SHORTER CONTRIBUTIONS

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Natural History and Conservation of Island Boas (*Boa constrictor*) in Belize

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Boa constrictors inhabiting islands off the coast of Belize have been historically collected for the pet trade, and enthusiasts have described these as a dwarfed race. Additionally, it has been suggested that these boas feed on birds, yet no dietary data are available. I initiated a mark-recapture study of five Belizean island populations and have accumulated data on mainland individuals to describe the natural history and population biology of boas in this region. Results indicate that adult island boas from West Snake Cay eat small passerine birds (gray-breasted martins, *Progne chalybea*) that average 7% of the snake's mass. Fecal samples from boas on other islands contained bird feathers and, although these feathers were unidentifiable, this indicates that other island boa populations also consume birds. Compared to mainland boas, island boas have significantly smaller litters of smaller neonates (lighter and shorter) and have extraordinarily small population sizes (range 8–88 total individuals). According to IUCN criteria, island boas can be classified as Endangered based solely on total population and subpopulation sizes. Collection data, gathered from the literature and unpublished sources, revealed a decline in one island population (Crawl Cay) that is currently estimated to consist of eight free-ranging individuals. Island populations of Belizean boas warrant immediate conservation priority due to their low reproductive output, small population sizes, and continued demand in the pet trade.

BOA constrictors (*Boa constrictor*, hereafter referred to as boas) are geographically widespread members of the Boidae, exhibiting a Neotropical distribution spanning 68° of latitude. Morphological variation within this range is extensive, and eight subspecies are currently recognized (Lazell, 1964; Peters and Orejas-Miranda, 1986). Boas have successfully colonized at least 43 marine islands throughout their range (Henderson et al., 1995; Porras, 1999). On some of these islands, for example, those off the coast of Belize, Central America, boas are dwarfed in size and exhibit different head shapes compared with boas on the adjacent mainland (Boback, submitted). It has been suggested that these island boas specialize on avian prey (Lillywhite and Henderson, 1993), yet no dietary information is available. Additionally, boas are heavily exported for both the skin and pet trades (Dodd, 1986) despite the fact that they have been listed by the Convention on International Trade in Endangered Species (CITES) under Appendix II since 1975 (www.cites.org). Under this appendix, animals may be exported for any purpose as long as the exportation is not detrimental to the survival of the species. Dwarf island boas have been in heavy demand by specialty breeders (Porras, 1999; Russo, 2004). In particular, boas from Crawl Cay were highly desired due to their docile nature, light coloration, and ability to change color (Porras, 1999). Although they are morphologically divergent (Boback, submitted), these island forms have not been recognized taxonomically and are currently referred to the widespread mainland subspecies (*B. c. imperator*). Due to their isolation, unique morphology (Boback, submitted), and demand in the pet trade (Porras, 1999), island boas probably are susceptible to extinction (e.g., Wilson and Cruz Diaz, 1993). Herein, I present information on the population biology, natural history, and conservation of island boas in Belize.

MATERIALS AND METHODS

This study was conducted on the Belize mainland (supplemented with information from the literature for other sites in Central America) and five offshore islands or cays (small low-lying islands composed of sand and coral fragments; Table 1). I surveyed populations of boas (*Boa constrictor*) during portions of three years: 2 August–15 August 2001, 13 May–1 July 2002, and 17 July–6 August 2003. Island sites were visited 1–2 days per year, but all islands were not surveyed each year. The islands (Crawl Cay, Lagoon Cay, False Cay, Peter Douglas Cay, and West Snake Cay) are located within a shallow

TABLE 1. ISLAND STUDY SITE CHARACTERISTICS AND POPULATION ESTIMATES. Symbols are as follows: Years = total number of years site was surveyed, DTM = minimum distance between island and mainland, Area = total area of island, Lat = Latitude, Long = Longitude, r = number of boas caught, marked, and released in 2001, n = number of boas caught in 2002, m = number of marked animals in n, Pop Est = Estimated population size using Petersen method with Chapman's modification (Chapman, 1951), SE = standard error, Density = estimated density using population estimate/total island area.

