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Spatial Ecology of the Turks Island Boa, *Chilabothrus chrysogaster* (Cope, 1871) (Serpentes: Boidae) on Ambergris Cay, Turks and Caicos Islands

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Abstract

Spatial ecology of Turks Island boas (*Chilabothrus chrysogaster*) was studied via radiotelemetry on Big Ambergris Cay in the Turks and Caicos Islands. A total of 13 female boas were radio tracked between August 2018 and January 2019 (mean SVL = 1040.2 ± 60.8 mm, mean mass = 438.7 g ± 98.2 g). Boas were implanted with internal radio transmitters via subcutaneous and intraperitoneal insertion, then relocated via radiotelemetry twice daily in 12 hour intervals. Boas did not use the same diurnal refuge, and traveled 1551.9 ± 688.1 meters on average. A kernel density analysis determined that an average of 24.9 ± 17.6 m^2 captured 95% of the boa's occupancy, while 3.9 ± 2.6 m captured 50% of boa home range occupancy. Density overlay analysis found 7/13 individuals to overlap in home ranges at any point on the island. These fundamental spatial ecology, movement pattern, and home range data can provide integral information that can contribute and further inform conservation formulae of this critically threatened taxa facing several multifaceted anthropogenic threats, as habitat fragmentation is one of the larger threats to the endemic and diverse reptile species in the West Indies.

1. Introduction

Knowledge of the spatial ecology of endangered species can provide significant implications for the conservation of threatened taxon in the wake of the biodiversity crisis[1,2]. Anthropogenic disturbances such as habitat fragmentation, introduced predators, and road-associated mortalities are all threats to biological diversity[3,4]. Habitat fragmentation poses significant threats to the diverse herpetofaunal assemblage in the West Indie region, which is of particular conservation concern owing to the fact that it is one of the great centers of biodiversity on the planet, with no fewer than 120 species of snake fauna alone[3,5]. However, the degree to which endemic species will be affected by such threats may depend on the scale of fragmentation and species' biology[6].

The Turks and Caicos Islands (TCI) are located at the southern terminus of the Lucayan (Bahamas) Archipelago[3]. Big Ambergris Cay, located in the southeastern margin of the Caicos Bank, houses the largest and most dense population of the Turks Island Boa (*Chilabothrus chrysogaster*), with an estimated 4,500 individuals on the island's ~400 hectares (R. Graham Reynolds pers. comm.). Despite this major stronghold for this taxon, the Turks Island Boa (*Chilabothrus chrysogaster*) is a crepuscular boid restricted to only 11 islands in the TCI, and is classified as Near Threatened due to concurrent anthropogenic threats[3,7]. In particular, Big Ambergris Cay is privately owned and currently undergoing a significant amount of development, as two thirds of the island is experiencing private development including dirt roads, vacation homes, a private airport, marina, and country club, placing its native animal species further at risk[2,4]. This has already impacted the wildlife there, as flamingos no longer visit the cay (R. Graham Reynolds pers. comm.), for example, and other TCI endemic reptiles such as the critically endangered Turks and Caicos Rock Iguana (*Cyclura carinata)* have been translocated to other islands with fewer threats[8,9].

One determinant of how biodiversity is affected by habitat fragmentation is their movement and response between overdeveloped patches[10]. Despite this importance, there is a lack of detailed literature on the spatial ecology for many *Chilabothrus* species[3,11,12,13]. In an effort to inform the conservation of this threatened taxon, spatial analyses conducted via radiotelemetry may provide valuable insight pertaining to their biological and ecological requisites. Accurate recommendations to mitigate habitat loss through conservation intervention can therefore be made with these data.

More recent model implantable transmitter packages revolutionized ecological research on snakes[14]. Transmitters are surgically implanted intraperitoneally, or subcutaneously in larger species, while the antennae is most often run subcutaneously[14]. Radiotelemetry has further been characterized as an effective technique for acquiring life history data on a species without conducting harmful or physiologically disruptive research. In doing so, fundamental data can be provided for species conservation, ranging from seasonal variation in movement patterns, home range sizes, degree of activity during reproductive seasons, habitat use, and site fidelity[1,15,16,17].

Previous telemetry studies have revealed that snakes exhibit seasonal variation in movement mostly primarily due to habitat availability and prey abundance, as well as basking and hibernaculum sites[16,18,19,20]. Brito (2003) found adult male *V. latastei* exhibited short movement rates and small annual average home ranges during most of their active season, and during the September reproductive season, males covered extensive areas and exhibited long daily movements in search of females which emphasizes the role of reproductive status in movement[16]. Radio-tracked pythons (*Morelia spilota imbricata*) in Dryandra Woodland, Australia exhibited high site fidelity, returning to previously occupied logs after long absences and reusing tree hollows for winter shelter[16,21].

Finally, one of the more important factors with regards to taxa conservation that might influence boa tolerance to various kinds of human-induced disturbance, is the role of social factors in space use. If individuals forage or nest throughout exclusive 'territories' rather than overlapping home ranges, the population density on Big Ambergris Cay might additionally be limited by social interactions rather than resource, prey, or habitat availability[22].

