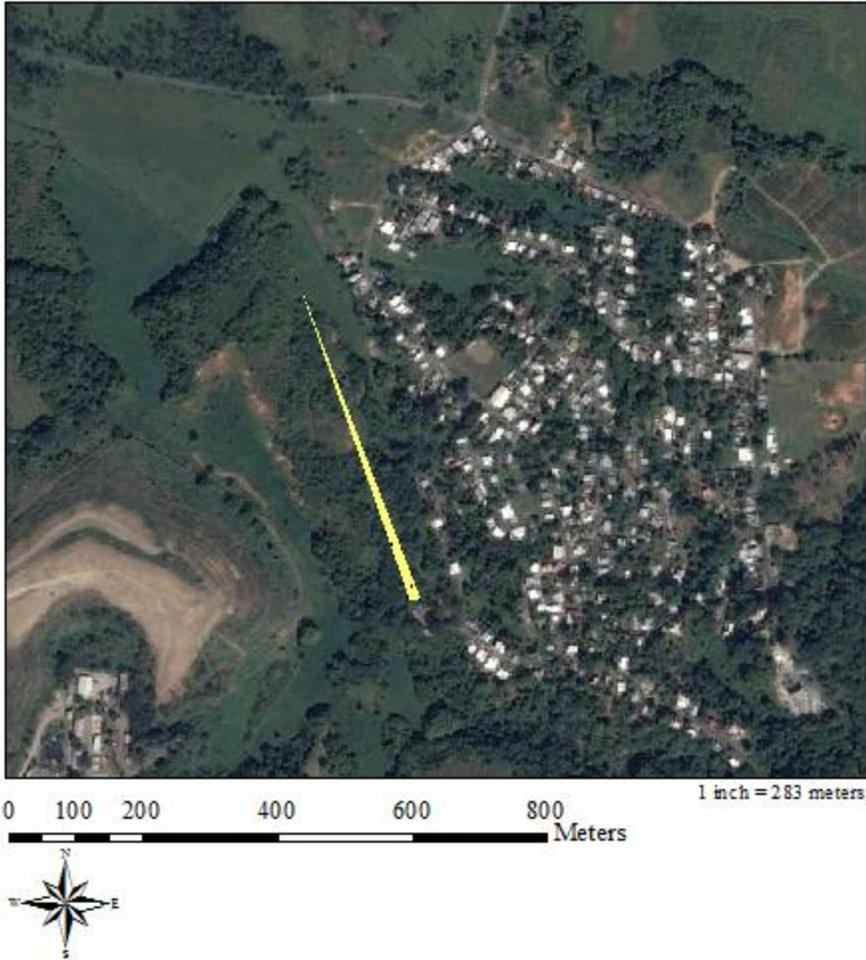
Reference Scale: 1:0



Coordinate System: NAD 1983 StatePlane Puerto Rico Virgin Islands FIPS 5200
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 200,000.0000
False Northing: 200,000.0000
Central Meridian: -66.4333
Standard Parallel 1: 18.0333
Standard Parallel 2: 18.4333
Latitude Of Origin: 17.8333
Units: Meter

Figure 1. 8. Minimum Complex Polygon for snake BOCO 5 (polygon pointed by the red arrow).

Reference Scale: 1:0



Coordinate System: NAD 1983 StatePlane Puerto Rico Virgin Islands FIPS 5200
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 200,000.0000
False Northing: 200,000.0000
Central Meridian: -66.4333
Standard Parallel 1: 18.0333
Standard Parallel 2: 18.4333
Latitude Of Origin: 17.8333
Units: Meter

Figure 1. 9. Minimum Complex Polygon for snake BOCO 8.

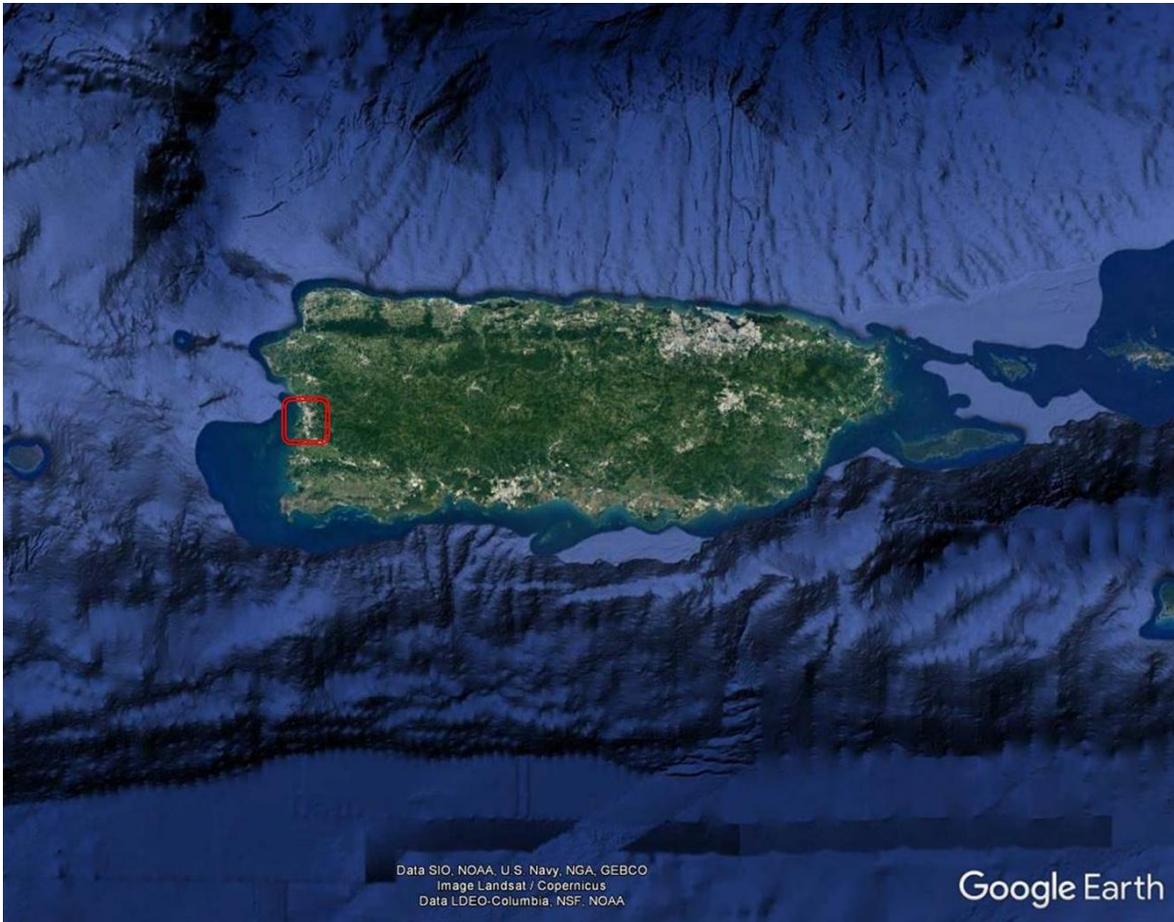


Figure 1. 10. Satellite image of Puerto Rico. The red square indicates the study site (Mayagüez Municipality).

Discussion

Movement and home range- Mean total movement was for all snakes was 431.12 ± 335.90 m (sum of all total distances divided by the number of snakes). A male individual (BOCO 8) had the biggest movement per fix (180.76 m), which can be linked with reproductive activity. Pizzatto and Marques (2007) documented *Boa constrictor* mating on June, but in the same article they suggest that boids can mate on the dry season months (Autumn-Winter) and parturition occurs on the rainy season (Spring-Summer). Since BOCO 8 was radio-tracked on the dry season, the movement data that was recorded on the months of October through November could suggest reproductive activity. It has been studied that the males of diamond pythons (*Morelia spilota spilota*), in Australia, and Eastern Massasauga Rattlesnake (*Sistrurus c. catenatus*), in Ontario, moved greater distances than females (Slip and Shine 1988; Weatherhead and Prior 1992). In my results, also females showed fewer movements' distances supporting the previous idea. Carfargo and Wetherhead (2008) found that *Coluber constrictor* snakes tended to be less active maybe do to escape predation or the inability to move quickly while gravid. Another reason of the snake being less active could be the high abundance of food source. Wasko and Sasa (2012) studied how snakes spatial distribution can be affected more by prey availability than other factors like habitat availability on *Bothrops asper*. They found that fed snakes spent more time in shelter than ambushing or foraging meaning that movement will be less frequent where food availability is higher. Overall, *B. constrictor* mean distance per move in Puerto Rico was 129.38 ± 555.54 m, while Holtzman et al. (2007) reported a mean distance of 72.99 ± 21.38 m per movement of residential *B. constrictor imperator* in Ometepe Island, Nicaragua. It is important to address that Ometepe is a smaller island (276 km²) than Puerto Rico (9104 km²) which can result on smaller areas

Home range was defined by Burt (1943) as “that area traversed by an individual on its normal activities of food gathering, mating and caring for young. Occasional movements outside the area, perhaps exploratory in nature, should not be considered part of the home range.” Studies have shown that the kind of food or prey that organism ingest can and will influence the home range where larger species must collect more energy to supply their requirements than smaller species (McNab 1963). Holtzman et al. (2007) studied movement in *Boa constrictor* in Nicaragua, its home range has never been studied out of their native range. In Puerto Rico, a female *B. constrictor* home range size (BOCO 1) had the biggest home range area (15,144.83 m²) and the mean for all snake home ranges was 5,730.72 m². I compared my results with the known data on home range for the Puerto Rican Boa and it is estimated that the Puerto Rican boas home range is from 5,000 m² to 1,055,000 m² (Mulero-Oliveras Unpubl.). It is important to address that even though the size of home range was smaller for *B. constrictor*, in comparison with the Puerto Rican boa, it would probably have been a bigger home range if there was more locations recorded for each *B. constrictor* in the study. In my study, *B. constrictor*'s transmitter signal disappeared before concluding the data collection which I suspect can be due to equipment failure. Another possible explanation can be that people are capturing and selling or killing the snakes.

Habitat use- Habitat structure may also have influenced *Boa constrictor* movements and habitat selection. All the snakes under the radio track study differ on the locality. BOCO 8 and BOCO 4 were located on a more urban area (Figure 1.7 and Figure 1.9) while the rest of the snakes were in a more rural area (Figures 1.5, Figure 1.6 and Figure 1.8). All shared the same characteristic; they were near a house, an infrastructure or road. Fahrig and Rytwinski (2009) reviewed the effects of roads on animal abundance and although most

wildlife were negatively affected by the presence of roads, small mammals and birds showed positive associations with roads. Small mammals and birds avoided crossing roads and used the forest edges as shelter; therefore, higher abundance of these animals were encountered on forest edges (Blouin-Demers and Weatherhead 2001; Fahrig and Rytwinski 2009). The fact that *Boa constrictor* spent more time on forest edges can be due to the possibility of higher food availability, even though there was not a statistical difference in forest edges and forest use. Future studies should focus on distribution of food resources at forest edges and forest are needed to understand habitat use by *B. constrictor*.