Population	Years	DTM (km)	Area (ha)	Lat	Long	r	n	m	Pop Est	SE	Density
Crawl Cay	3	12	16	16.36	88.13	2	8	2	8	0	0.50
Lagoon Cay	3	11.8	4.52	16.38	88.12	2	6	1	10	3	2.10
False Cay	2	1.5	24	16.36	88.20	7	2	0	23	13	0.96
Peter Douglas Cay*	1	13.9	11	16.42	18.10	7	5	0	47	29	4.30
West Snake Cay	3	5.9	5.35	16.11	88.34	18	13	2	88	36	16.40

*First collection period for Peter Douglas Cay was 28 March 2003 (W. Birkhead, unpubl. data) and second collection period was 20 July 2003. See text for details.

lagoon (10–40 km wide) between the Belize coast and the Mesoamerican Barrier Reef (Fig. 1). All islands sampled are small (5–24 ha; Table 1), located relatively close to the mainland, and support a simple vegetative community composed predominately of an overstory of mangrove (*Rhizophora mangle*, *Avicennia germinans*, *Conocarpus erectus*) and palms (*Cocos nucifera*, *Thrinax radiata*) and an understory consisting of salt-tolerant ground cover (esp. *Batis maritima*, *Canavalia rosea*, *Phyla nodiflora*). The fauna on these mangrove cays is dominated by land crabs (esp. *Coenobita* sp., *Cardisoma* sp.), passerine birds (esp. *Dendroica petechia*, *Vireo magister*, *Myiarchus*

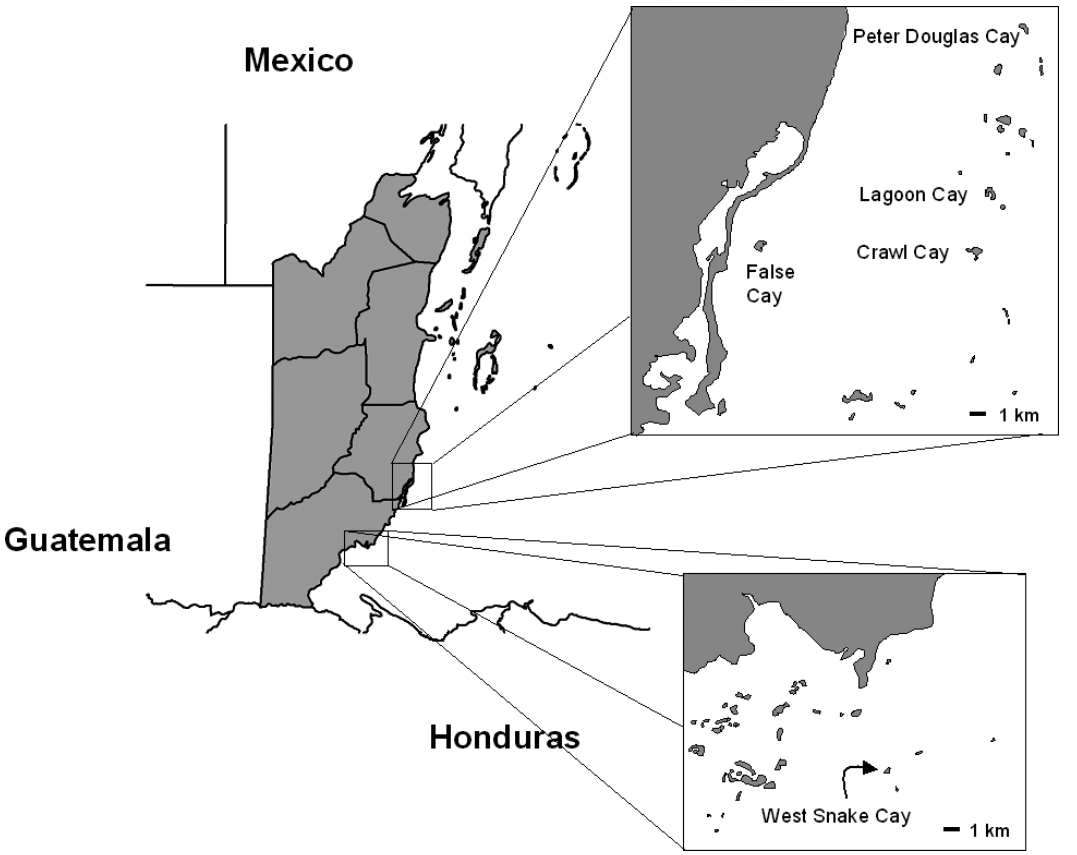

Fig. 1. Map of Belize showing the relative positions of islands (cays) surveyed in this study.

tyrannulus, Progne chalybea), and lizards (*Aristelliger georgensis, Phyllodactylus tuberculosus, Norops sagrei*). While *A. georgensis* is likely native to these cays, humans may have introduced *N. sagrei* during pre-Columbian times (Stafford and Meyer, 2000). There are no mammal species, and boas are the only snake species on these small islands.