While the use of radiotelemetry involves the assumption that the behavior of the telemetered individual is unaltered by the technique, and that data retrieved is representative of normal behavior, previous studies have shown that growth, reproduction, and survival of many snake species are affected by implantation either directly or indirectly (constant human disturbance)[1]. For example, black rat snakes (*Pantheropis obsoleta*) have exhibited lower annual growth in mass but not length, and females produced lighter clutches of eggs relative to their body size[22]. Such negative effects might be explained by impaired behavior, cost of movement, and infection, which were considered throughout the duration of this study.

In order for the wild *Chilabothrus chrysogaster* population to persist, access to suitable habitat of sufficient size and contiguity to provide essential resources is necessary. To determine the spatial extent of their ecological processes, we conducted a comprehensive radiotelemetry study to elucidate the natural history of the *Chilabothrus* species for its conservation. Moreover, this study will allow us to analyze habitat use and home ranges in an effort to identify the ways in which fragmentation, predation, and diversity in social interaction influence boid spatial ecology. Such information will provide the data necessary in considering the degree of development on the island and whether or not translocation is an option.

2. Methodology

2.1 Study Site

This study was conducted on the privately owned island of Big Ambergris Cay, Turks and Caicos Islands (21.299 °N, 071.633 °E, max. elevation 32 m). The island is 6.4 kilometers in length, 1.6 kilometers in width, and 4.5 km^2 in total area. It is geologically comprised primarily of limestone rock and sand interspersed with salt-resistant and salt-tolerant coastal vegetation varieties, drought-resistant low brush coppice, and palm forests[23].

2.2 Animal Collection and Radiotelemetry

Between July 23, 2018 and August 10, 2018, 13 Turks and Caicos Island boas, *Chilabothrus chrysogaster*, were collected from Big Ambergris Cay, Turks and Caicos. Boas visually assessed as being ≧ 200g in body mass were collected between 1800h and 0100h and maintained overnight at ambient temperature.

Two types of temperature-sensitive radio transmitters were custom-ordered from Holohil Systems, Inc., Ontario, Canada. Six “button-type” transmitters, model PD-2T, and 14 “barrel-type” transmitters, model SB-2T were ordered in two batches- one in June 2018 and one in November 2018. Transmitters were hand-carried to the Sterile Processing Department at the Memorial Campus of Mission Hospital (Mission Health, now HCA Healthcare), Asheville, North

Carolina. The transmitters were individually sealed in gas sterilization bags, then subjected to surgical-grade peroxide gas sterilization. Sterilization took place between 8 and 15 days prior to implantation, and transmitters were stored in a protective and cushioned bag during transport to the field site. Transmitters were implanted in 13 adult females (Table 1) weighing less than or equal to 8% of the mass of the snake, and either "button" or "barrel" transmitters (3.5 g, 5.5 g) were selected relative to the snake size. Transmitters had frequencies in the range of 172.202-172.965 MHz and a battery life of 6 months (button-type), or one year (barrel-type).

2.3 Anesthesia and Analgesia

All snakes underwent a brief pre-surgical health exam the morning following their capture. Injectable agents alfaxalone 10-20mg/kg IM, dexmedetomidine 0.05mg/kg and ketamine 5-10 mg/kg IM were injected intramuscularly (IM) per standard techniques. The antagonist to dexmedetomidine (atipamezole, 5mg per 1 mg dexmedetomidine IM) was administered at the conclusion of the procedure. The agents used were based on the temperament of the snake and surgical approach. Local analgesia was provided in all cases by injection of lidocaine 1% (maximum 5mg/kg) in a line along the intended surgical incisions. Subsequent to completion of the procedure, meloxicam was given IM at a rate of 0.2mg/kg once. All animals received at least one injection of the antibiotic ceftiofur crystalline free acid (Excede, Zoetis, Parsippany, New Jersey) IM at a dosage of 15mg/kg.

2.4 Surgical Procedure

Animals were maintained at ambient temperature for the duration of the procedure. Times were recorded for first effect (characterized by visual slowness), loss of righting reflex, and for start and end time of surgery for each procedure. All animals underwent surgical preparation by cleansing their bodies caudal to the heart with a dilute chlorhexidine solution left in contact with the skin for 2-3 minutes. Incision areas were further swabbed with alcohol. Animals were placed in right lateral recumbency and the body was manually held or held in position with paper tape. The eyes were covered with cloth, and sterile surgical drapes were placed on and around the body to establish a sterile field. Standard surgical techniques were used including sterile equipment and supplies (i.e. gloves, surgical mask, instruments, gauzes, sutures). Radio transmitters were surgically implanted using one of the two following techniques, generally following the methods of Weatherhead and Anderka[25].

For subcutaneous implantation, a small incision was made 2/3 of the way down the length of the snake on the dorsal-lateral left side. The transmitter was placed subcutaneously, caudal to the incision, and sutured to the underlying muscle. The teflon insulated antenna was passed subcutaneously towards the head (cranially) through a rigid polypropylene catheter or blunt surgical stylet guide. Skin incisions were closed using skin adhesive (Nexaband or equivalent) and monofilament suture of appropriate size (3-0 – 5-0 mm).