Thermoregulation in ectothermic animals is crucial to their development and based on this necessity it can influence the habitat selection (Reinert 1993). Even when there was not a statistical difference in preference of snakes in open or closed canopy areas, snakes were frequently located on open canopy areas that are important as thermoregulation habitats. This thermoregulation habitats need to be described for *Boa constrictor* in the novel environment where they have become established. Thermoregulation habitats are extremely important because studies have shown that body temperature increases are related with the possible advantages of increased rate of digestion (Toledo et al. 2003). Blouin-Demers and Weatherhead (2001) showed that Black Rat Snakes (*Elaphe obsoleta obsoleta*) used forest edges after ingesting a prey. This opens the possibility that addressing favorable thermoregulation habitats can increase our encounters of *Boa constrictor* in the field in order to achieve the captures and population management of this invasive species in Puerto Rico. In addition, Reed et al. (2007) in Cayos Cochinos that ambient temperatures where *B. constrictor* were found ranged from 24.5 to 36.22 °C and

body temperature ranged from 24.4 to 34.9°C. Thermoregulation studies on the *B. constrictor* population in Puerto Rico are needed to help to identify target areas for population control.

Longer rocks, locations with less percentage of shrub coverage and understory trees that had bigger DBH and lower height than the random points, were the variables that proved significance and selection preference by the snakes. Rock selection can be explained by thermoregulation behavior because it may function as a heat source. Garter snakes (*Thamnophis elegans*) prefer rocks of medium sizes (between 20 to 40 cm) because they offer the opportunity to achieve the optimal temperature to perform biological processes, like metabolism, without overheating (that can happen with thinner rocks) (Huey et al. 1989). Although, snakes did not prefer shrubs as the ground cover, my results support the data of Attademo et al. (2004) where he found that reproductive females of *Boa constrictor occidentalis* in Argentina, preferred sites with less herbaceous coverage. My results were not divided by sex or reproductive status of the snake and that is one of the reasons I cannot conclude that the results of snake's preference for these characteristics are due to reproductive reasons.

Holdridge's life zone that predominated in this area was the subtropical moist forest. Most of this area was deforested because it was suitable for crops. In my study sites, *Guarea guidonia* was present 40% of the time the understory tree among with coffee, mango and other introduced trees. *Guarea guidonia* was used in the past as a common coffee shade tree, known for its fast growth. Snakes in my study preferred areas with understory trees that were short but with a thicker DBH than the random points. Regardless the fact this could have been because our sites differ significantly in characteristics and

composition, one thing that they all shared was that the sites were used once for agricultural purposes and they are now secondary growth forest which are predominated by light tolerant and fast growth trees (Ewel and Whitmore 1973) and mango trees which are common in forest edges along roads in Mayaguez, Puerto Rico.

Habitat selection of *B. constrictor* in Puerto Rico was influenced by the understory tree composition, longer rocks and less ground coverage. It differed from the results from Attademo et al. (2004), where they found that non-reproductive females in Argentina preferred more ground cover and shrub cover with less tree coverage. We have to address that the study site in Argentina, was semidesert with marked seasons. They sampled during the winter season which can cause the difference in their selection (Attademo et al. 2014). Another study performed in Cayo Cochinos, Honduras, Reed et al. (2007) found that snakes preferred areas with fewer rocks, higher substrate vegetation and woody-stem density. In contrast to my study, snakes in Cayo Cochinos preferred highly vegetated places in the small island due to the possible fact that the island was only 0.64 km² and the available habitat was two types of forest dominated by oaks and Sea Grape (Reed et al. 2007). These results cannot be compared but can be used as a descriptive experimental data of preference in habitat use in different areas by *B. constrictor*. It is important to clarify that Puerto Rico, Argentina and Honduras differ significantly in temperature, precipitation, locality and seasonality. I hypothesize that the selection in all locations is primarily influenced by the snake's thermoregulation necessities and prey availability (foraging success). In Chapter 2 we are going to discuss foraging success, sexual dimorphism and diet of the snake under study.

CHAPTER 2: Sexual dimorphism, foraging success and diet, using stable isotopes, of *Boa constrictor* in Puerto Rico.

Introduction and Background

Scientists have dedicated their efforts to understand exotic invader's biology and what impacts they have in the new occupied habitats. Successful invasion processes are influenced by the lack of predators and abundant food sources (Wilcove et al. 1998; Gurevitch and Padilla 2004). Some studies have showed that invasive species once introduced in a novel environment can produce changes in ecosystems causing declines in populations of native species. The introduction of *Boiga irregularis* (Brown tree snake) in the Pacific island of Guam produced irreversible damages to the native biodiversity. Since its introduction, nine of Guam's twelve endemic birds were gone by 1997, two of three native bat species disappeared and six of the twelve native lizards have been displaced (Rodda et al. 1997). Another example of the impacts of invasive species is the appearance of Burmese python (*Python molurus*) in the state of Florida since 2000. Some studies have demonstrated population declines of raccoons, opossums and bobcats in the Everglades National Park due to the presence of this python (Dorcas et al. 2011).

Food resources provide the animal's energy intake that allows them to survive and carry out their life's vital biological processes. For snakes, prey items provide the energy used for growing and reproduction. Bonnet et al. (2001) found that snakes that were fed more frequently had greater number of follicles, which results on a greater litter size (number of offspring).

Another important biological process for snakes is movement. Movement has been proved to be influenced by food and shelter availability (Hoss et al. 2010). Studies on *Bitis arietans* showed that snakes that were provided with frequent food spent less time foraging and they

decreased their distance traveled when they were compared with a non-fed controlled group, suggesting that spatial activity can be influenced by the food availability (Glaudals and Alexander 2017).

Snakes body condition and size can be influenced by food acquisition. Snakes have ontogenetic shifts in diet throughout their life span, were larger snakes can predate upon bigger prey, but size can also be influenced by location (Madsen and Shine 2002; Aubret and Shine 2007). Boback (2006) found that *Boa constrictor* on islands close to the coast of Belize tend to be smaller and lost their sexual dimorphism when compared to the populations from mainland Belize. This shrinking effect on island *B. constrictor* can be explained by the reduced prey size availability on the island, which is additional evidence that supports the idea that snake's body size is influenced by prey size (Boback 2003).

One of the most common snakes in the exotic animal pet trade is *Boa constrictor* (Reed 2005). Its natural distribution is in the neotropics, but has been documented out of its native range since 1971 on Cozumel (Martinez-Morales and Cuarón 1999) on Aruba (Quick et al. 2005), presumably in 1992 on Puerto Rico (Reynolds et al. 2013) and more recently in St. Croix (Nicole Angeli Personal Communication). In Aruba, *B. constrictor*'s diet comprises of 40.4% of Birds, 34.6% of lizards and 25.0% of mammals (Quick et al. 2005). The main concern in Aruba is the possible diet and habitat competition with a critical endangered native rattle snake, *Crotalus unicolor*, although, more research is needed to confirm impacts on Aruba's fauna.

One way to address animal's diet is using stable isotopes. Kiszka et al. (2013) studied bottlenose dolphins (*Tursiops aduncus*) diet by observational events and stable isotopes. The study showed that observational data (what dolphins ate) was accurate with stable isotopes signals. An 87% of the observational events, the bottlenose dolphins fed fish

from Carangidae family and Houndfish (*Tylosurus crocodilus*). The stable isotopes data collected showed a 93% of the diet was composed by the prey items documented from observation (Kiszka et al. 2013). This novel technique is used to determine an animal's diet while using ratios of natural occurring isotopic signals of carbon and nitrogen. Also, it is used with the ratios of the stable isotopes in the consumer's tissues that reflect the proteins in their diet (Beashop et al. 2004). Ratios of the stable isotope of carbon and nitrogen ($\delta^{15}\text{N}$; $\delta^{13}\text{C}$) can help to determine foraging habits like for example consumers location and dietary variation or evenness (Beashop et al. 2004; Hobson and Wassenaar 2008; Brischoux et al. 2011).

In this chapter I will: 1) determine if there is an island effect on sexual dimorphism on the invasive *Boa constrictor* on Puerto Rico, 2) determine body condition indexes as an estimate of foraging success, and 3) describe the diet of *Boa constrictor* using the stable isotopes technique in order to identify possible competition for food resources with the endemic endangered Puerto Rican boa (*Chilabotrus inornatus*).

Materials and Methods

Foraging Success and Sexual Dimorphism of Boa constrictor in Puerto Rico- Snakes were captured by the Department of Natural and Environmental Resources and the personnel from the Juan A. Rivero Zoo in Mayagüez, Puerto Rico. After capture, snakes were humanely euthanized and given to the necropsy project performed at the Interamerican University of Puerto Rico, Arecibo Campus, conducted by Dr. Alberto Puente-Rolón. I selected 45 *B. constrictor* for morphological measurement of snout-vent length (cm), tail length (cm) and weight (g). Body condition indexes have been widely studied and referred as condition, condition index or condition factor (Jakob et al. 1996). Jakob et al. (1996) studied the body condition as an estimation of “recent foraging success” or as the food

acquisition success; in other words, the feeding success scores in this work will be correlated with prey acquisition which is directly correlated with growth of an animal and its reproductive success. Therefore, positive foraging success scores (how we will refer from now on) will reflect a positive foraging success (finding food; food acquisition) which results into a good body condition. By the contrast, negative foraging success scores will reflect a negative foraging success (not finding food; low prey availability). Foraging success scores were calculated performing a linear regression with weight and snout-vent length data transformed with natural logarithm. Residuals from the regression were used as an indicator of foraging success of *B. constrictor* in Puerto Rico. Snakes with positive residuals represented overweight snakes (high food availability; good foraging success), negative residuals represented underweight individuals (low food availability; low foraging success) and the residuals near zero represented snakes with good condition and/or foraging success (Jacob et al. 1996). Stoutness calculations were used to see which sex and species (compared with *C. inornatus*) had more excessive weight (most massive or corpulent). It has been previously discussed that female snakes are heavier than males, proving sexual dimorphism (Reed and Rodda 2009). Also we want to prove that *B. constrictor* is heavier and larger than the Puerto Rican Boa. Stoutness calculation was done by dividing the snake's weight per the total snake's length (snout-vent length plus tail length) (Jacob et al. 1996). Also, calculations of relative tail length were calculated to see if in proportion of their body, tails were longer or shorter. It has been estimated that females will have shorter tails than males, another supportive evidence of sexual dimorphism. Relative tail length was estimated by using the snout-vent length divided by the tail length (King 1989). Both, stoutness and relative tail length, were calculate for *B. constrictor* to determine if in Puerto Rico the species still show its sexual dimorphism. In its natural distribution, female *Boa*

constrictor tends to be more heavy and massive than males. For stoutness and relative tail length I compared sexes performing a t-test using Sigma Plot Software (Version 13, Systat Software Inc.) and compared these data with data of the Puerto Rican boa (*Chilabothrus inornatus*).