Boas were collected by hand during nocturnal and diurnal visual surveys. Some mainland boas were also obtained while driving roadways at night, usually between 2000 and 0200 h. Once a boa was captured, its location was noted and the snake was placed in a nylon bag. At the termination of a survey, I determined sex by probing retracted hemipenes (small individuals) or by the presence of enlarged anal spurs in males (large individuals) and obtained the following measurements: snout–vent length (SVL; closest 0.5 cm), tail length (closest mm), and body mass (Pesola spring scale; closest g). Dietary items were detected via visual inspection. Regurgitation was induced by applying pressure at the pyloric end of the stomach. However, many snakes voluntarily regurgitated prey before any attempt to force regurgitation. Prey items were identified to the least inclusive taxon possible. Prey mass was obtained using Pesola spring scales and recorded to the nearest g. Occasionally, prey items were partially digested so prey mass values may be slightly higher than those calculated. To calculate % prey mass, I used mass of prey item divided by snake mass when only one item was present or the combined mass of all prey items divided by snake mass when more than one prey item was present. Prior to release, each boa was uniquely marked by clipping a portion of a ventral scale and/or photographing the lateral aspect of the right side of the head and the dorsal aspect of the body. Recaptures were determined by the presence of a ventral scale clip and confirmed using unique spotting patterns from the photographs. Recapture data were obtained for the population from Peter Douglas Cay solely from photographs (W. Birkhead, unpubl. data). All individuals were released at the point of capture.

Relative prey masses (prey mass/snake mass) were compared between island and mainland boas using a Wilcoxon two-sample test. Prey masses for mainland boas were obtained from the literature (e.g., Greene, 1997; Boback et al., 2000; Boback, 2004). I also calculated the relative proportion of boas found with prey for each survey period (defined as the total number of days sampled in each year). Additionally, some boas produced fecal samples in captivity. These were examined for prey remains by placing the sample on a fine mesh screen and flushing it with tap water. Contents were examined by eye for identifiable structures indicative of prey remains (e.g., feathers).

Population sizes were estimated using the Petersen estimate with Chapman's modification (Chapman, 1951). This modification gives a more accurate estimate of population size when there are a low number of recaptures (Donnelly and Guyer, 1994). Due to incomplete sampling in 2003, population estimates were calculated using data from 2001 and 2002. Density was calculated by dividing the population estimate for an island by the island area.

To illustrate the potential impact of collection on island boa populations, data were gathered on collection records for boas from Crawl Cay from early explorations (B. Sears, unpubl. data), the herpetoculture literature (Porras, 1999, pers. comm.), and the current study. Using these data, I explored the population trend (inferred indirectly from collection records) for Crawl Cay boas over time.

In 2002, 16 female boas were collected and transported to Auburn University. Six females (three mainland, three island) gave birth in the lab. Relative clutch mass (Vitt and Congdon, 1978) was compared between island and mainland boas using a non-parametric t-test (Wilcoxon two-sample test). Litter size was compared between island and mainland boas using data from these captured females, data from the literature (Fitch, 1970), and unpublished data (Guyer and Donnelly, B. Sears, J. Ronne). Litter size and female mass were compared between island and mainland boas using a Wilcoxon two-sample test. Additionally, I compared island and mainland neonate length (SVL) and mass (g) using data from the six litters (Wilcoxon two-sample tests, t-test, respectively).

All statistical tests were performed using SAS (vers. 8.2, 4th ed. Vols. 1–2, Statistical Analysis Systems Institute, Inc., Cary, NC, 1990). Parametric tests were used unless data violated assumptions of normality, in which case nonparametric tests were performed. Dispersion about means was indicated with $\pm$ 1 SD and α was set at $P = 0.05$ for all tests (Zar, 1984).