For transmitters placed intraperitoneally (n=1), the initial skin incision was made 2-3 rows of scales above the intersection of the ventral and lateral scales. A small incision was made through the muscle below the ribs at that site. The transmitter was placed into the abdomen caudal to the stomach, and a suture surrounding the transmitter was placed through the musculature for affixation to the body wall. The antenna was brought out through the musculature and tunneled subcutaneously and anteriorly using a polypropylene catheter or blunt surgical stylet guide. The muscles were opposed using absorbable sutures, and the skin closed using 3-0 to 5-0 mm monofilament sutures and then covered with skin glue.

Post-surgery, snakes were kept in warm, individual enclosures until fully recovered from anesthesia and handling. Prior to full anesthetic recovery, blood samples equal to or less than 6% of the body mass of the animal were obtained from the tail vein using 23-27 gauge needles on one cc heparinized syringes. Microhematocrit tubes were filled and centrifuged at 2,000 x g speed using a microcentrifuge, and packed cell volume and total solids were determined using standard techniques. Blood smears were made on glass slides, air dried, and stained using a 3 step modified Romanowsky Stain system. Estimated total white and differential white blood cell counts were determined.

Passive Integrated Transponders (PIT tags, Trovan ®) were inserted subcutaneously and approximately 5 cm anterior to the cloaca on the left side of each boa pre-recovery for subsequent identification purposes, and tail tips were collected for future genetic analysis. Additionally, the lengths of each boa were determined.

2.5 Telemetry Data Collection

Animals were released at the site of original capture a minimum of five hours after completion of the surgery (when total recovery from anesthesia was confirmed). During the weeks of July 23 to August 10, 2018, December 16-21, 2018, and January 4-10, 2019, data points were retrieved once mid-day and once after dark for each snake with a minimum interval of 5 hours between consecutive locations via R1000 VHF Telemetry Receivers (Telonics Inc., Mesa, Arizona) used in conjunction with a hand-held Yagi three-element antenna and coaxial cable. Receivers were used to locate a signal from the corresponding transmitter, determine the direction it was coming from by dialing down the gain on the receiver, and ultimately visualize the snake or its location within $2m^2$ if inactive. Once a location was confirmed, a Garmin eTrex10 handheld GPS was used to mark and record the latitudinal and longitudinal coordinates of the site in decimal degrees.

2.6 Health Checks and Replacement of Transmitters

During the week of January 4–10, 2019, each snake with a functioning transmitter was collected for a health exam or surgical repair. Due to the lifespan of the button transmitters, healthy animals with buttons underwent a second surgical procedure to remove the button and place a new barrel transmitter intraperitoneally (n=1 and it was of sufficient size to receive a barrel, see Surgical Procedure). Health exams consisted of a weight, brief overview of site of incision and transmitter placement, and overall behavior. Animals that underwent surgery were released back to the site of collection after full recovery from anesthesia and radio tracking commenced.

2.7 Spatial Data Analyses

Movement and activity data were analyzed in R v. 3.5.3 running in RStudio 1.1.463[26]. The data matrix consisted of individual point locations with associated geolocation data. All data points were plotted in R using the *ggmaps* package to load a Google Earth satellite image as a background map[27]. Total distances were calculated by converting the latitudinal and longitudinal data into a spatial lines data frame, which calculates distance traveled in kilometers via *rgdal* and *rgeos*[28,29]. Kernel density plots ("kernelUD") were used to visualize the distribution of data over the continuous interval, finding interpretations in 95% and 50% confidence interval fields outside of the density estimation. Home range sizes were calculated using the functions *adehabitatLT* and *adehabitatHR* in conjunction with the kernel density plots to determine a range for each individual. Home range overlap was visualized using a custom R script to plot a matrix of kernel density overlaps calculated using the *kerneloverlaphr* function in the package *adehabitatHR*[30]. A classic measure of home range size was estimated using the minimum convex polygon (MCP) method using the mcp function in the package *adehabitatHR*[30].

3. Results

3.1 Morphology

Over the course of the experiment, 13 female boas were captured. The mean SVL was 1040.2 ± 60.8 mm, with a mean weight of 438.7 g ± 98.2 g and a range from 160 g - 1675 g (Table 1). Of the 13 specimens, 6 (46.2%) received button transmitters and 7 (53.8%) received barrel transmitters (Table 1). The weight range of those who received barrels was 182 g – 1290 g, and 160 g – 1675 g for those who received buttons. One specimen (T13) was confirmed heavily gravid via ultrasound.

3.2 Total Movement, Home Ranges, and Overlap

In total, 13 specimens traveled 20174.6 meters (Figure 1). The average distance traveled was 1551.9 ± 688.1 meters with a range of 44.9 - 3177.1 meters (Figure 1). The average area that captured 95% of boa occupancy was calculated via Kernel Density to be 24.9 ± 17.6 m^2, and 3.9 ± 2.6 $m^2$for the area that captured 50% of boa occupancy (Table 2). A density overlay plot additionally indicated that 7/13 (53.9%) snakes overlapped in home ranges with another individual (Figures 2, 3).