Diet using stable Isotopes- Thirty muscle samples (thirteen males and seventeen females) of *Boa constrictor* were obtained from the necropsy project at the Interamerican University of Puerto Rico, Arecibo Campus. Along with muscle samples, hair and feathers samples of prey found in the snake's stomach or gut were used for the stable isotope analysis. All samples were dried for 48 hours in a Shel Laboratory oven at 60⁰C. After the samples were dried, they were finely pulverized using Minilys Personal Homogenizer using 5,000 RPM (revolutions per minutes) for twelve minutes. These samples were individually placed in tin cups (5 x 8mm; Elementar, Hanau, Germany), weighted (from 0.9 to 1.2 mg) and sent to the Laboratory of Stable Isotope Ecology in Tropical Ecosystems at the University of Miami, Coral Gables, Florida. The tin spheres that had the samples were put in an automated elementary analyzer and pyrolyzed (Eurovector, Milan, Italy). Gases emitted by the pyrolysis were taken by a mass spectrometer and analyzed for abundance of ¹⁵N and ¹³C. Isotopes ratios were expressed as:

$$\delta^{13}\text{C} = [(R_{\text{sample}}/R_{\text{standard}}) - 1] (1000)$$

$$\delta^{15}\text{N} = [(R_{\text{sample}}/R_{\text{standard}}) - 1] (1000)$$

Note that R_{sample} and R_{standard} are the corresponding ratios for ¹³C/¹²C and ¹⁵N/¹⁴N. The standards (R_{standard}) are the Belemnite from the Pee Dee formation in South Carolina and atmospheric nitrogen for carbon and nitrogen isotopic ratios, respectively.

Data Analysis-

Comparison of stable isotopes ratios was performed between sexes to see if there is a difference in their isotopic signals. For this I performed a t-test (comparison of the means of stable isotopes signal) comparing male and female and comparing between species stable isotopes $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (*Boa constrictor* vs. *Chilabothrus inornatus*). A Levene's test for homogeneity of variance was done to detect differences on variations of the stable isotope ratios between male and female *B. constrictor* (JMP; version 4.0.4, SAS Institute 2001). All other analyses were performed with the Sigma Plot Software (Version 13, Systat Software Inc.).

Results

Foraging success scores- A total of 44 *B. constrictor* were processed for snout-vent length (cm), tail length (cm) and weight (g). Body condition scores were calculated for *B. constrictor* performing a linear regression (weight and snout-vent length) [$\ln_{\text{SVL}} = 3.593 + (0.182 * \ln_{\text{Weight}})$; $R=0.712$, $P=0.152$, $N=44$] (Figure 2.3). The linear regression calculated the residuals used for foraging success scores in which showed no statistical significance between sexes of *B. constrictor* [Mann-Whitney U Statistic; $T=390$, $n(\text{small})=18$, $n(\text{big})=26$, $P=0.729$](Fig.2.5). For descriptive purposes, on Figure 2.4, we visually compared the foraging success scores (residuals) of the Puerto Rican Boa (Mulero-Oliveras unpubl.) and *B. constrictor*, were it is observed no difference between the mean of the residual scored of foraging success between both species. This shows that both species are acquiring good amounts of food sources in areas where both snakes are foraging (although prey population was not measured in this study) but when foraging success are separated, another observable and descriptive result can be shown in Figure 2.5, were it can

be observed that male Puerto Rican boa (*C. inornatus*) have a slightly less mean foraging success score (-0.148 ± 0.114 SD) compared with the female Puerto Rican boa (0.0798 ± 0.237) and of *B. constrictor* ($\text{♀} = 0.0376 \pm 0.444$; $\text{♂} = -0.0420 \pm 0.298$). In addition in the same figure (Figure 2.5) it is observed that both males of the different species have a tendency of having a slight less mean foraging success score than the females.

Sexual Dimorphism and Size-

I compared stoutness between Puerto Rican Boas (*C. inornatus*) and *B. constrictor*. A Kruskal Wallis one-way analysis ($P < 0.001$) was done for snake sex and species followed by Dunn's Test ($H = 34.929$, $df = 3$, $P < 0.001$) (Figure 2.6). Female *B. constrictor* are more corpulent (heavier) than female *C. inornatus*. The same result was found between males of *B. constrictor* and *C. inornatus* [Females, Mann-Whitney U Statistics, $T = 203$, $n(\text{small}) = 17$, $n(\text{big}) = 27$, $P < 0.001$; Males ($t = 4.730$, $df = 25$, $P < 0.001$)] (Figure 2.6) but no statistical difference was found between male and female *B. constrictor* [Mann-Whitney U Statistics; $T = 360$, $n(\text{small}) = 18$, $n(\text{big}) = 27$, $P = 0.215$] (Fig. 2.6).

For all snakes, mean snout-vent length was 152.63 ± 25.43 cm and had mean tail length of 19.71 ± 4.72 cm. Mean weight for all snakes was 3061.54 ± 1797.08 g (Figure 2.1). No significant difference was found on the SVL between females (154.42 ± 28.78 cm) and males (149.95 ± 19.86 cm) [Mann-Whitney U Statistic; $T = 392$, $n(\text{small}) = 18$, $n(\text{big}) = 27$, $P = 0.618$] and neither on weight [Mann-Whitney U Statistic; $T = 372$, $n(\text{small}) = 18$, $n(\text{big}) = 27$, $P = 0.336$] (Fig. 2.1). On the contrary, I did find a statistical difference on tail length [Mann-Whitney U Statistic; $T = 549$, $n(\text{small}) = 18$, $n(\text{big}) = 27$, $P = 0.002$] where males had longer tails (22.20 ± 5.82 cm) than females (18.14 ± 3.12 cm) (Figure 2,1). The relative tail length (size of the tail divided by the snout-vent length) showed that females have shorter tails than males (Mann-Whitney U Statistic; $T = 607$, $n(\text{small}) = 18$, $n(\text{big}) = 27$,

$p < 0.001$) (Figure 2.7). No difference was found on total body length between male (172.01 ± 24.84 cm) and females for *B. constrictor* (176.26 ± 26.69 cm) ($t = 0.547$, $df = 42$, $p = 0.587$) (Figure 2.2).

Stable isotopes-

Stable isotopes signal for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ for all *B. constrictor* was -23.07 ± 0.34 and 9.24 ± 0.86 , respectively ($\delta^{13}\text{C}$ range from -19.76 to -25.23 , $\delta^{15}\text{N}$ range from 7.61 to 11.03).

Females had a mean $\delta^{13}\text{C}$ of -23.17 ± 1.38 (range from -19.76 to -25.05) and for the males mean for $\delta^{13}\text{C}$ was -23.01 ± 1.29 (range from -20.61 to -25.23). No statistical difference was detected on $\delta^{13}\text{C}$ ratios between male and female *B. constrictor* ($t = -0.405$, $df = 28$, $p = 0.689$) (Figure 2.9). For $\delta^{15}\text{N}$, female's mean ratio was 8.98 ± 0.83 (range from 7.61 to 11.03) and male's mean value was 9.62 ± 0.81 (range from 8.21 to 10.82). No statistical difference was found between males and females $\delta^{15}\text{N}$ ($t = -2.100$, $df = 28$, $p = 0.0449$) (Figure 2.9). After comparing the stable isotopes ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$), I also tested for homogeneity of variance with the Levene's test and found that $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ variances were not statistically different ($\delta^{13}\text{C}$, $df = 27$, $P = 0.7295$ and $\delta^{15}\text{N}$, $df = 27$, $P = 0.9604$). Data of stable isotopes $\delta^{13}\text{C}$ for the Puerto Rican Boa (*C. inornatus*) averaged -22.42 ± 1.48 (range from -24.56 to 20.02) and $\delta^{15}\text{N}$ mean was 8.49 ± 1.20 (range from 6.83 to 10.34). I found a significant difference in $\delta^{15}\text{N}$ values between the two species ($t = 2.147$, $df = 39$, $p = 0.0381$) but $\delta^{13}\text{C}$ did not differ ($t = -1.288$, $df = 39$, $p = 0.205$) (Figure 2.10).

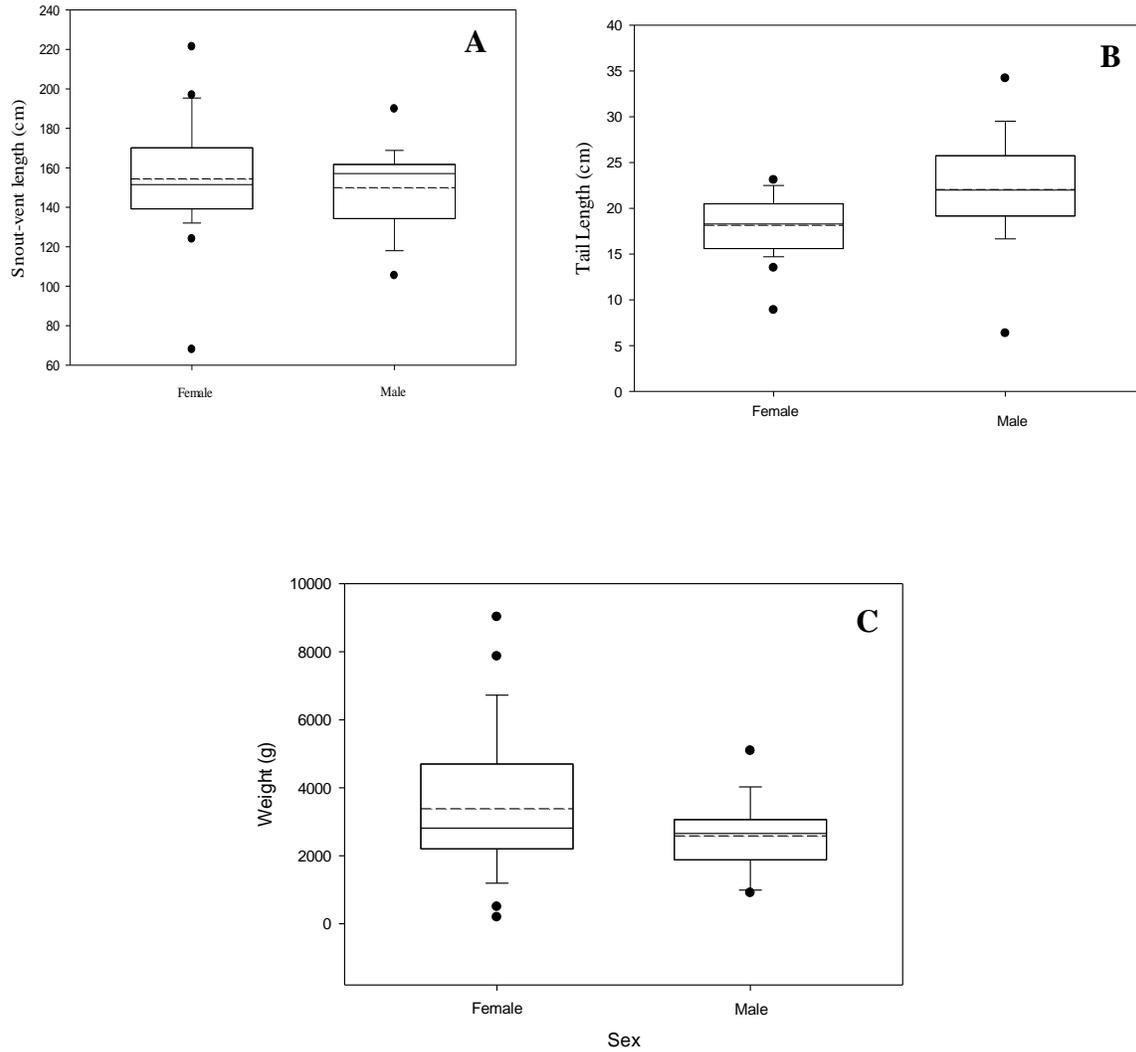


Figure 2. 1. Snout-vent length (N=44), tail length (N=44) and weight (N=43) of *B. constrictor* under the radio tracking study, stable isotopes study and necropsies.