Results

Eighteen percent (16 of 88) of island boas and 25% (2 of 8) of mainland boas had prey items in their stomachs. Twenty-three prey items were found in these 16 island boas, and all of these boas were from the West Snake Cay population. Of these items, four were left unpalpated and therefore unidentified. Of the remaining 19 prey

items, 18 were gray-breasted martins (*Progne chalybea*) and one was an unidentified bird (most likely the same species). Additionally, bird feathers were found in fecal samples of boas from West Snake Cay ($n = 2$) and Lagoon Cay ($n = 3$), but none of these feathers were identifiable. The proportion of snakes with prey in their stomachs was calculated for each sampling period. During two late summer surveys (3 August 2001 and 24 July 2003), 39% (7 of 18) and 75% (9 of 12) of the West Snake Cay boas, respectively, were found with food in their stomachs. In contrast, a spring survey (25 May 2002, 13 total captures) revealed no food items in the stomachs of West Snake Cay boas.

For those prey items that could be weighed, relative prey masses were compared between the island snakes (West Snake Cay) and the mainland. Boas from West Snake Cay consumed prey that weighed a smaller proportion of their overall mass compared to boas from the mainland (West Snake Cay mean = 7.3 ± 2.2%, $n = 9$; mainland mean = 44 ± 37%, $n = 6$; Wilcoxon two-sample test, $S = 74$, $P = 0.003$).

Population sizes were small for all islands (Table 1), with density being highest for the West Snake Cay population (16.4 snakes/ha). Collection records for Crawl Cay boas from 1970 to the present document a steady decline in the number of boas (Fig. 2).

Compared to mainland boas, island neonates weighed less (mean island mass = 34 ± 3.6 g, $n = 15$; mean mainland mass = 42 ± 4.7 g, $n = 87$; *t*-test, $t = -6.41$, $P < 0.0001$) and were shorter (mean island SVL = 39 ± 1.4 cm, $n = 15$; mean mainland SVL = 42 ± 2.1 cm, $n = 86$; Wilcoxon two-sample test, $S = 268$, $P < 0.0001$). Island boas also had smaller litter sizes than mainland boas (mean island litter size = 4.6 ± 1.9, $n = 7$; mean mainland litter size = 30 ± 18, $n = 11$; Wilcoxon two-sample test, $S = 28$, $P = 0.0006$). Although island mothers were significantly lighter than mainland mothers (mean mass island mothers = 1129 ± 127 g, $n = 3$; mean mass mainland mothers = 7368 ± 3172 g, $n = 3$; Wilcoxon two-sample test, $S = 15$, $P = 0.04$), boas from both localities invested a similar proportion of body mass to reproduction (mean island RCM = 15 ± 4%, $n = 3$; mean mainland RCM = 17 ± 1%, $n = 3$; Wilcoxon two-sample test, $S = 11$, $P = 1.0$).

Discussion

Island boas average half the length and 1/5th the mass of mainland boas (Boback, submitted). Additionally, island boas have long, narrow heads with large eyes, and males have proportionally longer tails compared to mainland boas (Boback, submitted). Researchers have suggested that the unique morphology of island boas is due to an arboreal habit and a dietary specialization on birds (Lillywhite and Henderson, 1993).

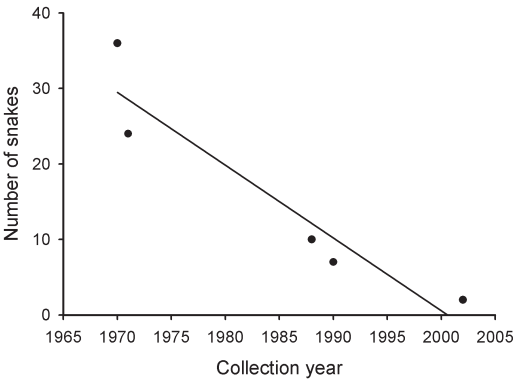

Fig. 2. A collection timeline for boa constrictors from Crawl Cay, Belize. Collection records were obtained from the herpetoculture literature (Porras, 1999), unpublished information (L. Porras, B. Sears), and the current study.