3.3 Visual Detectability

Of the 338 fixes, or GPS locations, made total, boas were observed in 108 (31.9%) instances. Fixes were taken for each individual, and boas were observed up to 50% of the as follows: T1, 2/7 visualizations, 28.6%; T2, 13/39 visualizations, 33.3%; T3, 1/16 visualizations, 6.3%; T4, 15/35 visualizations, 42.9%; T5, 10/34 visualizations, 29.4%;

T6, 9/20 visualizations, 45.0%; T7, 9/28 visualizations, 32.1%; T8, 8/18 visualizations, 44.4%; T9, 9/18 visualizations, 50.0%; T10, 10/36 visualizations, 27.8%; T11, 9/18 visualizations, 50.0%; T12, 5/36 visualizations, 13.9%; T13, 8/31 visualizations, 25.8%.

3.4 Implantation Success

Implantation surgeries resulted in zero deaths throughout the experiment. Of 13 implantations, 10 went successfully without any complications post-surgery. Three surgeries on individuals T1, T3, and T4, resulted in the transmitter and individual being removed during the study owing to health concerns.

T1 was recaptured within the first week of August with its transmitter (button) sloughing off of the skin. Skin was adhered to the top of the transmitter, and the fascia and muscle underneath the transmitter appeared healthy. The radio was removed, necrotic tissue trimmed, and wound was sutured with 4-0 PDS. The same transmitter was subsequently implanted into T13.

The transmitter on T3 (button) was also found to be sloughing off and was removed. The wound sutured was closed via GR and the individual was removed from the study in August.

T4 was found healthy in August, however once visualized in January, the antenna was fully protruding from its skin. Upon reexamination of the animal, a fibrous capsule of thick purulent material was surrounding the barrel transmitter and the snake weighed 110 g less than its original 900 g weight. However, the original skin incision fully healed anterior to the transmitter and protruding antenna, so a new incision was made caudal to the transmitter so that the capsule could be dissected, the surrounding area flushed, and the incision sealed with 2-0 PDS mattress stitching.

T5 was visualized on August 4th digesting a 350 g iguana, causing the sutures at the incision site to break. The incision was cleaned and repaired the following day, and the animal was re-released without regurgitation.

3.5 Transmitter Success

While button transmitters have a battery life of 6 months and barrels one year, the signal of T6, T8, T9, and T11 could not be found in December or January. Additionally, T5, T7, T10, and T12 could be located in January, but were not observed and their status could not be confidently determined.

3.6 Transmitter Replacement

T13 received a new transmitter in January. The original button transmitter was removed from its subcutaneous placement and a new barrel transmitter was placed intraperitoneally following the aforementioned methods. Post replacement, this individual had an uncomplicated and full recovery.

3.7 Blood Characteristics

Hematocrit levels and total solids were recorded with blood samples from the tail. Hematocrit values ranged from 4-41%, while total solids ranged from 3.8-76.8 g/dL (Table 3). For reptiles in general, HCT is 20-40%, depending on the hydration of the animal and sample collection. Normal TS range from 3.0- 7.0 depending on stage of folliculogenesis, dehydration, illness, or dilution of the blood sample with lymphatics.

Table 1. Transmitter type, mass, and snout-vent lengths (SVL in mm) of 13 female *Chilabothrus chrysogaster* individuals that underwent implantation for tracking via radiotelemetry (mean SVL = 1040.2 ± 60.8 mm, mean mass = 438.7 g ± 98.2 g).

ID	Transmitter Type	Mass (g)	SVL
T1	button	162	820
T2	barrel	182	815
T3	button	166	830
T4	barrel	900	1355
T5	barrel	855	1315
T6	button	227	900
T7	barrel	320	1030
T8	button	259	949
T9	button	276	953
T10	barrel	505	1170
T11	button	271	920
T12	barrel	330	990
T13	button	1675	1475