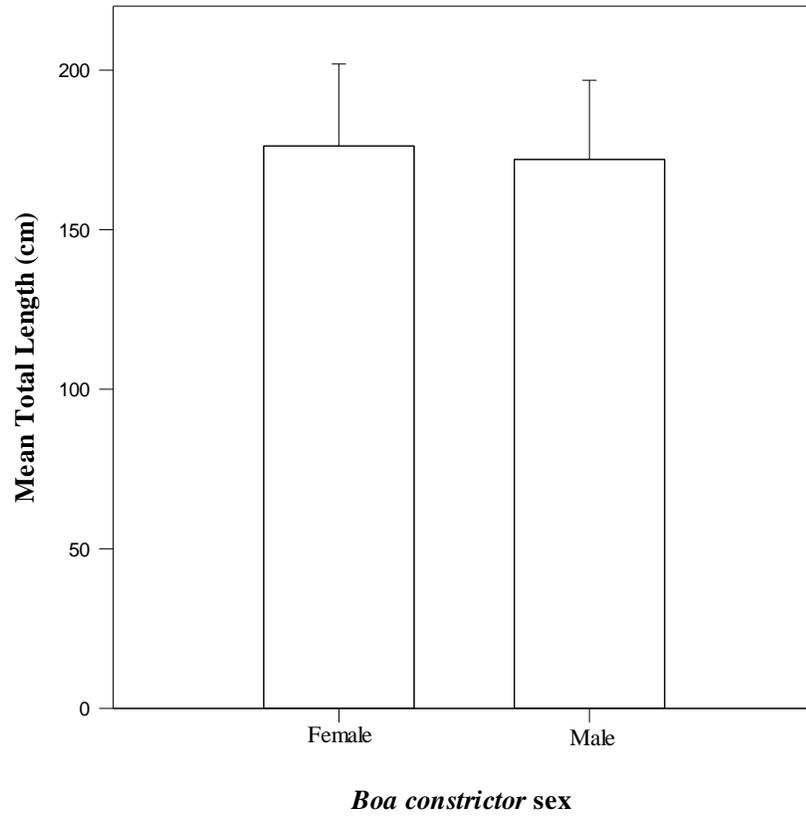


Figure 2. 2. Mean total length for female (N=27) and male (N=17) *B. constrictor*.

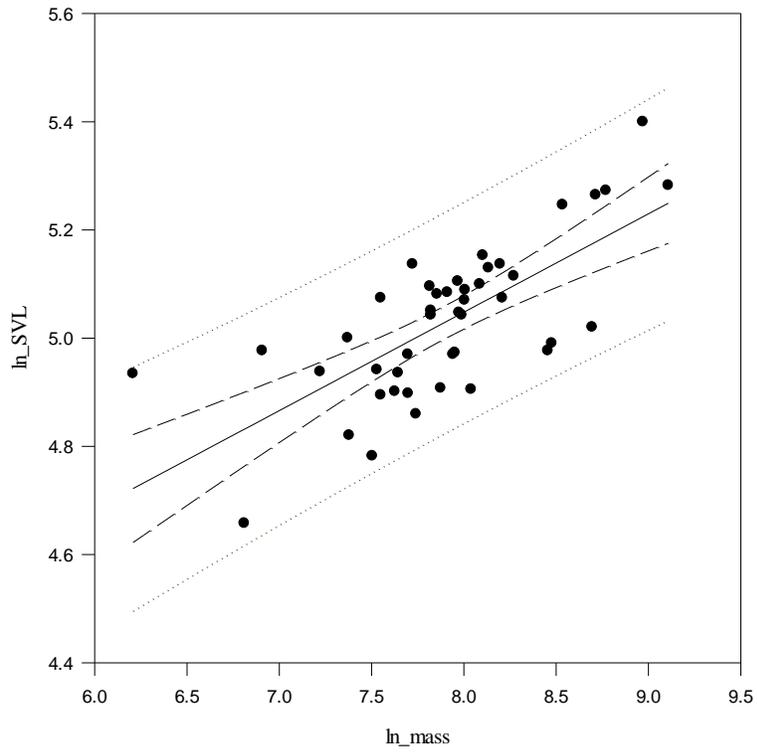


Figure 2. 3. Linear regression for transformed snout-vent length and mass data of *B. constrictor* (N=44). We used the residuals (scores) after performing the linear regression to estimate the foraging success.

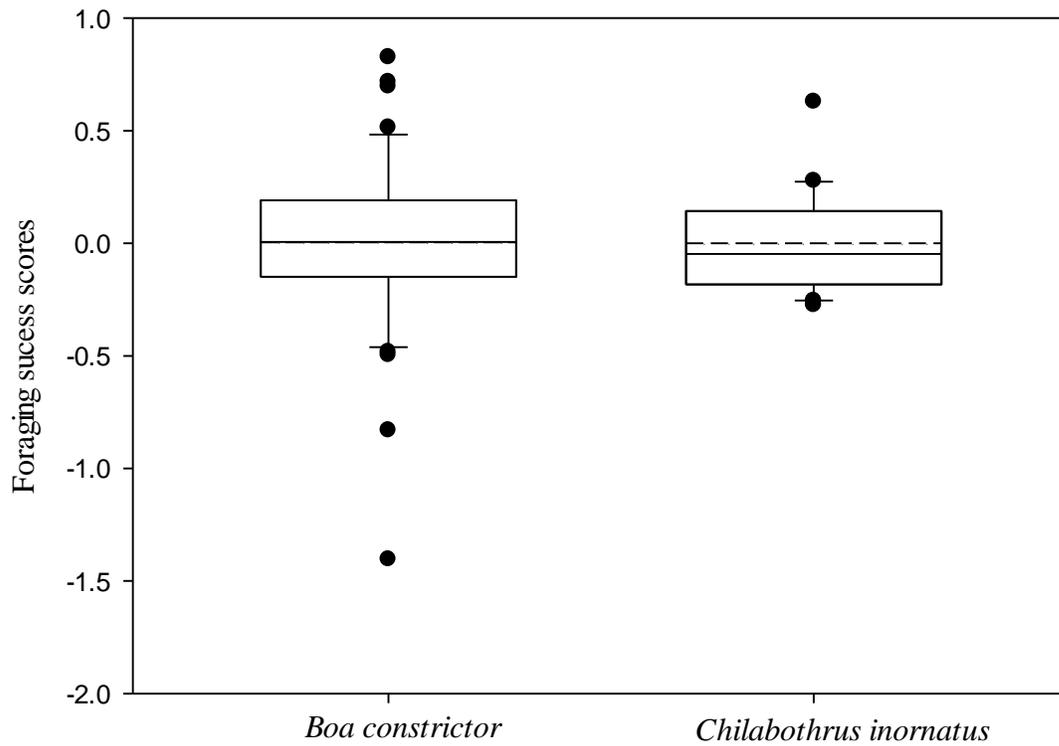


Figure 2. 4. Foraging success scores (residuals of linear regression) for *B. constrictor* (N=44) and *C. inornatus* (Puerto Rican Boa; N=26). Dashed lines represent the mean. If the mean is below zero, it represents a low foraging success while if it is above zero represents great foraging success. If the mean lies in zero, this represents good foraging success or body condition.

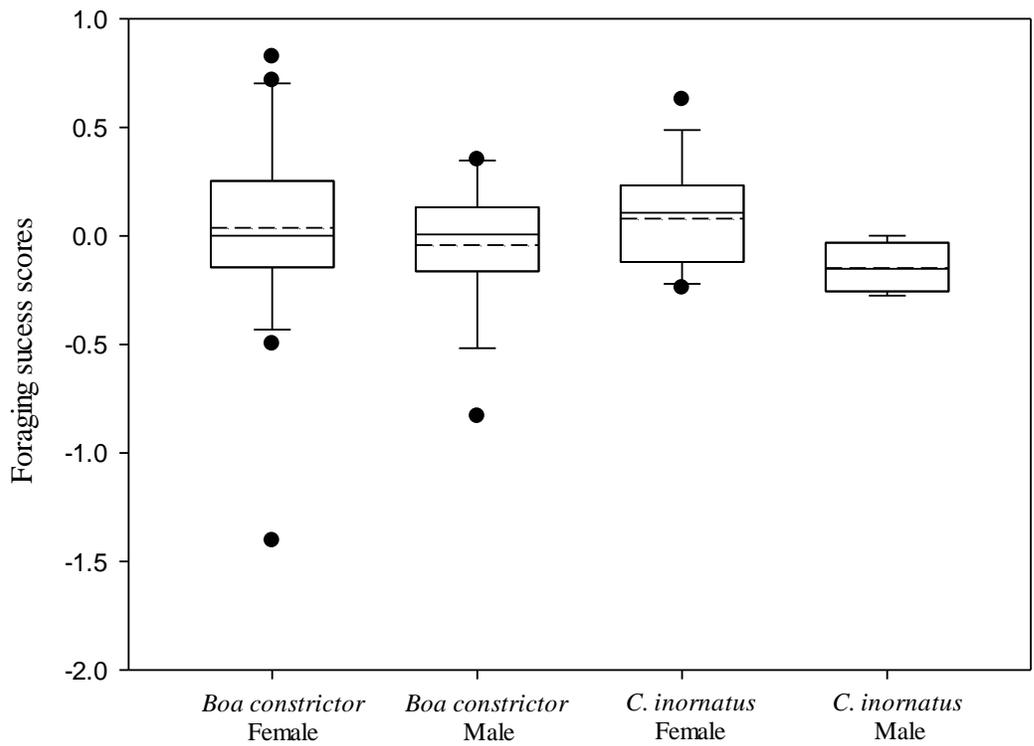


Figure 2. 5. Foraging success scores for male (N=17) and female (N=27) *B. constrictor* and male (N=9) and female (N=17) Puerto Rican Boa. Dashed lines represent mean. If the mean is below zero, it represents a low body condition index while if it is above zero represents better body condition index. If the mean lies in zero, it represents good body condition.