The results from the current study suggest that adult boas inhabiting the small mangrove cays off the coast of Belize consume migratory passerine birds as their primary prey. All identifiable prey items recovered from island boas were gray-breasted martins (*Progne chalybea*), and the only boas found with this prey item were from a single island, West Snake Cay. Large flocks of martins were seen circling West Snake Cay when I departed the island in the early evening (~1730 h) during two fall surveys (7 Aug. 2001 and 24 July 2003), but were not present during a spring survey (25 May 2002). The fall surveys coincided with the fall martin migration in Belize that begins in late July, peaks in August, and ends in early September (L. Jones, pers. comm.). Surveys of other islands during this same time period did not include boas that had eaten gray-breasted martins, likely because the martins do not frequent cays far from the mainland (L. Jones, pers. comm.). However, martins were not found on False Cay, the island closest to the mainland (Table 1). I found bird feathers in the fecal matter of boas from Lagoon Cay and, on another island (Wee Wee Cay), locals have observed boas consuming migratory warblers (P. Shave, pers. comm.), suggesting that other island populations of boas also feed on birds. Two other island endemic snake species (*Bothrops insularis*, Duarte et al., 1995; and *Gloydius shedaoensis*, Sun et al., 2001) have an adult diet predominately composed of migratory birds. Juveniles of both of these snake species consume lizards or arthropods. Lizards (esp. *Norops sagrei*,

Phyllodactylus tuberculosus) are extremely abundant on Belizean islands (pers. obs.) and locals have observed boas consuming them (*P. tuberculosus*, P. Shave, pers. comm.). Therefore, lizards are likely an important component of the diet of juvenile island boas.

Mainland boas likely have a broader diet that includes relatively larger prey. For instance, of the 54 diet items reported in the literature for mainland *Boa constrictor* (Greene, 1983; Smith, 1994; Sironi et al., 2000), only 18% (10) were birds. Unfortunately, only a handful of these records included both predator and prey masses. Nevertheless, in comparing mainland records to the island diet records from this study, mainland boas appear to consume relatively heavier prey compared to island boas. If adult island boas rely on acute peaks in prey abundance (passerine migrations) and consume relatively small meals during this time, this may be the primary cause of morphological (Boback, submitted) and litter size (this study) differences between island and mainland boas.

Estimates of population size for most islands sampled indicate extraordinarily small populations. However, the habitat structure of the islands may influence the number of boas that can be supported. For example, all of these islands are extremely low and at least partially inundated with seawater. Many of the boas captured were found on sandy portions (the highest points) of the island that supported large buttonwood (*Conocarpus erectus*), black mangrove (*Avicennia germinans*), and/or palm trees. Boas may be restricted to these areas due to a scarcity of suitable refugia (e.g., hollowed buttonwood and mangrove trunks) on the remainder of the islands. Density estimates for boas on most islands are comparable to moderate-sized colubrids (e.g., *Coluber constrictor* 1/ha, *Elaphe obsolete* < 1/ha, *Heterodon platyrhinos* 1–7/ha; reviewed in Parker and Plummer, 1987), but the estimates for the West Snake Cay population approach other extraordinarily dense island snake populations (e.g., *Notechis scutatus*, 22/ha, Bonnet et al., 2002).

Island boas off the coast of Belize can be classified in the category of Endangered on the basis of population sizes alone, using criteria C (Total population size estimated at less than 2500 mature individuals and no subpopulation estimated to contain > 250 mature individuals) of the IUCN Red List of Threatened Species (IUCN, 2001, www.redlist.org). Although I surveyed a small proportion of the possible cays that might support boas, it is likely I surveyed islands with the highest densities and largest population sizes because I surveyed four additional cays and found at most one boa per cay, and locals informed me of the best cays to find snakes.

Results from this study also indicate island boas have a reduced reproductive output compared to mainland boas (small litters of small neonates), have been impacted by the pet trade, and can be relatively easily collected. This last feature is a result of an apparent restriction/concentration of boas to large trees (and thus refugia) located on the highest areas of the islands (sand spits). Using Crawl Cay as an example, population sizes appear to have plummeted over the last three decades due to overcollection and the population has not recovered. By adding the number of boas collected from Crawl Cay over the last 34 years to the current population estimate, we might envision a population on Crawl Cay that was similar in size (not necessarily density) to the current population on West Snake Cay. Other sources for mortality appear to be less important. For instance, aside from humans, obvious predators are absent from these islands. Further, island boas may be relatively resistant to hurricanes. My censuses occurred before and after the direct impact of a category four hurricane (Iris, 4–9 October 2001). The recapture of marked animals the following year provides evidence that at least some individuals can survive these storms. In the absence of other major sources of mortality, overcollection of island boas could be of paramount management importance. Thus, the susceptibility of these populations to extinction (small population size, low reproductive output, and illegal collection) demands conservation priority to preserve the biodiversity of this region and ensure the future of island boas in Belize.

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