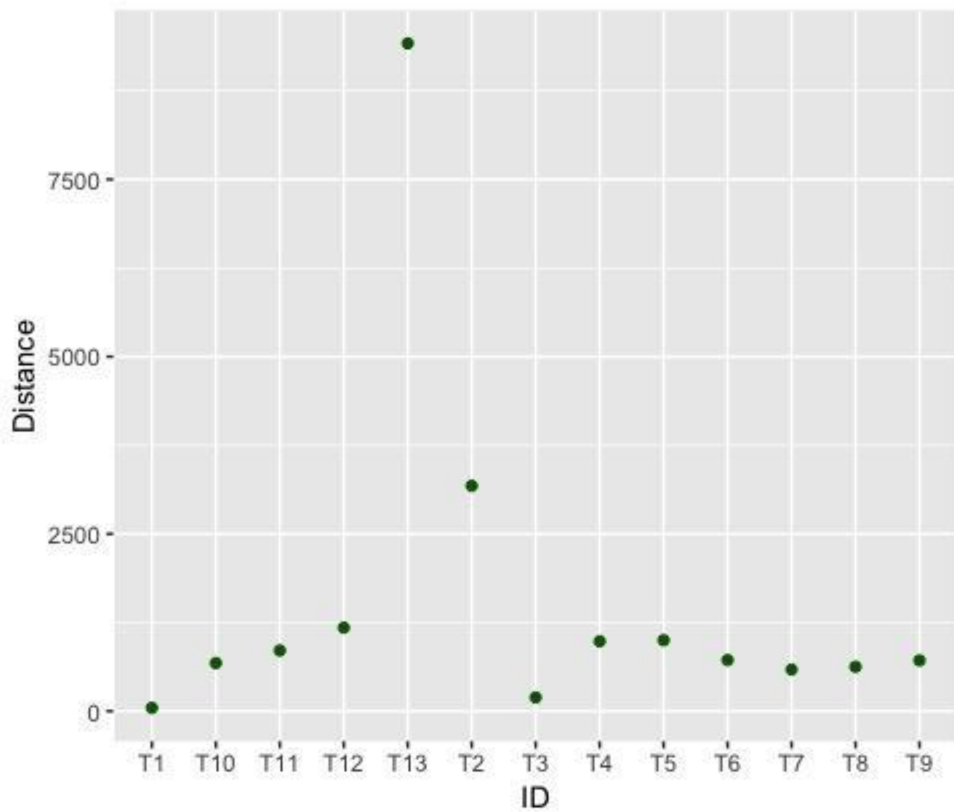

Figure 1. Total distances traveled in meters by 13 female *Chilabothrus chrysogaster* individuals tracked via radiotelemetry (mean = 1551.9 ± 688.1 meters).

Figure 1 Distances were calculated in meters by converting the latitudinal and longitudinal data into a spatial lines data frame via the *rgdal* and *rgeos* packages in RStudio. T3, T5, T7, T10, T12, and T1 ceased movement in January due to suspected anthropogenic associated mortalities, difficulty in recovery, transmitter sloughing/removal, or gravidity, and are therefore representative of December movement.

Table 2. Average area estimation capturing 95% and 50% of boa occupancy outside of the density fields of *Chilabothrus chrysogaster* movement.

ID	Area of 95% of boa occupancy (m)	Area of 50% of boa occupancy (m)	Minimum Convex Polygon (hectares)
T1	0.11	0.02	0.002
T2	8.79	1.32	2.63
T3	0.84	0.11	0.01
T4	2.01	0.36	0.71
T5	50.55	10.77	0.94
T6	2.09	0.51	0.69
T7	6.84	1.34	0.94
T8	1.69	0.33	0.24
T9	3.31	0.59	0.57
T10	7.59	1.74	1.37
T11	2.52	0.73	0.85
T12	7.07	0.61	1.64
T13	230.96	33.12	1.21

Density was calculated via kernel density analysis in RStudio (mean 95% = 24.9 ± 17.6 meters, mean 50% = 3.9 ± 2.6 meters). T3, T5, T7, T10, T12, and T1 ceased movement in January due to anthropogenic associated mortalities, difficulty in recovery, transmitter sloughing/removal, or gravidity, and are therefore representative of partial data.

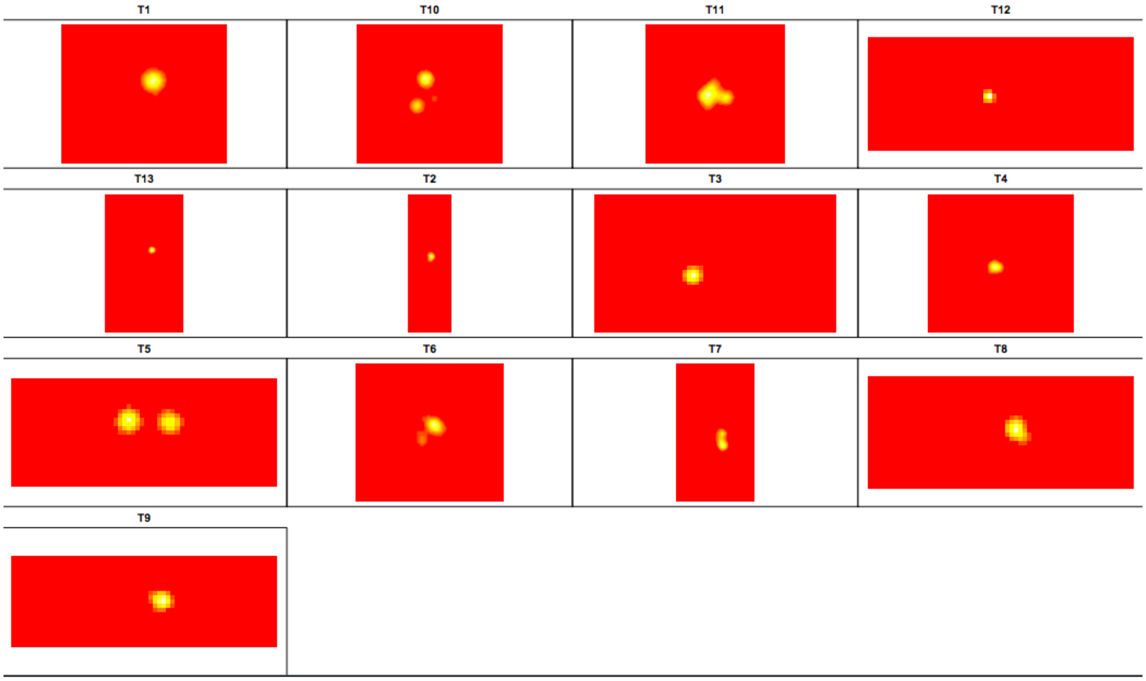

Figure 2. Kernel density estimation plots of 13 female *Chilabothrus chrysogaster* individuals tracked via radiotelemetry.