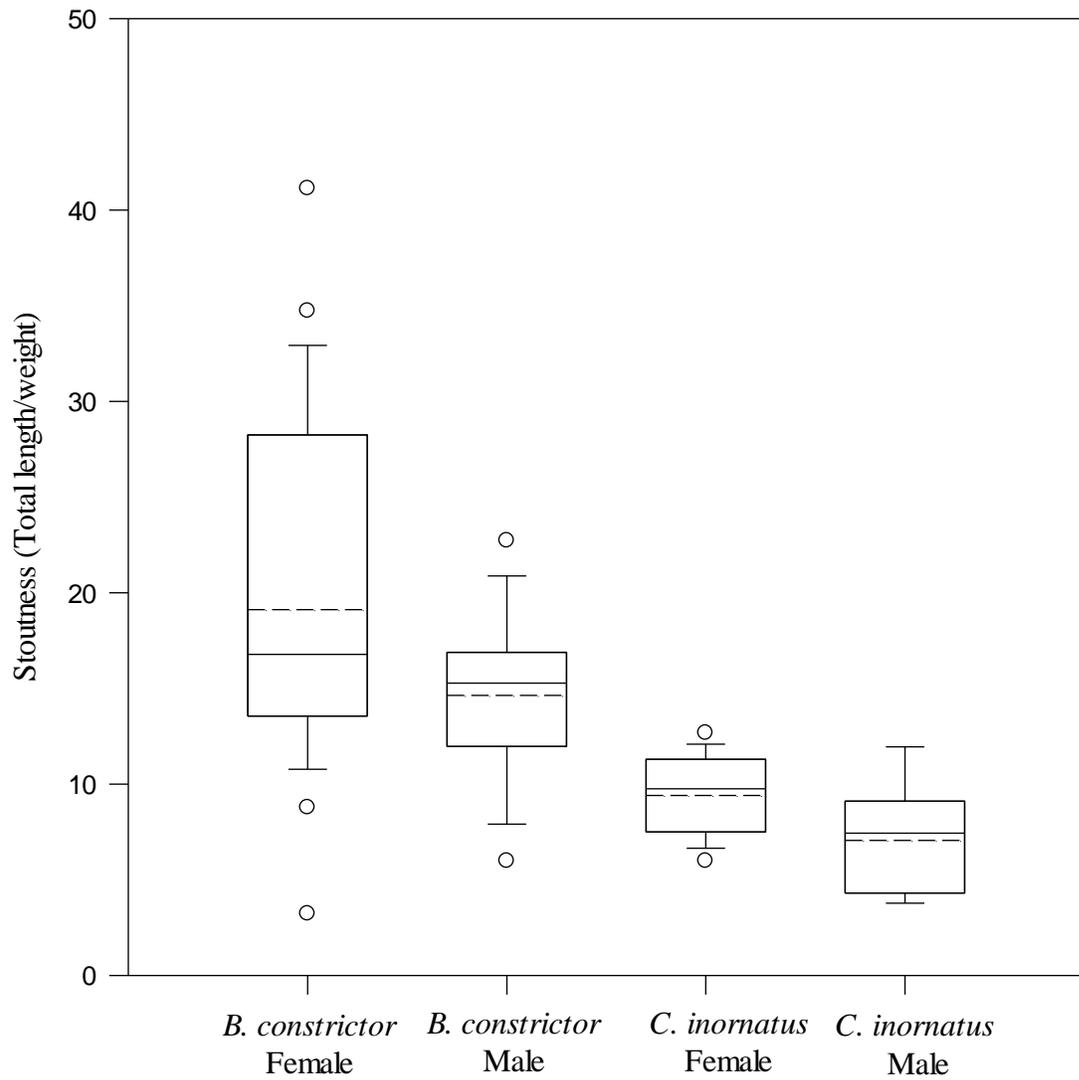


Figure 2. 6. Stoutness for female (N=27) and male (N=17) *B. constrictor* and for female (N=17) and male (N=9) *C. inornatus*. Stoutness was calculated tacking the total length of the snake and dividing it by its weight. Dashed lines represent mean values.

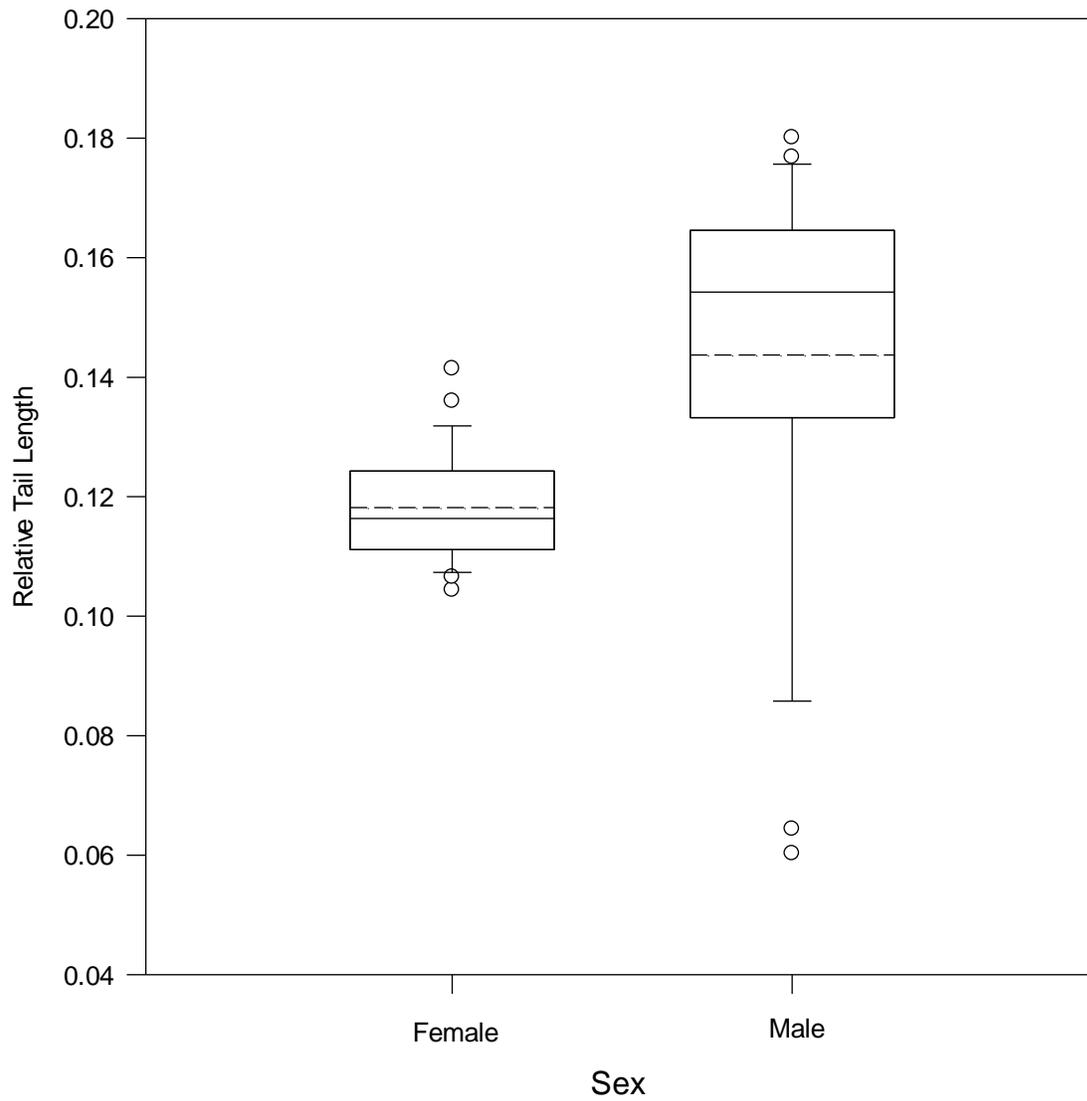


Figure 2. 7. Relative tail length (tail length/snout-vent length) for female (N=27) and male (N=17) *B. constrictor*.

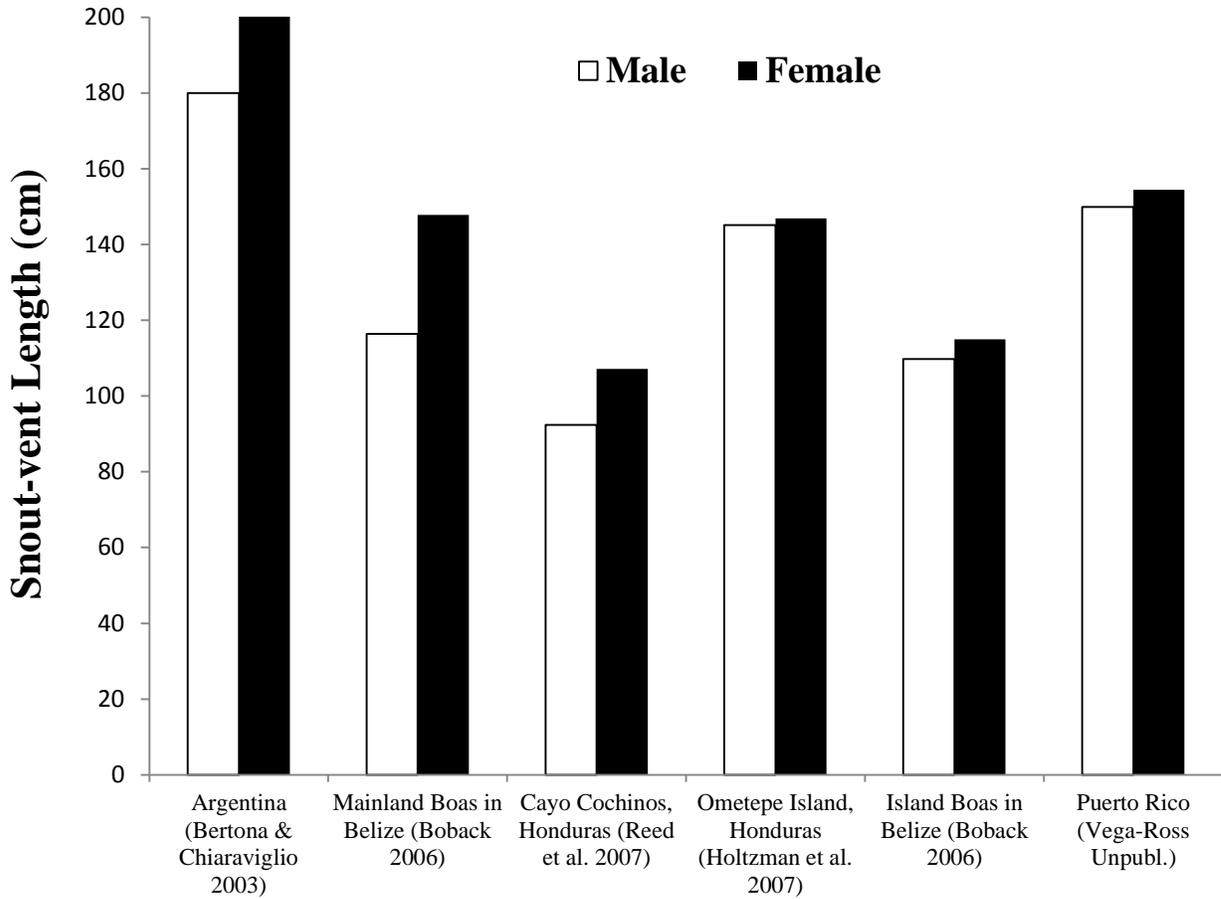


Figure 2. 8. Comparison of snout-vent length (cm) of female and male *B. constrictor* in different areas. *B. c. constrictor* is the subspecies under this study. The following subspecies belong to each study site: *B.c. occidentalis* (Argentina), *B.c. imperator* (Nicaragua, Belize, Honduras) All areas are within their natural distribution except for Puerto Rico.

Table 2. 1. Mean snout-vent length measurements of female and male *B. constrictor* in their natural distribution and in Puerto Rico.