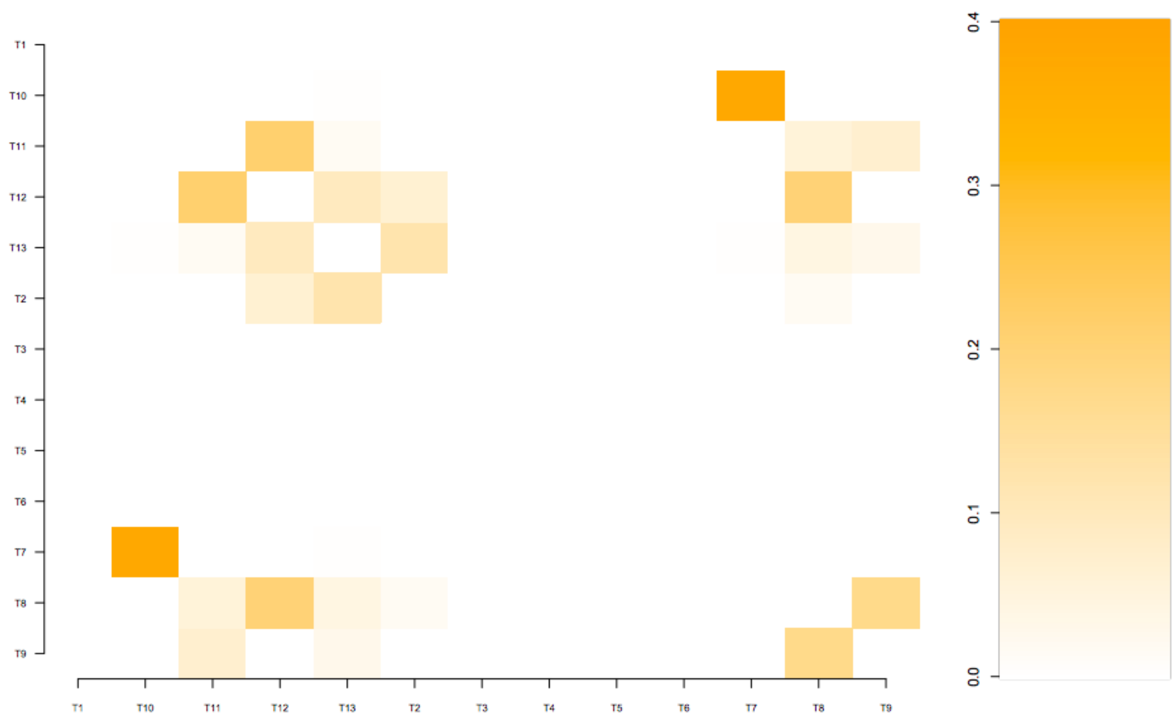

Figure 3. Density overlay plot exhibiting overlap in home ranges of 13 *Chilabothrus chrysogaster* individuals tracked via radiotelemetry.

Figure 3 Home ranges were calculated via *adehabitatHR* and density was estimated via kernel density analysis in RStudio. Overlap can be visualized as a proportion where 1.0 is one individual's home range fully overlapping with another individual's home range. Seven of the 13 (53.9%) snakes overlapped in home ranges with another individual.

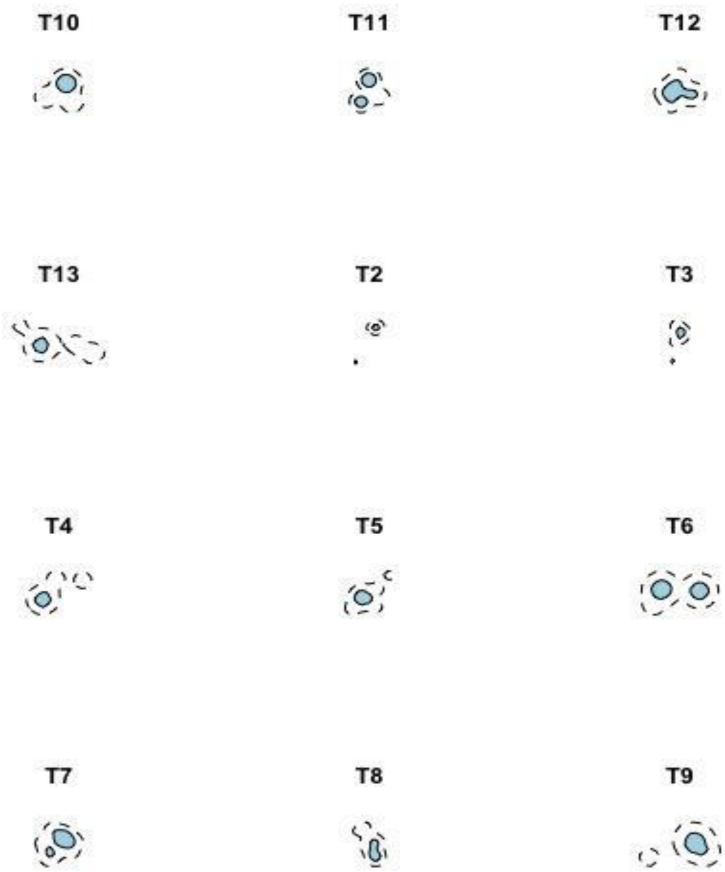

Figure 4. Home range plots (in ha) of 13 female *Chilabothrus chrysogaster* individuals.