Sex	Argentina (Bertona & Chiaraviglio 2003)	Mainland Boas in Belize (Boback 2006)	Honduras (Reed et al. 2007)	Nicaragua (Holtzman et al. 2007)	Island Boas in Belize (Boback 2006)	Puerto Rico (Vega-Ross Unpubl.)
Male SVL (cm)	180 ± 3	116.4 ± 11	92.4 ± 12	145.1 ± 5.9	115.8 ± 18.6	149.95 ± 19.9
Female SVL (cm)	205 ± 4	147.8 ± 51.3	107.2 ± 28	146.9 ± 10	109.8 ± 19.5	154.429 ± 28.78

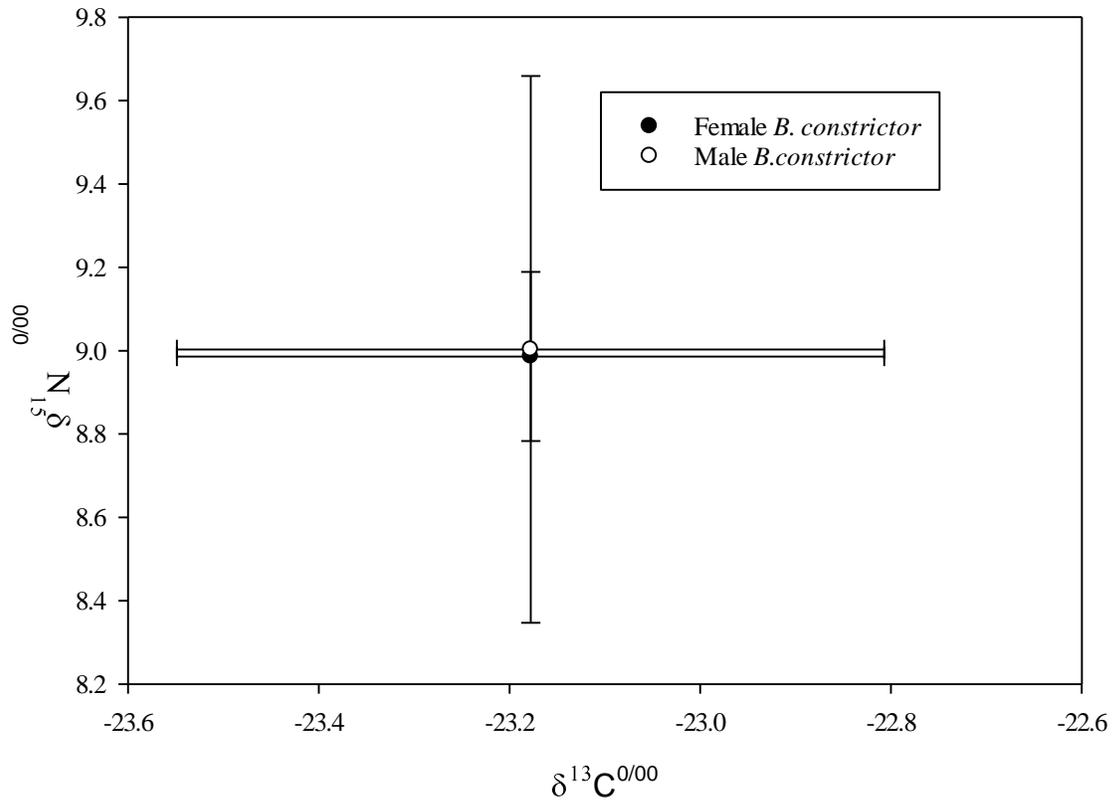


Figure 2. 9. Stable isotope ratios ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) for female (N=17) and male (N=13) *B. constrictor* in Puerto Rico.

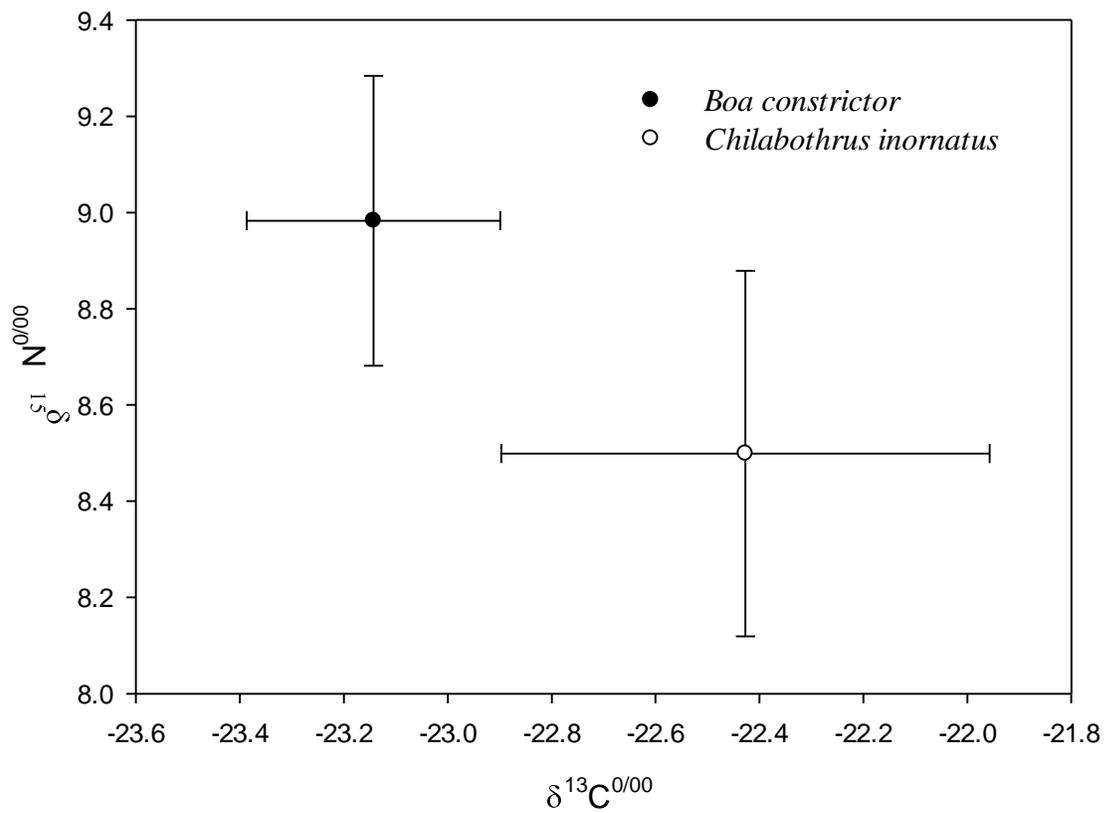


Figure 2. 10. Comparison of stable isotope ratios for *B. constrictor* (N=30) and *C. inornatus* (N=10)(Puente-Rolón 2016).

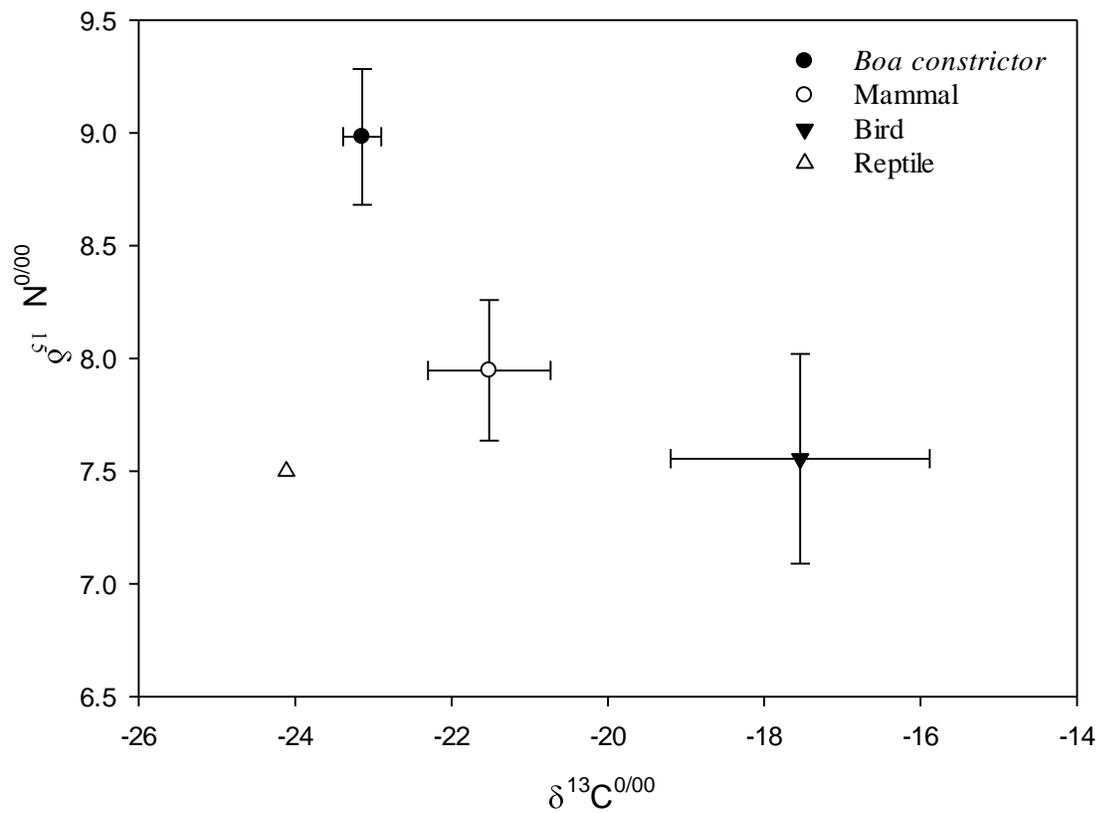


Figure 2. 11. Stable isotope ratios for *B. constrictor* in Puerto Rico and its prey (Mammal (N=28), Bird (N=9) and Reptile (N=1)).

Discussion

Foraging success –

A good body condition can be crucial for snakes in order to accomplish important biological processes for their survival, like mating and reproduction. It has been studied that males can benefit by selecting larger and heavier mates because they can produce bigger and numerous offspring (Shine et al. 2003). In *Vipera aspis*, females with large body reserves (taking in account, mass and length of the snake) responded to courtship and copulation of males. It is crucial that females of *Vipera aspis* reproduce with good body conditions because more than three quarters of females do not survive after parturition if they have low percentage of body reserves (Aubret et al. 2002). In my data there observable differences in foraging success scores (residuals of linear regression) between sex of *Boa constrictor* and *Chilabothrus inornatus* were males presented negative scores (represent low foraging success) versus females that showed positive scores (good foraging success) (Figure 2.5). Negative scores represent low foraging success for males but this can be explained by the fact that males spend most of their energy seeking a mate. Many studies suggest that male snakes during mating season travel more distances and move more frequently than female snakes (Brown et al. 2005; Scott- Keogh et al. 2007)

Stoutness or corpulence was not different between sexes in *B. constrictor* and between sexes in Puerto Rican Boas (*C. inornatus*), but I did find that *B. constrictor* were more corpulent than Puerto Rican boas. These differences can be explained due to the fact that *B. constrictor* are more terrestrial species and the Puerto Rican boas have more arboreal habits. Studies have shown that species with arboreal habits tend to be thinner, narrower and lighter than snakes with terrestrial habits (Lillywhite and Henderson 1993; Pizzatto et al. 2007). The fact suggests that arboreal snakes have a disadvantage compared

with terrestrial snakes because smaller and thinner snakes, in this case arboreal snakes, produce smaller clutch sizes (Pizzatto et al. 2007). Therefore, the successful establishment of *B. constrictor*, not only has been accompanied by the fact that it does not have predators in Puerto Rico, but also with the matter that their bigger size and good body condition could allow the production of numerous offspring. For instance, *Boa constrictor* can produce 20 to 64 neonates (Reed and Rodda 2009), while the Puerto Rican Boa can produce 13 to 30 neonates (Wiley 2003). This effective reproductive success of *Boa constrictor*, by having more offspring, benefits this species because a higher volume of neonates means a higher colonization and establishment on non-invaded areas.