Figure 4 Home ranges were calculated via the *adehabitatHR* function in RStudio and estimated via kernel density analysis. Dashed lines are descriptive of 95% encompassed home ranges, and 50% encompassed home ranges are represented by filled in circles. T3, T5, T7, T10, T12, and T1 ceased movement in January due to anthropogenic associated mortalities, difficulty in recovery, transmitter sloughing/removal, or gravidity, and are therefore representative of partial data.

Table 3. Hematocrit levels (HCT %) and total solids counts (TS g/dL) taken from blood samples from 10 female *Chilabothrus chrysogaster* individuals.

ID	HCT (%)	TS (g/dL)
T1	N/A	N/A
T2	N/A	N/A
T3	N/A	N/A
T4	4	6.0
T5	41	7.5
T6	32	7.2
T7	8	4.4
T8	9	4.2
T9	40	N/A
T10	N/A	N/A
T11	29	6.0
T12	25	6.5
T13	30	5.0

All blood samples were taken from the tail. For reptiles in general, HCT is 20-40%, depending on the hydration of the animal and sample collection. Normal TS range from 3.0- 7.0 depending on stage of folliculogenesis, dehydration, illness, or dilution of the blood sample with lymphatics.

4. Discussion

4.1 Total Movement

Movement was calculated in each individual, which is consistent with the opportunistic foraging strategy involving both active search and ambush strategies of a general boid predator[31]. However, the home range data suggests the same diurnal refuge was not utilized on a daily basis because many of the ranges were in two distinct areas, and the exact geographic locations were never repeatedly measured for active boas. Additionally, active boas were never visualized in the same exact location the following morning after a nightly fix. On a per move basis, movement ceased in T3, T5, T7, T10, and T12 in January 2019. T1 additionally exhibited no movement in August 2018. T3 was repeatedly located in roadside brush for approximately one week in August 2019 and deemed inactive, contributing to its lack of movement. However, it resurfaced from an iguana burrow with its transmitter sloughing off and underwent a second removal surgery (no active fixes were made on the individual post-surfacing). T3 was approximately 166 g, approximately 34 g below the suggested weight for button implantation. Therefore, the transmitter likely sloughed off due to pressure necrosis, and T3 sought refuge underground for the duration of the experiment. By December 2018, T5 was assumed a road associated mortality, as it was repeatedly located roadside, next a commonly used dumpster. It exhibited no movement in January 2019, supporting this assumption. Similarly, T10 was consistently located in a small hole within a limestone slab roadside. It can therefore be assumed that T10 is a road associated mortality. T12 was very active in the initial week of August 2019, and became static within a rock wall during week two. With the knowledge that the transmitters have the ability to slough off, and that rock walls provide a thermoregulatory site during the morning and before sunset periods, it can be assumed that the transmitter on T12 may have fallen out as it was traveling through the wall[17]. Both T2 and T13 traveled the distance of three hills South and East of the ruin site, and notably, T12 was found foraging within the mangroves, a confirmed habitat that has been utilized by the *Chilabothrus* genus in the West Indies[32]. The reduction in movement and eventual immobility of T1 was expected due to it being heavily gravid. Reduced locomotor performance of gravid snakes, especially before parturition, has been previously distinguished[31,33]. These causations can be utilized in understanding the success of subcutaneous transmitter implantation, as well as to provide examples of road associated mortality on this island.

4.2 Home Range Analysis

Temporal or spatial overlap of home ranges of snakes were observed, suggesting a lack of territorial systems in the species. This supports the general understanding that they do not actively avoid conspecifics while foraging, unlike their close allies the lizards[34]. Home ranges have never been measured for *Chilabothrus chrysogaster*, and determining such area is important, as exclusive home ranges may mitigate against successful natural recolonization if the species is to be relocated, or even isolated by fragmentation on the island via development. Therefore, with a calculated minimum home range area of 0.71 ha for snake active throughout the duration of the experiment, we can assume that this is the amount of space necessary for high survivorship rates of this species in a differing habitat (an isolated fragment or if it were to be relocated to another island in the future). It can be additionally assumed that if snakes were relocated to a zoological park or to a differing habitat fragment, they would survive in a large population rather than in solidarity. This is due to the overlap in home ranges and lack of territorial systems, as multiple snakes were visualized in the same location when acquiring nightly fixes.

The accuracy of home range calculations must also be taken into consideration, as the projected movements do not confirm the actual movement of the snakes after stress inducing surgery. Animals can be expected to experience some level of trauma associated with capture, handling, and transmitter implantation. Therefore, transmitter longevity greater than one year will maximize the likelihood that the data from the telemetered snakes are collected after the animal has recovered from that trauma and are representative of their actual movement in the wild[25].

Based on the area of 95% occupancy calculated via kernel density analysis, active snakes did not exhibit strong site fidelity and frequently moved between daytime locations (Figure 2, Figure 4). For example, T5, T6, and T10 moved between two areas of the island in their foraging efforts, and active snakes were never visualized in the same exact previously occupied location. While studies have shown radio-tracked pythons to exhibit high site fidelity, this attribute cannot be applied to the Ambergris *Chilabothrus*[16,21]. Different sites, therefore, should be managed to ensure that all features needed by the species are available within larger or multiple patches. With regards to future conservation efforts, feeding and thermoregulatory requirements and the provision of shelter and protection should be available within a larger area.

4.3 Visual Detectability

Of the 230 fixes that were not visualized, in such instances individuals were beneath a limestone slab or within an iguana burrow. Additional boas were anticipated in January of 2019 for implantation, however significantly fewer were seen roadside in January versus August of 2018. Relative examples of seasonal trends in habitat use have come from studies regarding other boa species, pythons, and vipers[16,35,36]. Therefore, future work on *C. chrysogaster* can include a seasonal analysis of movement. Female versus male movement has differed on both a per move basis (mean daily movement per move) and monthly basis (mean daily movement per month) in *C. inornatus*, where males moved farther than females and females were immobile for significantly longer average time periods[31]. Additionally, an increase of male boa movement can be seen throughout the reproductive season (April-June for *C. inornatus* in Puerto Rico, September for *Vipera latastei* in Portugal), suggesting that males actively search for females during specific months of the year[16,31]. Subsequently, additional data concerning spatial ecology associated with reproductive seasons of male and female individuals would strengthen the home range analysis and overall life history of this species.

4.4 Implantation Success

Three surgeries on individuals T1, T3, and T4, resulted in the transmitter and individual being removed during the study. Both T1 (162 g) and T3 (166 g) weighed less than the suggested button implantation weight (approximately

200 g), and their transmitters likely sloughed off due to pressure necrosis. In future studies, button transmitters should be implanted at a limit value of 4-5% of the body mass in an effort to prevent mobility limitations, and to increase implantation success and survival rates.

Additionally, previous research suggests avoiding transmitter implantation late in the activity season, as cool weather can hinder healing of the surgical wound[37]. While T1 and T3 both underwent surgery in August, T13 underwent a replacement surgery in January 2019, posing a concern for its recovery. A new barrel transmitter was placed intraperitoneally, however, in an effort to prevent the wire from breaking through the incision site and the transmitter from sloughing off during a season of cool weather and subsequently a more difficult recovery.

The intraperitoneal surgery utilized a longer catheter in an effort to minimize the incisions made in the skin, as the antennas were approximately 7 inches in length while the catheters were only 5.5 inches. Therefore, a third incision had to be made to pass the antenna subcutaneously towards the head. It is likely that this third incision provided more opportunity for the antenna to protrude through the skin and more incision sites to heal, which may have contributed to transmitters sloughing off with more ease. By placing the transmitter into the abdomen and suturing the transmitter to the musculature for affixation to the body wall, the transmitter could not slough off. Further, the antenna was brought out through the musculature and tunneled subcutaneously and anteriorly so that the wire was less likely to protrude from the body. This method has been adopted in several other studies, and there are instances of snakes carrying radio transmitter in the coelomic cavity for 9 years without disturbance[38,39,40].

With regards to the implantation success of T4, it was found with the antenna wire protruding from the skin, likely due to the aforementioned subcutaneous transmitter placement. Additionally, it was found anemic and high in total solids count in August 2018, and decreased 110 g in weight by January 2019. The transmitter was removed in December, and it can be noted that the fibrous capsule of thick purulent material surrounding the barrel transmitter was likely a bacterial infection contributing the weight loss of the animal.

Finally, it can be noted that the N/A values recorded for the hematocrit levels and total solids in individuals T1-3, T9, and T10 were likely due to the inability to draw blood from the tail and unreadable slides or capillary tubes. Additionally, individuals with HCT and TS levels within the normal range exhibited shorter times of induction and quicker recoveries from anesthesia.

4.5 Transmitter Success

The signal of T6, T8, T9, and T11 could not be found in December or January and subsequently no fixes were obtained for these individuals. This is likely due to the 6 month battery life of the button transmitters that were placed in these individuals. While transmitter longevity greater than one year will maximize the accuracy of boa movement data, a longer battery life would reduce the frequency of transmitter replacement and subsequently decrease the level of stress upon the boids.

4.6 Conservation

In conclusion spatial ecology data provide integral data that can inform conservation decisions for threatened *Chilabothrus* species. By continuing analysis of the movement patterns of *Chilabothrus*, fundamental data can be provided for species conservation, ranging from seasonal variation in movement patterns to home range sizes, habitat use, site fidelity, degree of activity during reproductive seasons, and the effect of habitat fragmentation on the population. In order for the *Chilabothrus chrysogaster* population to persist in the face of development on Big Ambergris Cay, access to suitable habitat of sufficient size and continuity to provide essential resources is necessary.

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