Size and Sexual Dimorphism-

Populations of the invasive *B. constrictor* in Puerto Rico do not exhibit sexual dimorphism in snout-vent length (Figure 2.1A) or total length (Figure 2.2). In Figure 2.8, you can find a summary of *B. constrictor* studies where they show mean size for *B. constrictor imperator* (Boback 2006), *B. constrictor* (Vega-Ross Unpubl.), *B.c. occidentalis* (Chiaraviglio and Bertona 2003) and *B.c. imperator* (Holtzman et al. 2007; Reed et al. 2007). It has been suggested that in South America, *Boa constrictor* located the north or south of the Amazon basin tend to be smaller (no specific measurement published) (Rodda and Reed 2009).

Figure 2.8, shows that in Argentina, snakes have a bigger size (female: 205 ± 4 cm; males 180 ± 3 ; Bertona and Chiaraviglio 2003) than snakes studied on mainland Belize (females 147.8 ± 51.3 cm; males 116.4 ± 11 cm; Baback 2006), Honduras (females 107.2 ± 28 cm; males 92.4 ± 12 cm; Reed et al. 2007), Nicaragua (females 146.9 ± 10 cm; males 145.1 ± 5.9 cm; Holtzman et al. 2007) and Puerto Rico (females 154.429 ± 28.78 cm; males 149.95 ± 19.9 cm; Vega-Ross Unpubl.) (Table 2.1). The smallest (body-size) populations of *Boa constrictor* were recorded in cays near mainland Belize along with the population from

Cayos Cochinos, Honduras. The middle sizes relied on the populations of *B. constrictor* from Nicaragua (*B.c. imperator*), Puerto Rico (*B.c. constrictor*) and mainland Belize (*B. constrictor*). It is important to address that the *B. constrictor* subspecies introduced in Puerto Rico, are the second biggest out of the seven subspecies compared with the populations previously discussed and studied across its native ranges. In addition, populations of *B. constrictor* in Argentina, mainland Belize and Nicaragua, had sexual dimorphism; on the other hand, populations of cays near Belize, Nicaragua and Puerto Rico lacked sexual dimorphism (snout-vent length). The lack of diversity of prey on islands and the availability of only smaller preys can have an influence on the sizes on the areas discussed. Boback (2006) explained that the diet in mainland populations of *B. constrictor* had more abundant and diverse food sources. He stated that in island populations snakes may feed mainly on birds which may be the reason for size differences (smaller snakes in islands) and lack of sexual dimorphism. As conclusive results, we can suggest that the island effect (lack of sexual dimorphism) is happening to the *B. constrictor* populations introduced in Puerto Rico.

Introduced population of *Boa constrictor* in Aruba reported mean total length of 104.5 cm (± 7.65 SE) and had a smaller size than the population currently established in Puerto Rico (total length of 174.52cm). Aruba's *B. constrictor* populations are ingesting mainly lizards and birds, while in Puerto Rico these snakes are preying on mammals and birds (Quick et al. 2005). Snout-vent length did not differ between male and females, but tail length was different and also, when I estimated relative tail length, males had longer tails and relative tail length (compared with body size) than females. Relative tail length is explained by evolutionary adaptations were in males longer tails can be an advantage because longer tails represent longer hemipenes. This evolutionary trait has been studied in

Thamnophis sirtalis parietalis (red-sided garter snakes), where males with longer tails had a better reproduction success (mated) compared with snakes that had shorter or stubbed tails (Shine et al. 1999). Despite, Boback (2006) found that tails were longer in islands (cays) when compared with data mainland Belize, raw data were not available in order to compare tail length with the introduced populations of *B. constrictor* in Puerto Rico.

Diet –

In their native distribution *Boa constrictor* can feed upon a wide variety of prey. Some of the prey items that have been identified are green iguanas, birds, opossum, Asian mongoose, and ocelot among others. In Puerto Rico, *Boa constrictor*'s diet is composed of 80% of mammal (96% which are rats or mice), followed by 17.86% of Birds and a 4.29% of reptiles (58% green Iguanas) (Figure 2.11; Puente-Rolón, unpub.). On the contrary, in Aruba, *B. constrictor*'s diet was constituted by 40.4% of Birds, 34.6% lizards and 25% of mammals (Quick et al. 2005). More research is needed to determine if the species is having an impact on prey populations. In Guam, the invasive brown tree snake (*Boiga irregularis*) first had an impact on bird population (their main prey), where they contributed to the extinction of nine of twelve species encountered in the island (Savidge 1987; Savidge 1988; Burnett et al. 2006).

Stable isotopes have been used as a tool to determine an animal's position in trophic interactions and what resources the animal is using for its survival, among others (Layman 2012). Carbon ($\delta^{13}\text{C}$) and Nitrogen ($\delta^{15}\text{N}$) stable isotopes ratios are useful because they can tell us information about the consumer and its energy resources (in our study, preys). In addition, stable isotopes can determine the diversity of food sources of the snake and which source of energy is preferred to them according to the isotopic signal. One example of the previous discussed can be observed on Figure 2.11, where you can see the isotopic signals

of *B. constrictor* and its food sources. On our study, *B. constrictor* did not differ in signals of stable isotopes ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) and sexes did not varied in signals, suggesting that female and male *B. constrictor* are feeding upon the same prey type (Figure 2.9). Even though $\delta^{13}\text{C}$ signals did not differ in between *Boa constrictor* and the Puerto Rican Boa (*Chilabotrhys inornatus*), $\delta^{15}\text{N}$ did differ significantly probably because Puerto Rican Boas samples were from another locality (north of Puerto Rico).

The main food source of the *Boa constrictor* and the Puerto Rican boa is mainly rats and mice. This fact is a concern not only because it can represent a food source competition for other species, but also invasive species have been determined to cause displacement of native species. Human and Gordon (1996), discovered on an experimental design, that Argentine ants (*Linepithema humile*) fought and successfully displaced native ants 60% of the time. This species not only displaced native ants, but also reduced native Californian species foraging success, Argentine ants also were better at recruiting more quantities of ants of their species and spent more time foraging and prevented the establishment of new native communities (Human and Gordon 1996). In terms of vertebrate studies, tadpoles of the invasive Cuban tree frog (*Osteopilus septentrionalis*), reduced the growth rates when present with native tadpoles of *Bufo terrestris* and *Hyla cinerea* (Smith 2004).

As previously discussed, in other islands, *Boa constrictor* has been a cause for extirpation of local fauna like lizards in Aruba, these ecological consequences like the loss of biodiversity in Guam caused by the Brown tree snake can be experienced with other invasive species. Even though we know that *Boa constrictor* can be a generalist in terms of habitat and diet, other aspects are still unknown like suitable thermoregulation habitats and other prey items that we can be missing from the data. We highly encourage the continuing research on the spatial ecology and adaptive behavior in a novel environment. We also need

to target ahead of time potential invasive species and threats to the island of Puerto Rico which have not been addressed. Last but not least, the correspondent agencies need to perform more outreach to the community and address the potential harms of a non-native species already established in a novel environment as a prevention method to lower the chances of other establishment of non-native species.

Conclusion

- *Boa constrictor* snakes appeared to have abundant food sources because they are not moving far distances.
- Habitat use was influenced by the rock length, lack of shrubs in the area, and understory tree characteristics in *Boa constrictor* populations established in Puerto Rico, all of which can indicate a possible relationship with potential suitable habitats for thermoregulation.
- Although, there was no statistical difference in snake's preference on open versus close canopy, there was a trend observed on areas open canopies. Also there was a trend encountering them in forest edges near buildings or houses. Even though this weren't statistically different, further studies looking deeper on these trends should be developed.
- *Boa constrictor* in Puerto Rico, do not show sexual dimorphism when taking in account snout-vent length but tail length remains longer on males than on females. This absence on sexual dimorphism in snout-vent length can be due to the small prey availability.
- *Boa constrictor* has had a successful establishment in the island of Puerto Rico possibly because of the abundance of food sources. Even though, populations of prey were not estimated I observed a good body condition that may be representative of good prey availability.
- Stable isotopes suggest that female and male *B. constrictor* are preying on the same food sources.

Recommendations

The aim of this study was to gather knowledge on the biology of the invasive *Boa constrictor* in Puerto Rico. More movement and home range studies are needed with larger sample size to determine temporal patterns. However, the lack of movement can suggest high amount of food sources on areas where they are currently established. I recommend that future studies can be focused on:

1. Population estimates
2. Prey availability in areas where *B. constrictor* are more frequently encountered, (to see which are the prey that are more vulnerable to predation and that can be impacted (population declines).
3. Study *Boa constrictor* thermoregulation behavior and preferences.
4. Determine if there is any competition for specific food sources between *Boa constrictor* and *Chilabothrus inornatus*.
5. Implement educational outreach at the University of Puerto Rico and other entities (or agencies) to show the impacts of invasive species.
6. Development and implementation of effective capture methods to control populations of the invasive *Boa constrictor*.

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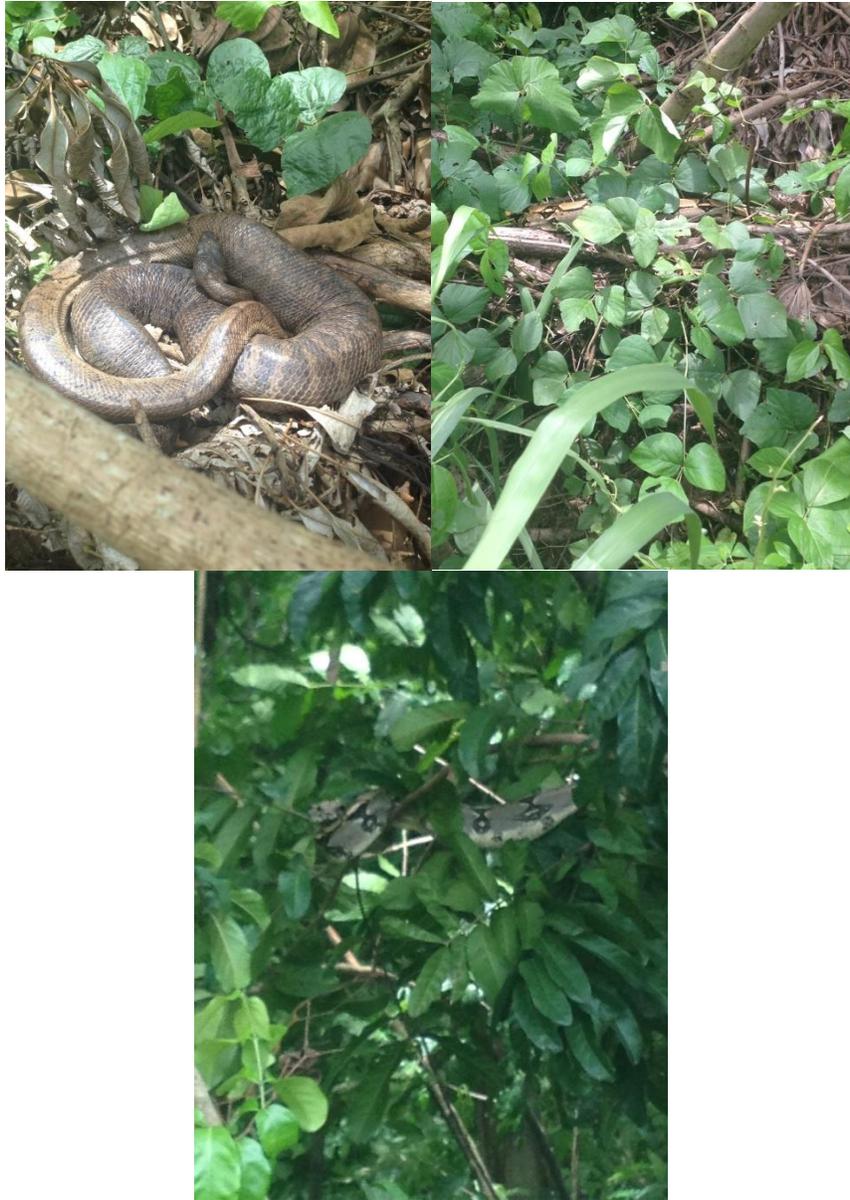
Appendices

Appendix 1. Description *Boa constrictor* body measurements.

Snake ID	Sex	Weight (g)	ln _e mass	SVL (cm)	ln _e SVL	TL (cm)	Total Length (cm)	Stoutness	Residuals Scores
BOCO 1	Female	2902.99	7.97349652	155.6	5.04728861	19.7	175.3	16.5601255	0.0235
BOCO 2	Female	2812.27	7.94174727	144	4.9698133	17.9	161.9	17.37041384	0.224
BOCO 4	Female	2086.52	7.64325289	139.2	4.93591175	15.5	154.7	13.48752424	0.0268
BOCO 5	Female	2630.84	7.87505847	135.3	4.90749454	15.6	150.9	17.43432737	0.344
BOCO 6	Female	2494.76	7.82194781	154.94	5.04303795	19.05	173.99	14.3385252	-0.115
BOCO 8	Female	6441.012	8.77044095	195	5.27299956	21	216	29.8195	0.144
BOCO 9	Female	1859.73	7.52818659	140	4.94164242	16.5	156.5	11.88325879	-0.105
BOCO 12	Female	3628.74	8.19664076	170.18	5.1368567	20.32	190.5	19.04850394	-0.0216
BOCO 13	Female	190	5.24702407	67.945	4.21869855	8.89	76.835	2.472831392	-0.221
BOCO 16	Female	2494.76	7.82194781	156.21	5.05120126	19.05	175.26	14.23462285	-0.14
BOCO 58	Female	5977	8.69567405	151.5	5.02058562	20.6	172.1	34.72980825	0.826
BOCO 98	Female	3409	8.13417427	169	5.12989871	18	187	18.22994652	-0.0633
BOCO196	Female	1600	7.3775891	124	4.82028157	13.5	137.5	11.63636364	0.108
BOCO 2	Female	1367	7.22037384	139.5	4.9380646	16.5	156	8.762820513	-0.403
BOCO 177	Female	4700	8.45531779	145	4.97673374	20.5	165.5	28.39879154	0.717
BOCO 181	Female	4800	8.4763712	147	4.99043259	18.5	165.5	29.00302115	0.697
BOCO 187	Female	2200	7.69621264	144	4.9698133	18	162	13.58024691	-0.0218
BOCO 4	Female	2257	7.72179178	170.2	5.13697422	18.3	188.5	11.9734748	-0.497
BOCO 261	Female	496.65	6.20788555	139	4.93447393	15.5	154.5	3.214563107	-1.404
BOCO 31	Female	7863	8.96992349	221.4	5.39997102	23.1	244.5	32.1595092	-0.0364
BOCO 301	Female	3306	8.10349428	173	5.15329159	21.5	194.5	16.99742931	-0.164
BOCO 223	Female	3100	8.03915739	135	4.90527478	15	150	20.66666667	0.514
BOCO 94	Female	9022	9.10742132	196.9	5.28269599	22.5	219.4	41.12123974	0.452
BOCO 103	Female	2886	7.96762674	164.9	5.10533923	18	182.9	15.77911427	-0.156
BOCO 116	Female	2480	7.81601384	163.4	5.09620118	19	182.4	13.59649123	-0.28
BOCO 142	Female	6090	8.71440336	193.4	5.26476058	22.5	215.9	28.20750347	0.113
BOCO 148	Female	2204	7.69802917	134	4.8978398	15.5	149.5	14.74247492	0.196
BOCO 3	Male	3674.1	8.20906348	159.9	5.07454862	26.5	186.4	19.71083691	0.177
BOCO 7	Male	1587.57	7.36995982	148.5	5.00058496	21.5	170	9.338647059	-0.44
BOCO 10	Male	2726.09	7.91062363	161.54	5.08475279	19.05	180.59	15.09546487	-0.152
BOCO 11	Male	1814.37	7.50349358	119.38	4.78231168	19.2	138.58	13.0925819	0.347
BOCO 14	Male	907.185	6.8103464	105.41	4.65785751	6.35	111.76	8.1172602	0.0267
BOCO 15	Male	2948.35	7.98900097	154.94	5.04303795	25.5	180.44	16.33978054	0.0517
BOCO 17	Male	2993.71	8.0042687	159.26	5.07053809	20.1	179.36	16.69106824	-0.0154
BOCO 76	Male	3250	8.08641028	164	5.09986643	29	193	16.83937824	-0.0211
BOCO 88	Male	1900	7.54960917	133.6	4.89485026	17.8	151.4	12.54953765	0.0561
BOCO 5	Male	2050	7.62559507	134.5	4.9015642	18.4	152.9	13.40745585	0.112
BOCO 40	Male	5090	8.53503311	189.9	5.24649762	34.2	224.1	22.71307452	-0.0116
BOCO 198	Male	1000	6.90775528	145	4.97673374	22.5	167.5	5.970149254	-0.831
BOCO 96	Male	3909	8.27103687	166.5	5.11499531	22.6	189.1	20.67160233	0.118
BOCO 93	Male	2840	7.95155933	144.5	4.97327951	22.5	167	17.00598802	0.223
BOCO 84	Male	2580	7.85554468	161	5.08140436	24.9	185.9	13.87842926	-0.197
BOCO 44	Male	2300	7.7406644	129	4.8598124	19.9	148.9	15.44660846	0.352
BOCO 47	Male	1900	7.54960917	159.9	5.07454862	26.5	186.4	10.19313305	-0.482
BOCO 78	Male	3000	8.00636757	162.3	5.08944647	20.5	182.8	16.41137856	-0.0699

Appendix 2. Description of *Boa constrictor* stable isotopes signals, and direct diet description and location.

Snake ID	Sex	$\delta^{13}C$	$\delta^{15}N$	Prey Description	Prey Location	$\delta^{13}C$	$\delta^{15}N$
BOCO 2	Female	-19.76810292	8.467785183	Mammal	Gut	-24.11738767	9.748152623
BOCO 4	Female	-22.95251772	9.472327437	Mammal	Gut	-19.53302482	6.92451205
BOCO 31	Female	-23.75176597	9.169559769	Mammal	Gut	-16.9468898	7.20521825
BOCO 58	Female	-23.60489972	7.965308724	Mammal	Gut	-19.16842241	10.77463386
BOCO 94	Female	-21.11077623	11.02998236	Mammal	Gut	-23.70550228	10.16033666
BOCO 98	Female	-23.16041271	7.61276954	Bird	Gut	-23.11836594	8.060416665
BOCO 103	Female	-22.22203727	8.682882499	Mammal	Gut	-17.79825189	7.007824588
BOCO 116	Female	-24.46892575	9.25924553	Mammal	Gut	-23.90046047	9.253137182
BOCO 142	Female	-22.61412635	9.883415553	Mammal	Gut	-23.31830499	6.469844998
BOCO 148	Female	-24.21135014	8.378294475	Mammal	Gut	-17.40613036	5.694261981
BOCO 177	Female	-24.93006263	8.508403185	Mammal	Gut	-23.81397371	7.327839345
BOCO 181	Female	-25.05442247	8.520464902	Mammal	Gut	-24.43127296	6.381559075
BOCO 187	Female	-24.59212026	9.993026235	Bird	Stomach	-13.20715875	6.941024564
BOCO 196	Female	-22.19366597	8.299227633	Mammal	Gut	-22.88825593	7.223515751
BOCO 223	Female	-23.42163104	9.236211332	Bird	Stomach	-16.79175545	6.184093529
BOCO 261	Female	-23.95760989	9.448740067	Mammal	Stomach	-14.65217275	8.619483166
BOCO 301	Female	-22.65292303	8.834231707	Bird	Stomach	-15.82472089	8.892600965
BOCO 5	Male	-23.32960317	10.79543638	Mammal	Gut	-26.6222365	8.112167563
BOCO 40	Male	-22.62830452	9.32329274	Mammal	Gut	-13.78278984	8.242885687
BOCO 76	Male	-22.4864406	9.366642669	Mammal	Gut	-24.8602323	9.607110212
BOCO 84	Male	-23.99469995	9.30377469	Mammal	Gut	-15.82848182	9.991547642
BOCO 88	Male	-22.94519613	10.07768425	Reptile	Gut	-24.1145657	7.499073432
BOCO 93	Male	-22.29609601	10.6625338	Mammal	Gut	*	*
BOCO 198	Male	-24.00014099	9.562919729	Mammal	Gut	-24.25385768	9.028447516
BOCO 1	Male	-23.89464954	9.209156504	Mammal	Gut	-23.44393374	7.05416199
BOCO 44	Male	-25.23531751	9.031548178	Mammal	Gut	-24.63924505	5.004884602
BOCO 47	Male	-23.66950197	8.709126041	Mammal	Gut	-17.65430873	6.650062932
BOCO 78	Male	-20.73462152	10.82405183	Mammal	Gut	-25.32403974	6.663699215
BOCO 96	Male	-23.35581678	10.05195312	Mammal	Gut	-23.91307884	8.609292705
BOCO 383	Male	-20.61362873	8.20970997	Bird	Gut	-18.75119407	7.694713408
BOCO 411	Male	-25.30331407	0.91577575	Mammal	Gut	-24.42151027	8.981560377
BOCO 9	Male	-21.41011762	8.656487411	Bird	Gut	-20.58350985	6.34499048



Appendix 3. Photo of a gravid Puerto Rican Boa (1), *Boa constrictor* near the Puerto Rican Boa (2) and the same *Boa constrictor*, in a tree (3). Both snakes were located in the Department of Biology at the University of Puerto Rico, Mayaguez Campus. This observation was recorded on September, 2014. Puerto Rican Boa and *Boa constrictor* were localized within 15 feet from each other. The *Boa constrictor* was under the radio telemetry study (BOCO 4).



Appendix 4. Performing telemetry in the field with the equipment.



Appendix 5. *Boa constrictor* under radio telemetry study killed (BOCO 7).



Appendix 6. Outreach workshop about Puerto Rican Herpetofauna and Invasive species.